Draft

Faro Mine Interim Works Project Proposal

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Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

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Executive Summary

Introduction

The Government of Yukon (YG) Assessment and Abandoned Mines (AAM) and the Government of Canada (Canada), as represented by Aboriginal Affairs and Northern Development Canada (AANDC), are continuing to prepare a final remediation plan for the Faro Mine Complex (FMC). While preparing the Faro Mine Remediation Plan (FMRP), YG and AANDC will continue activities similar to those that have taken place at the FMC since mine operations ceased in 1998. These interim activities, called the Faro Mine Interim Works (IW), will continue for up to 10 years until YG and AANDC have completed the design, permitting, approvals and procurement for the FMRP. The IW are the subject of this Interim Works Project Proposal (IWPP) and have two main purposes:

1. To control and reduce the effects of the existing FMC on human health and safety, and the environment
2. To compile sufficient site and environmental information to support design, assessment and permitting for the FMRP

Proposed Project

The proposed IW include the following components:

1. Site Operations

Site operations are the ongoing site activities that prevent adverse effects of the FMC on persons, property, or the environment, and that mitigate adverse effects that occur. These include care and maintenance activities, as well as the implementation of comprehensive risk assessment, monitoring, and adaptive management programs. Because of changing conditions at the FMC, the site operations scope includes the implementation of responses that arise from the adaptive management plan (e.g., interim groundwater collection systems).

2. Site Investigations

Site investigation activities will occur throughout the site and extend over the duration of the proposed IW to support the development of the FMRP and the design of remediation and closure elements. Site investigation activities will include the following types of activities:

- Soil and rock sampling
- Geotechnical investigations
- Aquifer testing
- Environmental monitoring
- Field trials
- Vegetation sampling
- Wildlife surveys
- Aquatic studies
- Geophysics

Specific investigation requirements and locations will evolve to address site conditions, the results of sequential investigations, and design requirements.

3. Down Valley Interim Hydraulic Upgrades

The Down Valley Interim Hydraulic Upgrades (DVIHU) are intended to improve the flood routing capacity for the Down Valley Tailings Area. The Intermediate Dam (ID) spillway and the Rose Creek Diversion will be upgraded so that both facilities can convey the estimated flow for a 1-in-500-year flood event (115 cubic metres per second), the minimum suitable inflow design flood for these facilities to meet the guidelines in the Canadian Dam Association Dam Safety Guidelines (2007). The proposed upgrades will reduce flood-related risks during the 10-year IW duration, before construction of more robust upgrades as part of the FMRP. The DVIHU includes the following:

- Increasing the depth of the ID spillway
- Improving erosion protection in the ID spillway
- Constructing a temporary raise of the ID
- Increasing the capacity of the Rose Creek Diversion

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It is likely that the ID interim upgrades will not experience flow during the IW period because they provide secondary flood-routing capacity. Primary flood routing is provided by the Rose Creek Diversion.

4. Ancillary Activities

Ancillary activities are also needed to support the site operations, site investigations and DVIHU tasks, and include the following activities:

- Site security and access control
- Emergency response
- Facilities and equipment
- Existing borrow areas
- Worker accommodations
- Supplies and energy sources
- Waste materials
- Fresh water
- Septic systems

Current Conditions

The FMC consists of the Faro Mine Area, the Rose Creek Tailings Area, and the Vangorda/Grum Area. The 14-kilometre Haul Road connects the Faro Mine Area and Vangorda/Grum Area.

- The Faro Mine Area includes the Faro Pit, approximately 30 waste rock dumps, ore processing and handling facilities, the Emergency Tailings Area, and the Faro Creek Diversion. It also includes contaminated water management facilities, including the S-Wells and ETA Seepage Interception Systems, and contaminated water pumping, conveyance, and treatment facilities.
- The Rose Creek Tailings Area covers an area of over 200 hectares in the original valley of Rose Creek. It comprises four dams – the Original, Secondary, Intermediate and Cross Valley Dams – and the Rose Creek Diversion. The Original, Secondary, and Intermediate Dams retain a total of 55 million tonnes of tailings in the Rose Creek valley. The Cross Valley Dam retains a pond that is used for final polishing of treated water.
- The Vangorda/Grum Area includes the Vangorda Pit, the Grum Pit, the Vangorda Waste Rock Dump, the Grum Waste Dump, the Grum Overburden Dump, the Grum Ore Transfer Pad, the Vangorda Creek Diversion, the Vangorda Water Treatment Plant, and the Little Creek Dam. There are no tailings stored at the Vangorda/Grum Area because all ore was processed in facilities at the Faro Mine Area.

The FMC is a legacy mining project that presents long-term chemical and physical stability risks. Much of the waste material at the FMC is acid-generating. Tailings, waste rock, and pit walls continue to oxidize and release contaminants. Water infiltration has led to contaminated seepage and groundwater downgradient of some waste rock dumps, and seepage interception systems currently operate in some areas. Contaminants from the tailings are migrating into the Rose Creek Alluvial Aquifer, which flows beneath the tailings. None have reached concentrations that are ecologically significant to warrant collection and treatment. Because of the contaminant load associated with the tailings, the physical stability of the structures in the Rose Creek Tailings Area is critical to protect the downstream environment. In their current configuration, the dams achieve suitable factors of safety for seismic and static stability for the IW period. The flood routing capacity for the Rose Creek Tailings Area warrants improvement and will be addressed by the proposed DVIHU.

Since the mine ceased operating, YG and AANDC have conducted extensive monitoring programs and investigations to characterize environmental conditions at and around the FMC. These programs have collected, compiled, and analyzed data to characterize site conditions, reference (i.e., background) conditions, and mine effects. The results of these programs have been used to define the current baseline conditions for geology, soils, climate, air quality, groundwater, surface water, fish, fish habitat, wildlife and wildlife habitat.

As part of the closure planning process over the past 10 years, YG and AANDC have engaged with communities with the intent to be open and transparent and to provide information to support community understanding and involvement. Further research in 2013 provided supporting information to help define the current baseline conditions for First Nations and communities that may be affected by the proposed IW. The Devolution Transfer

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Agreement (Public Works and Government Services Canada, 2001), lists the Affected First Nations for the Faro Type II mine site:

- Ross River Dena Council
- Liard First Nation
- Selkirk First Nation
- Kaska Dena Council

The Town of Faro is considered an affected community because of proximity and reliance on the project. It is the closest community to the FMC.

Environmental and Socio-economic Effects Assessment

The environmental and socio-economic effects assessment employed a valued-component (VC) -based approach to focus the assessment on key interactions between the project and the environment or people. The following VCs, selected by considering the environmental and socio-economic context and the type and scale of activities proposed for the IW, were assessed:

- Air quality
- Surface water quality
- Fish and fish habitat
- Wildlife and wildlife habitat
- Economy and employment
- Community stability and well-being
- Infrastructure and services
- Land use and access
- Culture and heritage
- Human health and safety

The environmental and socio-economic assessment used two main steps to identify and characterize effects. The first step identified potential interactions between IW activities and the VCs, then classified potential interactions according to the following criteria to create a matrix of project activities and VCs:

- “0” = No Interaction: no measurable interaction that could cause an effect
- “1” = Minor Interaction: minimal interaction where measureable effects are possible, but the effects will be avoided or suitably mitigated through compliance with regulatory requirements and application of standard best management practices
- “2” = Major Interaction: potential interaction where measurable effects are likely even with application of best management practices, or where understanding the scale or magnitude of effects requires detailed analysis

The second step characterized the “Major” interactions to define and describe the potential effects, and evaluate their significance.

The assessment addressed Minor interactions by identifying specific regulatory requirements and best management practices that will eliminate or suitably mitigate potential effects. For each Major interaction, the assessment followed a systematic approach to understand the interaction pathways, predict the effects, identify appropriate mitigation measures, evaluate the significance, and design monitoring plans.

The evaluation of significance of effects considered direction, magnitude, likelihood, duration, geographic extent, probability/frequency, reversibility and socio-economic context, as appropriate for each VC. Ratings of High, Moderate, or Low were established for each criterion, and for overall significance. Any interaction with a High rating for overall significance was deemed to be a significant effect that would require further mitigation. The project definition proceeded iteratively to address any potential significant adverse environmental or socio-economic effects.

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Results and Conclusion

For air quality, the major potential effects of the IW are associated with release of dust from the FMC. The assessment evaluated the significance of the potential effects by comparing predicted concentrations of total suspended particulates, particulate matter (PM_{10} and $PM_{2.5}$), and metals against provincial and territorial air quality criteria.

For surface water quality and fish and fish habitat, the major potential effects of the IW are associated with release of contaminants of concern to receiving water. The assessment evaluated the potential effects of sulphate, cadmium, cobalt, iron, lead, manganese, and zinc. The evaluation of significance of potential effects compared predicted concentrations of contaminants for both normal and adverse conditions against water quality guidelines and aquatic toxicity thresholds.

For wildlife and wildlife habitat, the major potential effects arise from the permanent or temporary destruction or alteration of habitat, metals uptake through feeding or exposure, entrapment or drowning in site facilities, vehicle collisions or equipment-related trauma, or sensory disturbance (i.e., visual, olfactory, or auditory). The assessment evaluated effects on moose, Thinhorn sheep, grizzly bear, avian nesting habitat, waterfowl and small mammals. The evaluation of significance compared the expected effects of the IW against ecological objectives for habitat loss, mortality, local habitat use, and metals uptake.

For economy and employment, the major potential effects arise from the increased employment and spending. The assessment characterized the potential changes in business development, economic diversification, employment and income levels, and education and training.

For infrastructure and services, the major potential effects arise from the influx of workers. The assessment characterized potential effects on roads and traffic, housing, health services, emergency services, and community infrastructure.

For land use and access, the major potential effects arise from two pathways: (1) increased access to currently undisturbed areas during site investigations, and (2) changes in access to the area by local users, resulting from changes in access management at the FMC. The assessment characterized potential effects on traditional land use, hunting and fishing, recreation, tourism, and forestry.

For community stability and well-being, potential effects may arise from the potential influx of workers for certain IW activities. The assessment characterized potential effects on demographics, social cohesion and cultural well-being.

No major potential effect were identified for culture and heritage, and human health and safety. In addition, extreme events including floods, earthquakes, forest fires, and malfunctions and accidents are not expected to cause significant adverse environmental or socio-economic effects during the IW.

None of the ratings of overall significance are High, and therefore none of the potential effects exceed the defined threshold for overall significance. YG and AANDC have concluded that the IW will not cause significant adverse environmental or socio-economic effects.

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Acronyms and Abbreviations

°	degree
°C	degree Celsius
<	less than
≤	less than or equal to
>	greater than
µg/m^3	microgram per cubic metre
AAM	Assessment and Abandoned Mines
AANDC	Aboriginal Affairs and Northern Development Canada
AAQC	ambient air quality criteria
AAQS	ambient air quality standards
AMP	Adaptive Management Plan
ARMC	Anvil Range Mining Corporation
AYFN	Affected Yukoners and First Nations
B&B	bed and breakfast
BGC	BGC Engineering Inc.
BMP	best management practice
C&M	care and maintenance
$CaCO_3$	calcium carbonate
Canada	Government of Canada
CH2M HILL	CH2M HILL Canada Limited
CCME	Canadian Council for Ministers of the Environment
CDA	Canadian Dam Association
cm	centimetre
cm/hr	centimetre per hour
CO	carbon monoxide
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSM	conceptual site model
CSP	corrugated-steel pipe
CVD	Cross Valley Dam
CVP	Cross Valley Pond
DES	Denison Environmental Services
DFO	Fisheries and Oceans Canada
DVIHU	Down Valley Interim Hydraulic Upgrades

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EDI	EDI Environmental Services, Inc.
ELR	Ecological Logistics & Research Ltd.
EMSRP	Environmental Monitoring and Surveillance Reporting Plan
ETA	Emergency Tailings Area
EY	Environment Yukon
Faro	Town of Faro
FCD	Faro Creek Diversion
FMC	Faro Mine Complex
FMRP	Faro Mine Remediation Plan
GID	Grum Interceptor Ditch
GLL	Gartner Lee Limited
GMS	Game Management Subzone
GSC	Grum Sulphide Cell
HDPE	high-density polyurethane
HHERA	human health and ecological risk assessment
HP	horsepower
ID	Intermediate Dam
IDF	inflow design flood
IE	Independent Engineer
IPRP	Independent Peer Review Panel
IW	Interim Works
IWPP	Interim Works Project Proposal
KCB	Klohn Crippen Berger Ltd.
KDC	Kaska Dena Council
kg	kilogram
kg/mon	kilograms per month
km	kilometre
km^2	square kilometre
L	litres
L/min	litres per minute
L/s	litres per second
LCD	Little Creek Dam
LFN	Liard First Nation
LSA	local study area
M	magnitude
m	metre

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m/s	metre per second
m^2	square metre
m^3	cubic metre
m^3/day	cubic metre per day
m^3/min	cubic metre per minute
m^3/sec	cubic metre per second
Ma	million years
masl	metre above sea level
MCE	maximum credible earthquake
MDL	Method Detection Limit
mg/L	milligram per litre
mm	millimetre
mm/year	millimetre per year
Mm^3	million cubic metre
n/a	not applicable, not available
NAPS	National Air Pollution Surveillance
NFRC	North Fork Rose Creek
NFRD	North Fork Rock Drain
NHC	Northwest Hydraulic Consultants Ltd.
NOx	nitrogen oxides
NTU	nephelometric turbidity unit
O.I.C.	Order in Council
O_3	ozone
OHS	Occupational Health and Safety
PM	particulate matter
PMF	probable maximum flood
PMP	probable maximum precipitation
ppbv	part per billion volumetric
ppm	part per million
Project Charter	Faro Mine Remediation Project, Project Charter: Bi-lateral Governance
RCAA	Rose Creek Alluvial Aquifer
RCD	Rose Creek Diversion
RCTA	Rose Creek Tailings Area
RGC	Robertson GeoConsultants
RH	relative humidity
RRDC	Ross River Dena Council

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RSA	regional study area
SAR	Species at Risk
SARA	Species at Risk Act
SD	standard deviation
SENES	SENES Consultants Limited
SFN	Selkirk First Nation
SFRC	South Fork Rose Creek
SIS	seepage interception system
SO_2	sulphur dioxide
SPP	Sheep Pad Ponds
SRK	SRK Consulting Engineers and Scientists
STEP	Student Training and Employment Program
TAC	Technical Advisory Committee
TDS	total dissolved solids
TEES	Tłı̨chǫ Engineering and Environmental Services Ltd.
the Regulations	Assessable Activities, Exceptions and Executive Committee Projects Regulations
tpy	tonne per year
TSP	total suspended particulates
TSS	total suspended solids
USgpm	United States gallon per minute
VC	valued component
VCD	Vangorda Creek Diversion
WKA	Wildlife Key Area
WMC	Water Management Consultants Inc.
WRD	waste rock dump
WTP	water treatment plant
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental Socio-Economic Assessment Board
YG	Government of Yukon
YT	Yukon Territory
Zn	zinc

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SECTION 1

Introduction and Overview

The Government of Yukon (YG) Assessment and Abandoned Mines (AAM) and the Government of Canada (Canada), as represented by Aboriginal Affairs and Northern Development Canada (AANDC), are continuing to prepare a final remediation plan, the Faro Mine Remediation Plan (FMRP), for the Faro Mine Complex (FMC). While the FMRP is being prepared, YG and AANDC will continue their activities on the FMC to protect and minimize risks to human health and safety and the environment, as well as to support the development of the FMRP. These interim activities, collectively referred to as the Interim Works (IW), are the subject of this Project Proposal and include the following tasks:

1. Ongoing site operations
2. Site investigations in support of design and environmental characterization for the FMRP
3. The Down Valley Interim Hydraulic Upgrades (DVIHU) that comprise improvements in flood routing capacity for the Rose Creek Tailings Area (RCTA)
4. Ancillary activities associated with completing these activities

This Project Proposal is referred to as the Interim Works Project Proposal (IWPP). The IWPP is intended to meet the requirements for a Designated Office Evaluation under the *Yukon Environmental and Socio-economic Assessment Act* (YESAA) for the activities associated with the IW for up to 10 years.

1.1 Proponent Information

The governance and management structures for the FMRP are defined in the *Faro Mine Remediation Project, Project Charter: Bi-lateral Governance* (the Project Charter) (YG and AANDC, 2012a). Section 2 of the Project Charter confirms that YG and AANDC are co-proponents for the YESAA assessment for the FMRP. This same approach applies for the IW. AANDC represents the federal government as the IW funder. YG manages environmental and engagement aspects of the IW in conjunction with AANDC. YG leads and directs the design, planning, procurement, construction, and operations at the FMC, and is the main contact for the IWPP:

Energy, Mines and Resources Assessment and Abandoned Mines Branch Box 2703, K-419 Whitehorse, Yukon Y1A 2C6	Contact: Ms. Patricia Randell, Manager, Assessment and Type II Phone: 867-667-3208 Email: patricia.randell@gov.yk.ca

YG and AANDC have shared responsibility for managing the FMC since April 1, 2003, when the Yukon Northern Affairs Devolution Transfer Agreement took effect. Upon devolution, YG assumed administration and control of public lands, including abandoned mine sites. Canada remained responsible for unfunded liabilities related to major sites including the FMC (YG and AANDC, 2013). In March 2009, YG and AANDC assumed more direct responsibility for daily FMC operations, taking over when the interim receiver (appointed in 1998 under the *Companies' Creditors Arrangement Act*) concluded its responsibilities. At that time, YG agreed to direct and lead FMC site operations. YG engages contractors with appropriate expertise to support its responsibilities at the FMC. Currently, these include the following firms:

- Tłı̨chǫ Engineering and Environmental Services Ltd. (TEES) - responsible for operations, maintenance, site management and environmental monitoring.
- CH2M HILL Canada Limited (CH2M HILL) – responsible for designing remediation measures and preparing assessment and regulatory applications.

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The governance structure for the FMRP includes two mechanisms to independently review project execution. The Independent Peer Review Panel (IPRP), comprising experts in mine site reclamation, is responsible for reviewing designs and technical issues, reviewing regulatory submissions, and providing subject-matter expertise on technical issues. The Independent Engineer (IE) is responsible for monitoring the FMRP's performance, progress, and quality. The IPRP and the IE are both accountable to the Management Board that includes senior representatives from YG and AANDC (YG and AANDC, 2013).

1.2 Project Purposes and Objectives

The IW is a continuation of activities that have taken place at the FMC since mine operations ceased in 1998. These activities will continue until the FMRP is implemented, and have two main purposes:

1. To control and reduce the effects of the existing FMC on human health and safety, and the environment.
2. To compile sufficient site and environmental information to support design, assessment and permitting for the FMRP.

As part of the IW, ongoing site operations and the DVIHU are intended to achieve the first purpose by completing the following activities:

- Managing clean and contaminated water
- Maintaining, repairing, and monitoring mine facilities and structures
- Implementing site security measures
- Monitoring site and environmental conditions
- Responding to changes in accordance with an adaptive management plan (AMP) and risk assessment

Site investigation activities for the IW are intended to achieve the second purpose of compiling sufficient site and environmental information to support development of the FMRP.

Past mining activities left a legacy of waste storage facilities (e.g., waste rock dumps [WRDs] and tailings dams), water management structures (e.g., stream diversions and dams), and mine infrastructure over the FMC. The IW are being proposed to manage significant chemical and physical stability risks as a result of this legacy. In the long term, the FMRP will remediate conditions at and near the FMC and protect humans and the environment from these risks, by working to achieve the following overarching objectives (YG and AANDC, 2013):

- Protect human health and safety.
- Protect and, to the extent practicable, restore the environment including land, air, water, fish and wildlife.
- Return the mine site to an acceptable state of use that reflects pre-mining land use where practicable.
- Maximize local and Yukon socio-economic benefits.
- Manage long-term site risk in a cost-effective manner.

The design, permitting, and procurement for the FMRP will take several years. During this time, the IW are intended to manage effects and risks at the FMC; however, the overarching objectives will be fulfilled most effectively by the FMRP. For example, geochemical conditions at the FMC are deteriorating, leading to increased contaminant mobilization. The IW may include constructing seepage interception systems in accordance with the AMP, which will prevent contaminants from migrating to the receiving environment. While these measures help protect human health and the environment, they alone do not provide the degree of remediation and contaminant control that will produce suitable long-term conditions. Consequently, other long-term source control measures (e.g., covers) are planned as part of the FMRP to further reduce mobilization and transport of contaminants. The IW move towards reaching the overarching objectives, while the FMRP will be the main instrument for fulfilling those objectives in the long-term.

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SECTION 2

Assessment and Regulatory Requirements

2.1 Requirement for YESAA Assessment

The *Proponent's Guide to Project Proposal Submission to a Designated Office* (Yukon Environmental Socio-Economic Assessment Board [YESAB], 2010) identifies three criteria (from YESAA s.47) that together require a project to undergo an assessment and receive a decision document under YESAA before the project is undertaken. YG and AANDC have concluded the IW requires assessment, as it meets all of these criteria and that they are Decision Bodies under YESAA, as shown by the following:

1. The project is located in Yukon.
2. The IW include activities that are identified, and not excepted, in Schedules 1 and 2 of the *Assessable Activities, Exceptions and Executive Committee Projects Regulations* (the Regulations) (Canada, 2005). For example, the proposed site operations, site investigations, DVIHU, and ancillary activities include activities that fall within the following items in the Regulations:
    - Part 1, Item 3: Construction, operation, modification, decommissioning, or abandonment of, or other activity in relation to, a mine.
    - Part 9, Item 1: Drilling, operation, modification, decommissioning, abandonment of, or other activity in relation to, a well for the extraction of groundwater.
    - Part 9, Item 2: Construction, operation, modification, decommissioning, abandonment of, or other activity in relation to, a facility or installation for the extraction of groundwater.
    - Part 9, Item 3: Direct use of water.
    - Part 9, Item 4: Construction, modification, decommissioning or abandonment of, or other activity in relation to, a watercourse crossing that is 5 metres (m) or more in length.
    - Part 9, Item 9: Construction, modification, decommissioning or abandonment of, or other activity in relation to, a structure for flood control.
    - Part 9, Item 12: The deposit of waste into water.
    - Part 13, Item 3: Earth drilling using power-driven machinery that has an operating weight exceeding 500 kilograms (kg).
    - Part 13, Item 12: On Crown land, moving earth or clearing land using a self-propelled power-driven machine.
    - Part 13, Item 13: On Crown land, levelling, grading, clearing, cutting or snow plowing of a: (a) trail, (b) right-of-way of a road, or (c) route that provides access to land for the purposes of a geophysical, geological or engineering survey.
    - Part 13, Item 15: On Crown land, the extraction of sand, gravel or stone.
    - Part 13, Item 16: Operation, or expansion of a gravel or sand pit or stone quarry.
3. YG and AANDC are co-proponents of the IW and many of the activities (e.g., earth drilling) would require authorization if a private individual undertook them. The use of water and deposit of waste into water also meet the criteria for licensing under the *Waters Act*.

The activities proposed as part of the IW are not identified in Schedule 3 of the Regulations. As a result, YG and AANDC have concluded in accordance with YESAA Subsection 50(1) that they are obliged to submit the IWPP to a Designated Office.

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2.2 Current Operating Authority

On February 28, 2009, at the same time as the Ontario Superior Court discharged Deloitte and Touche Inc. from its responsibilities as interim receiver and YG assumed responsibility for day-to-day management of the FMC, the site water licence expired. Since then, YG has conducted its activities at the FMC under the authority of a Minister's Determination granted in accordance with Subsection 37(1) of the *Waters Act*. This Subsection provides the Minister with authority to take "any reasonable measures to prevent, counteract, mitigate, or remedy any resulting adverse effect on persons, property, or the environment" if the effects may arise from an abandoned site. The Minister's Determination for the FMC issued in late February 2009, provides authority for AAM to take reasonable measures to protect persons, property and the environment (especially surrounding waters) from effects that may be caused by the facilities and conditions at the FMC.

While many of the activities that make up the IW fall within the scope of the Minister's Determination, YG and AANDC recognize that some activities are not directly related to preventing, mitigating, or remedying adverse effects on persons, property, or the environment. As such, they have chosen to proceed with a YESAA assessment for the IW. At the same time, the conditions at the site require continued operation and adaptation at the FMC under the current operating authority granted by the Minister's Determination. Once the YESAA assessment and licensing processes are complete, the Minister's Determination will no longer provide the sole authority for all activities that will be undertaken at the FMC.

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SECTION 3

Project Location, Background and Engagement

3.1 Project Location

3.1.1 Geographical Location

The FMC is located in the Yukon Territory approximately 200 kilometres (km) north northeast of Whitehorse, approximately 15 km north of the Town of Faro, and approximately 50 to 65 km northwest of Ross River (Figure 3-1). The mine Access Road extends approximately 22 km from the Town of Faro to the FMC, gaining over 400 m in elevation.

The FMC consists of three main areas: the Faro Mine Area, the RCTA, and the Vangorda/Grum Area (Figure 3-2). The 14-km Haul Road connects the Faro Mine Area and Vangorda/Grum Area. The Faro Mine Area and RCTA are in the Rose Creek watershed, and the Vangorda/Grum Area is in the Vangorda Creek watershed. Rose Creek flows to Anvil Creek, a tributary of the Pelly River, while Vangorda Creek flows directly to the Pelly River.

The disturbed area of the FMC is generally oriented southeast to northwest, with the following geographic extents:

- 62 degrees (°) 14’30.8” N to 62°21’59.1” N
- 133°10’57.5” W to 133°29’3.8” W

The FMC is found primarily on National Topographic System Map 105K/6, with a small portion on 105K/3. The FMC is located within the Southeast YESAA Assessment District. The Designated Office for the Southeast District is located in Watson Lake.

3.1.2 Traditional Territories and Affected Yukon First Nations

The FMC is located in the traditional territories of the Ross River Dena Council (RRDC) and the Liard First Nation (LFN), members of the Kaska Dena. The Selkirk First Nation (SFN) traditional territory extends upstream on the Pelly River to a few kilometres downstream of the confluence with Anvil Creek (Figure 3-3). The Yukon Northern Affairs Program Devolution Transfer Agreement (Canada and YG, 2001) identifies the RRDC, LFN, Kaska Dena Council (KDC), and SFN as Affected First Nations for the FMC.

Neither RRDC nor LFN has finalized a land claim agreement but several land selections surrounding the FMC are subject to interim protection for the RRDC (Figure 3-3). RRDC R12-B follows the left banks of Rose Creek and Anvil Creek, beginning approximately 5 km downstream of the FMC and continuing to the mouth of Anvil Creek. RRDC R21-A follows the right bank of Anvil Creek for several kilometres upstream from the mouth of the creek. RRDC S11-B is located on the right bank of Rose Creek immediately downstream of the FMC, within Order in Council (O.I.C.) 2008/168, which withdraws the FMC from staking, and Internal Yukon Government Reserve of Land 2008-2582.

3.1.3 Land Tenure

The FMC is located entirely on Crown land administered by YG. Much of the Vangorda/Grum Area falls within the municipal boundary for the Town of Faro (Figure 3-4). YG holds Internal Yukon Government Reserve of Land 2008-2582 for the FMC and surrounding area, effective November 8, 2013 (Figure 3-4). This reserve provides the following restriction:

> *“Any land use activities planned for the reserve area must be provided to Assessment and Abandoned Mines for approval prior to the activity being authorized.”*

The entire FMC and areas that may be subject to disturbance as a result of the FMRP are subject to O.I.C. 2008/168 (Figure 3-4). The O.I.C. prohibits staking and prospecting under both the *Quartz Mining Act* and the *Placer Mining Act*. YG established the O.I.C. to prevent future conflicts between FMC closure/remediation activities and mineral exploration activities.

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A sheep range wildlife reserve, encroaches on parts of the Vangorda/Grum Area and the Haul Road (Figure 3-4). The FMC falls within Group Trapping Concession 405 that is managed by the Ross River Dena Council and used by First Nation members. It also falls within Outfitting Concession 9, held by Deuling Stone Outfitters Ltd. Outfitting Concession 8, held by MacMillan River Adventures, overlaps with Anvil Creek and the lower portion of Rose Creek, downstream from the FMC.

The FMC is located in the Kaska Land Use Planning Region established by the Yukon Land Use Planning Council. A planning commission has not been appointed for this planning region, and the regional land use planning process has not been initiated.

3.2 Project Background

3.2.1 Site History

Before ore bodies were discovered in the Vangorda and Rose Creek watersheds, people of the Kaska Nation, specifically the Ross River Dena and their ancestors, used the land where the FMC is located. Weinstein (1992) describes the use of the area by the Ross River Dena in *Just Like People Get Lost: A Retrospective Assessment of the Impacts of the Faro Mining Development on the Land Use of the Ross River Indian People.* The Dena moved across the landscape to where the resources were available in a seasonal "round." The FMC area was an important part of the traditional seasonal round in the Mount Mye area for several Kaska extended families:

> *"The people for whom the Mye Mountain/Anvil Creek/Blind Creek areas were primary resource lands at the time of development included the direct descendants of the earlier generation of people from that country. These included Selkirk Billy, Aklack, Billy Atkinson, Long Hair John, Gumbala, Nahlier, Pat Johnnie (Peter Ladue's maternal grandfather), and Sue Bill (Jack Ladue's first wife's father) and their spouses. The group also included people who married into these families or who were invited to join these groups. During the period prior to the mine construction, Joe Ladue, Hoole McLeod, Jack Sterriah, Old Man Jules and Jack Ollie's wife and some of their family members regularly trapped in the affected areas."*
>
> Weinstein, 1992 - pp. 87-88

In the seasonal round, people gathered at fish camps (e.g., Blind Creek, Pelly River at Faro, and Fish Hook near the mouth of Anvil Creek) in late July and early August. After the salmon run, people travelled to Mount Mye area to hunt arctic ground squirrels and hoary marmot, and to pick berries. With the fall moose rut, people moved to lower elevation areas to hunt moose, and dry and cache supplies of meat. Following the moose hunt, people walked back to the trading post at Ross River to purchase supplies for the winter, and then returned by raft to the Mount Mye area, where they dispersed to trapping areas around the mountain and its streams. After the winter trapping season, families converged at Swim Lakes to trap lynx and for the spring fishery. In late spring, men would travel to Sheldon Lake for the spring beaver hunt, while women and children remained at Swim Lakes to continue to prepare stocks of dried fish. In late May, families would walk to Ross River to trade the supply of furs, where they remained until the round began again with the salmon fishery (Weinstein, 1992). Figure 3-5 shows key locations.

The development of the FMC displaced traditional land uses, and damaged an environment that was steeped in family and cultural history. The words of Arthur John, a respected elder of Ross River, as quoted by Weinstein, convey the depth of loss experienced from the mining project:

> *"Now no one goes there. The mine tore up half the mountain now. People from that country try other areas, could not find anything as good. After that, just like people get lost, don't know where to go. They tried back in there, up that way. Not as good as down there no more. So people don't get good living like long time ago."*
>
> Weinstein, 1992

Al Kulan, with the assistance of Kaska prospectors Jack Ladue, Robert Etzel, Joe Etzel, Art John, and Jack Sterriah, discovered and staked the Vangorda deposit in 1953. While this deposit was considered too small and remote for

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development at the time, it led to the 1965 discovery of the Faro deposit by Dynasty Explorations. The Grum deposit was discovered in 1973.

Mining at the FMC began in 1969 and continued until 1998, with several temporary cessations of varying lengths. Anvil Mining Corporation opened the Faro Mine in 1969 and continued operations, under the name Cyprus Anvil Mining, until 1982 when economic conditions forced a shut down. Operations at the Faro Mine resumed under Curragh Resources Ltd. in 1986. Curragh continued mining the Faro Mine while seeking approvals and constructing infrastructure for the Vangorda and Grum Mines. Mining at Vangorda Pit began in 1990 and continued, concurrent with mining at Faro Pit, until mid-1992, when resources in the Faro Pit were depleted. In late 1992, Curragh sought bankruptcy protection and ceased mining operations. Curragh began stripping overburden and waste rock from the Grum Pit in 1991, but did not begin ore production before the 1992 shut down.

Anvil Range Mining Corporation (ARMC) purchased the FMC from the interim receiver and resumed operations in 1994 with a Grum Pit pre-stripping program. Ore production began at the Grum Pit in August 1995, followed by resumed production at the Vangorda Pit. ARMC terminated mining operations in late-1996 for economic reasons and, following a financial restructuring, restarted in 1997. Mining continued until early 1998 when ARMC sought bankruptcy protection.

After the mine shut down in 1998, Deloitte and Touche Inc. undertook FMC care and maintenance (C&M) activities, serving as the interim receiver for ARMC under the *Companies' Creditors Arrangement Act*. Deloitte and Touche Inc. continued in this role until early 2009, when it was discharged from these duties and YG assumed management responsibility. In 2003, YG and the federal government acknowledged that mining at the FMC was no longer economically viable and began planning for the site to be permanently remediated. Since the mine shut down in 1998, AANDC has provided funding for C&M and closure planning activities.

As part of initial mine development, Cyprus Anvil Mining constructed the Town of Faro near the confluence of Vangorda Creek and the Pelly River, about 22 km by road from the mill facilities at the FMC. Construction began in 1968, but a forest fire destroyed most of town in June 1969. In 1970, the population in the Town of Faro was about 800 people, and it grew slowly over the years as the mine expanded, until 1981 when the population was just under 2,000. In 1985, with the mine shut down, the population reached a low point with only 97 Faro residents remaining. After the mine closed permanently in 1998, many Faro residents remained, with a few continuing to work at the closed mine. Today, the Town of Faro has approximately 400 inhabitants, with tourism identified as a major economic growth factor (Town of Faro, 2013).

3.2.2 Faro Mine Complex – Site Overview

As Section 3.1 stated, the FMC consists of the Faro Mine Area, the RCTA, and the Vangorda/Grum Area. The 14-km Haul Road connects the Faro Mine Area and Vangorda/Grum Area. This section provides an overview of the current site conditions; Section 6.1 provides additional detail.

3.2.2.1 Faro Mine Area

The Faro Mine Area (Figure 3-6) includes the following components:

- The Faro Pit (1,675 m long, 975 m wide, and 335 m deep, containing approximately 15 million tonnes of tailings)
- Approximately 30 WRDs (totalling approximately 260 million tonnes that cover approximately 335 hectares)
- Ore processing and handling facilities
- The Emergency Tailings Area (ETA)
- The Faro Creek Diversion (FCD)

It also includes contaminated water management facilities, including the S-Wells and ETA Seepage Interception Systems (SIS), and contaminated water pumping, conveyance, and treatment facilities. A second pit at the Faro Mine Area, the Zone II Pit, was filled with waste rock during subsequent mining. Dewatering the Zone II Pit prevents contaminated water from accumulating and discharging.

Much of the waste material at the FMC is acid-generating, whereby oxidation of sulphide minerals releases sulphuric acid that mobilizes metal contaminants. Waste rock and pit walls at the Faro Mine Area continue to oxidize and release contaminants. Although sulphide cells, low/medium-grade ore stockpiles, and oxide fines stockpiles contain the most consistent highly mineralized wastes, the waste rock at the Faro Mine Area is generally poorly segregated.

Water infiltration has led to contaminated seepage and groundwater downgradient of some WRDs at the Faro Mine Area. Seepage interception systems currently operate at the S-Wells and the ETA to collect contaminated water for treatment. Contaminant migration in additional areas is managed through the practices described in the AMP (Appendix 5C). The Faro Pit serves as a contaminated water storage reservoir, providing storage capacity to support seasonal water treatment and to reduce site water management risks. Water treatment at the Faro Mine Area relies on lime precipitation technology. The existing water treatment plant (WTP) is located in the former mill building, but will no longer be used due to concerns about safety and reliability. Planning is underway for establishment of an Interim Water Treatment System that will operate throughout the IW and be located near the former concentrate load-out facility. Discharge from the treatment system flows to the CVD Pond before discharging into the North Wall Interceptor Ditch and eventually Rose Creek.

3.2.2.2 Rose Creek Tailings Area

The RCTA (Figure 3-7) covers an area of over 200 hectares in the original valley of Rose Creek, just downstream of the confluence of the North Fork Rose Creek (NFRC) and South Fork Rose Creek (SFRC). The RCTA comprises four dams – the Original, Secondary, Intermediate and Cross Valley Dams – and the Rose Creek Diversion (RCD). The Original, Secondary, and Intermediate Dams retain a total of 55 million tonnes of tailings in the Rose Creek valley. The Cross Valley Dam (CVD) retains a pond that is used for final polishing of treated water. Sludge cells on the Original Tailings provide storage for water treatment sludge from the Faro Mine Area water treatment system.

Contaminants from the acid-generating Rose Creek Tailings are migrating into the Rose Creek Aquifer, which flows beneath the tailings. While concentrations of some contaminants are increasing in groundwater downgradient of the RCTA, none have reached levels that are ecologically significant to warrant collection and treatment. Planning and design have been initiated for seepage interception downstream of the CVD. The AMP will guide the construction and implementation of an SIS. Assessment and regulatory requirements will be addressed before construction.

Contaminated surface water accumulates in the Intermediate Dam (ID) Pond. Site operations includes collecting and treating this water at the Faro Mine Area water treatment system. The RCD conveys clean water in Rose Creek around the RCTA.

Because of the contaminant load associated with the tailings, the physical stability of the structures in the RCTA is critical to protect the downstream environment. YG and AANDC have engaged qualified engineers to evaluate the seismic and static stability of the tailings dams and RCD Dike, as well as the flood routing capacity of the RCD. In their current configuration, the dams achieve suitable factors of safety for physical stability for the IW period. However, the RCTA's flood routing capacity warrants improvement to reduce risks associated with floods. These improvements are addressed by the DVIHU component of the IW (described in Section 5), which involves upgrading the hydraulic capacity of both the ID spillway and the RCD to provide capacity for the system to convey a 1-in-500-year flood event.

3.2.2.3 The Vangorda/Grum Area

The Vangorda/Grum Area (Figure 3-8) includes the Vangorda Pit (1,150 m long, 350 m wide, and 150 m deep), the Grum Pit (1,100 m long, 700 m wide, and 200 m deep), the Vangorda Waste Dump, the Grum Waste Dump, the Grum Overburden Dump, the Grum Ore Transfer Pad, the Vangorda Creek Diversion (VCD), the Vangorda WTP, and the Little Creek Dam (LCD). There are no tailings stored at the Vangorda/Grum Area because all ore was processed in facilities at the Faro Mine Area.

Almost all waste from the Vangorda Pit is acid-generating. To address this issue, the Vangorda Waste Dump was designed and constructed with a seepage collection system. Seepage from the Vangorda Waste Dump flows into Little Creek Pond, where it is pumped to the Vangorda Pit and eventually to the Vangorda WTP.

The mine plan for the Grum Pit included placing sulphide waste in a sulphide cell within the Grum Waste Dump. In 2010, YG and AANDC placed a geosynthetic cover over the Grum Sulphide Cell (GSC) to reduce infiltration and contaminant migration. Seepage and surface flows from the Grum Waste Dump historically flowed into a natural depression referred to as Moose Pond, where they exfiltrated to ground on their way to Vangorda Creek. Downgradient well monitoring continues to confirm that contaminant concentrations have not reached ecologically significant levels. However, the physical stability of Moose Pond in high flow events has led to the construction of an SIS for the Grum Waste Dump. This SIS operates seasonally, pumping water into the Vangorda Pit and eventually to the Vangorda WTP.

Both the Vangorda and Grum Pits serve as contaminated water reservoirs, providing for seasonal water treatment at the Vangorda WTP. The WTP was constructed in 1990 as part of the initial mine development, relying on lime precipitation technology to reduce concentrations of contaminants of concern. Historically, sludge from the Vangorda WTP was stored in sludge cells on the Grum Overburden Dump or in the Vangorda Pit. Discharge from the WTP flows into the Grum Northeast Interceptor Ditch and through the Sheep Pad Ponds (SPP) before discharging into Vangorda Creek.

The VCD conveys clean water around the highly contaminated Vangorda Pit, relying primarily on a half-culvert flume. The VCD was constructed with capacity to convey the estimated peak flow for a 1-in-100-year flood, but the facility presents maintenance challenges, because of icing and the condition of the flume. There are also risks associated with the stability of the nearby Vangorda Pit wall.

3.2.3 Current Care and Maintenance Activities

After active mine operations ceased at the FMC in 1998, the site transitioned to a C&M phase. YG assumed management responsibility at the FMC in 2009, and began overseeing the C&M activities. Currently, YG engages TEES under a contract to carry out the following activities:

- Operate, maintain, and repair the following components:
  - Fresh water systems
  - Contaminated water systems
  - Pumping systems
  - Collection ditches
  - Dams and diversions
  - Contaminated water containment areas
  - Contaminated water treatment systems
  - Equipment
  - Site buildings and infrastructure
  - Electrical distribution systems
  - Roads and culverts
- Perform sludge management
- Perform tailings dust management
- Implement the preventative maintenance plan
- Provide emergency response capability and respond to emergencies
- Provide security, health, and safety for the FMC
- Purchase and manage use of electricity, fuels, and lubricants
- Maintain all permits and licences as required
- Implement an Affected Yukon First Nation (AYFN) and Yukoner Participation Plan
- Provide site management and administration services
- Comply with specified environmental standards
- Conduct environmental and site monitoring.

Continued C&M is part of the site operations component of the proposed IW.

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3.2.4 Closure Planning Status

In 2003, YG and AANDC acknowledged the FMC would not reopen, and initiated a process to develop an overall closure and remediation plan. YG, AANDC, RRDC (on behalf of the Kaska Nation), and the SFN agreed to establish a joint project Oversight Committee. The Oversight Committee's role was to provide strategic leadership in the identification and development of a recommended approach to long-term site closure and remediation. The LFN joined the Oversight Committee in 2007. The Oversight Committee provided a forum for the direct participation of the affected First Nations in defining, evaluating and selecting remediation options for the FMC.

In early 2009, the Oversight Committee selected a preferred option that would form the basis for the long-term closure and remediation plan. This selection considered input from the following sources:

- Hundreds of technical studies conducted by a multidisciplinary team of engineers and scientists
- Consultations with First Nations and communities
- The IPRP, comprising nine leading experts in various facets of mine closure
- A multiple accounts-decision analysis that compared a range of options against the project objectives, conducted by a group comprising community members, technical consultants, and government representatives

The preferred option emphasizes the need to stabilize contaminants, rather than remove them from the FMC. Key features of the FMRP include upgrading dams so tailings remain in place, re-sloping waste rock, installing engineered soil covers over tailings and waste rock, upgrading stream diversions, and installing state-of-the-art water collection and treatment systems.

Once the Oversight Committee reached consensus about the long-term closure and remediation plan, the focus of remediation planning efforts shifted to the design, assessment, and permitting for the chosen option. In 2011, YG and AANDC selected CH2M HILL as the main technical designer for the FMRP, to provide engineering and scientific support for this phase of the remediation planning. The site investigation component of the IW will be a major contributor to the documentation needed to support design, assessment, and permitting. YG and AANDC currently anticipate submission of a Project Proposal for the FMRP in May 2017 (Figure 3-9). To achieve this schedule, plans include a substantial field investigation program in 2014, as described in Section 5 of this IWPP.

3.3 Community and Regulatory Engagement

3.3.1 Overview and Intent

This section provides an overview of the engagement activities that have occurred for the FMRP with specific reference to how these engagement activities relate to the IWPP. Appendix 3A, Supporting Documentation of Engagement Activities, includes specific documentation for these sessions, such as meeting agendas, presentations, and notes.

Over the past 10 years, the community and regulatory engagement process for the FMRP has included, in order, the following phases:

- Initial 2003-2008 5-year closure planning and options selection process that included engagement with First Nations, other governments, communities and other stakeholders. To support effective participation in this process, YG and AANDC established funding agreements with the AYFN communities.
- Since 2008, development and implementation of an AYFN Participation Strategy and other engagement meetings related to the FMRP.
- In 2013, IWPP-specific discussions.

YG and AANDC structured the process with the intent to be open and transparent and to provide information to support community understanding and involvement.

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3.3.2 Parties Considered

Section F of Appendix H (Inventory of Sites) of the Devolution Transfer Agreement (PWGSC, 2001), lists the Affected First Nations for the each of the Yukon Abandoned Type II mine sites. The Faro Type II mine site has the following four AYFN governing bodies that represent First Nation Citizens affected in the communities of Watson Lake, Ross River and Pelly Crossing:

1. RRDC, centred in Ross River
2. LFN, centred in Watson Lake
3. SFN, centred in Pelly Crossing
4. KDC, centred in Lower Post British Columbia and established by five Kaska First Nations in Yukon and British Columbia

The Town of Faro is also considered an affected community because of proximity and reliance on the project. It is the closest community to the FMC.

Figure 3-1 shows the location of these communities in relation to the FMC.

3.3.3 Approach

3.3.3.1 Closure Planning (2003-2008)

From 2003-2005, potential environmental issues at the mine site were characterized through technical studies and assessments, and technical workshops were held with communities from the AYFNs and the Town of Faro and with regulatory agencies to provide information on the project and to gather input on different approaches to mine remediation to address the overarching closure objectives (Section 1.2). Meetings also took place over the same period with other interested parties, including the Yukon Chamber of Mines, Yukon Chamber of Commerce, Yukon Conservation Society, Canadian Parks and Wilderness Society, Yukon Fish & Wildlife Management Board, the Yukon Salmon Committee, and members of the general public.

In the spring of 2006, additional community consultation meetings were held to provide an overview of the project and potential remediation alternatives. With the findings of the technical studies, 12 “example alternatives” were identified to represent the spectrum of what was potentially technically feasible to address the environmental issues present at the site and address the overarching closure objectives. These alternatives were reviewed by an IPRP, and the IPRP findings (along with feedback from two rounds of community consultations in fall 2006/spring 2007) led to the 12 alternatives being refined to five final closure options: three for the Faro Mine Area (pit, tailings, and waste rock areas) and two for the Vangorda/Grum Area.

In 2007, the community, regulators, technical consultants, and government representatives further evaluated the five short-listed options against the project objectives, using a multi-attribute utility analysis method. A summary of this process up this juncture is provided in the January 2008 presentation ‘Faro Mine Closure: Arriving at Closure’ (refer to Appendix 3A, Attachment 3A-1). In November 2008, the findings of the assessment and evaluation process were presented to the Faro Mine Oversight Committee, which reviewed the findings and agreed on a preferred option that is the overall closure and remediation plan for the FMC.

3.3.3.2 AYFN Funding Agreements and Governance

AAM has held funding agreements with both the RRDC (representing KDC) and SFN since 2003, and with the LFN since 2007. Initially, the purposes of these funding agreements were to cover costs for engaging representatives from these AYFN in participating in the Faro Mine closure planning process (particularly in the selection and endorsement of a final closure option) and for each AYFN to have a dedicated FMRP office with a Community Coordinator (and assistant in some cases) to provide community communications, community meetings/workshops and technical advice related to the FMRP. Once the closure option was selected, the scope and budgets of the funding agreements expanded with the change in roles and responsibilities to include projects related to Traditional Knowledge), community socio-economic planning for remediation, projects aimed at increasing awareness of youth, and mine site tours for youth and elders.

The 2011/12 YG proposed modifications to funding agreements to address community participation on technical issues of the project, and include both the hiring of Community Coordinators to inform the communities of

project updates and training and employment opportunities through contractors working on the FMRP, and the formation of a Technical Advisory Committee (TAC). Only SFN entered into a funding agreement. The SFN TAC was comprised of representatives of different facets of the SFN community to encourage greater communication and knowledge within the community about the project, and to seek greater community input into the project.

Meetings and discussions have taken place since 2010 with representatives of the AYFNs and the Governments of Canada and Yukon, to develop a proposed governance structure for the FMRP. A final governance structure is still to be developed.

In August 2012, the KDC notified AAM that they no longer wished to be represented on the FMRP through RRDC and would represent themselves in future negotiations and discussions.

In May 2013, letters were sent to all the AYFNs to initiate the process for drafting the 2013/14 funding agreements. As of December 2013, SFN is the only AYFN to have entered into an agreement.

3.3.3.3 AYFN and Yukoner Participation Strategy

In accordance with the Devolution Transfer Agreement, the Yukon Government Contracting Policy, and the policy objectives of the Northern Contaminated Sites Program and the Government of Canada Contracting Policy, AAM has adopted a three-pronged AYFN and Yukoner Participation Contract Strategy (herein referred to as the Participation Strategy). Following that, contractors working on the FMRP must develop specific Participation Plans with targets to demonstrate how they will maximize AYFN and Yukoner participation on the FMRP through the following:

- Training and capacity building
- Contracting and subcontracting
- Direct employment

In 2008, the overall Participation Strategy was first developed with the Chiefs of the SFN and RRDC to address the C&M contract at the FMC, and has subsequently been adopted by AAM for inclusion in all major contracts where reasonable opportunities exist for AYFN and Yukoner participation. The contractors' performance is to be assessed based on agreed upon performance outcomes of their specific Participation Plans and any mitigating circumstances that may have hindered the ability to meet those targets.

As part of their Participation Strategy responsibilities, the C&M contractor meets with the communities to provide a project status update (as it relates to training and onsite activities). While these meetings may be quarterly, the timing and frequency depends on the ability of the contractor to schedule around community activities. AAM has participated in some of these meetings to provide other project updates where appropriate, as follows:

- In May 2010, the Kaska communities of Ross River, Lower Post, and Good Hope Lake were visited and an FMRP update was provided that included a discussion on the Participation Strategy (see Appendix 3A, Attachment 3A-2 PowerPoint presentation).
- At a November 2011 community meeting with the LFN in Watson Lake related to the FMRP, the C&M contractor and AAM (1) provided an update on the project (including surface water and wildlife surveys and site operations contracting efforts), (2) reinforced the message of the Community Coordinators being points of contact regarding the FMRP, and (3) advised of the ongoing governance structure discussions for the FMRP that were being developed with the AYFN Chiefs (see Appendix 3A, Attachment 3A-3 poster and PowerPoint presentation).
- An April 2013 community meeting with the SFN in Pelly Crossing was used to provide a project update on activities that had been completed on the site from 2010 to 2012 and on activities planned for 2013, including data collection for the IWPP (see Appendix 3A, Attachment 3A-4 PowerPoint presentation).

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In 2010, YG hired an AYFN/Community Affairs Project Manager to further enhance AYFN and Yukoner participation coordination efforts in the FMRP. The key role and responsibilities for this position are as follows:

- Liaise with Community Coordinators to attempt to foster a participatory relationship between the AYFN communities and AAM through mechanisms such as weekly update meetings.
- Assist Community Coordinators in fulfilling funding agreement obligations such as quarterly and annual reports to ensure funding is available to continue working level relationships.
- Liaise with C&M contractors and the Community Coordinators on projects with AYFN involvement to assist in fulfilling the project objective of maximizing local and Yukon socio-economic benefits.
- Draft annual funding agreements from work plans submitted by the Community Coordinators or other AYFN representatives.
- Provide input on upcoming large contracts (such as C&M) to maximize socio-economic benefits through such actions as the hiring of a dedicated AYFN Training Coordinator as part of C&M.
- Assist AAM project managers with AYFN involvement where necessary.

3.3.3.4 Engagement Activities (2009 to 2013)

Following the identification of the preferred option for the overall closure and remediation plan for the FMC, engagement sessions were held in the communities in February 2009 to present the recommended closure option. In May to August 2009, meetings were held with the Environmental Assessment/Socio-economic Assessment Working Group, a group formed with representatives of the communities to discuss and provide feedback on the environmental and socio-economic aspects of the FMRP. In 2010 and 2011, AAM and AANDC were in discussion with AYFN Chiefs about a proposed governance structure for the FMRP.

In late 2011/early 2012, discussions on the engineering, environmental, and socio-economic aspects of the FMRP resumed. This section provides an overview of the key community and regulatory engagement activities around these FMRP discussions with an emphasis on how these activities relate to the IWPP.

Table 3-1 provides a summary of the engagement activities discussed in this section that occurred from 2011 to 2013 and includes reference to where the supporting activity documentation can be found in Appendix 3A.

Community Engagement

In addition to the community meetings that have been held in Ross River, Watson Lake, and Pelly Crossing in conjunction with the C&M contractor meetings (as discussed in Section 2.3.3.3), there have been four other meetings with the SFN (Table 3-1) to provide project updates (in conjunction with the C&M contractor). Two other meetings were SFN TAC meetings focused on technical issues with specific concerns around how the FMRP and IWPP will affect water quality.

Regulatory – Yukon Socio-Economic Board

Four meetings were held with YESAB from October 2011 through to July 2013 (Table 3-1). The first two meetings in late 2011 were held to introduce members of the FMRP team to YESAB and to discuss the FMRP scope and assessment approach. The third meeting was held in April 2013 to discuss the IW project scope and confirm that YG and AANDC would submit the IWPP to the Watson Lake Designated Office for an evaluation. YG also convened a site tour for YESAB members and staff in July 2013. Documentation for these meetings can be found in Attachments 3A-5 to 3A-8 in Appendix 3A, Supporting Documentation of Engagement Activities.

Regulatory – Government Agencies

A meeting was held with Yukon Environment in January 2012 (Table 3-1) to discuss wildlife information requirements (particularly for caribou, moose, sheep and grizzly bear) to prepare a YESAB Project Proposal for the overarching FMRP. It was agreed in the meeting that no further investigations were required for caribou and sheep information, and that it would be confirmed whether additional work would be required for moose (a late winter moose survey) or grizzly (denning habitat mapping). In 2013, the information needs from this meeting

were then reviewed for the purposes of the IWPP, and given the scope of the IWPP it was decided to use existing information for these species. The meeting notes can be found in Attachment 3A-9 in Appendix 3A, Supporting Documentation of Engagement Activities.

Government agencies have also been engaged on an as-needed topic basis. For example, YG consulted with Fisheries and Oceans Canada (DFO) and YESAB before conducting the fish telemetry surveys to review the plan and seek input. Posters were developed on the program and Community Coordinators posted these around waterbodies. YG also engaged the Northern Contaminants Program in 2011 to look more closely at the issue around containment effects on wildlife, and developed a wildlife monitoring program that included an organ collection program for hunted caribou, moose and sheep.

The poster for the Hunted Wildlife Organ Collection Program can be found in Attachment 3A-10 in Appendix 3A, Supporting Documentation of Engagement Activities.

3.3.4 Issue and Concern Themes and Response

There have been four main issue and concern themes raised during the engagement sessions:

1. Contamination of wildlife (namely moose) from tailings dust
2. Effect of water quality on fish
3. Employment and contracting opportunities
4. Dam risks and safety

These issues and concerns have been addressed as follows:

1. YG engaged a biologist in 2011 to look more closely at the issue around containment effect on wildlife and developed a wildlife monitoring program that included a sample organ collection program for hunted caribou, moose, and sheep.
2. A variety of monitoring programs have taken place (monthly water quality and benthic invertebrates monitoring, specific salmon studies, and a 2012/13 fish telemetry program) to characterize water quality conditions and to support the evaluation of effects. YG funded an SFN Pelly Aquatics Study from 2005 to 2010 whereby the water was sampled and monitored at approximately 20 locations upstream and downstream of the site. Since 2011, AAM has funded the program through a local contractor.
3. There is an AYFN and Yukoner Participation Strategy to maximize AYFN and Yukoner participation on the FMRP through providing training and capacity building, contracting and subcontracting, and direct employment opportunities. This was implemented for the Grum Sulphide Cell project, where the contractor funded training opportunities geared towards increasing the capacity of the communities and individuals who may wish to work on the FMRP, and it continues to be implemented by the C&M contractor.
4. The DVIHU that are part of the scope of the IW are designed to address the risks related to dam safety and major flood events.

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TABLE 3-1
FMRP and IWPP Engagement Activities 2011 to 2013
Faro Mine Interim Works

Date	Event	Location	Community/ Organization	Purpose	Issues/Concerns Raised or Decisions Made	Documentation	Appendix 2A Reference
October 7, 2011	Meeting	Whitehorse (YESAB Office)	YESAB	To introduce members of the Faro Project Design Team to YESAB and discuss proposed approach and schedule for the Remediation Project Proposal.	No issues raised. Request for a follow-on meeting to review project at a conceptual level and alternatives analysis, and further discussion on consultation requirements. Meeting scheduled for November 16, 2013.	Agenda	2A-5
November 16, 2011	Meeting	Whitehorse (YG-AAM Office)	YESAB	To provide a project overview, describe alternatives analysis, and discuss consultation requirements.	No issues raised. Request for a follow-on meeting to further discuss the assessment methodology and establishment of a Regulatory Working Group. A follow-up meeting was not scheduled as FMRP Project Proposal was put on hold.	Agenda PowerPoint presentation	2A-6
November 29, 2011	Meeting	Watson Lake	LFN / Watson Lake	To provide an update on the project (specifically data collection programs and contracting efforts and introduce the new Community Coordinators).	No issues or actions.	Poster PowerPoint presentation	2A-3
January 19, 2012	Meeting	Whitehorse (YG-AAM Office)	Yukon Environment	To discuss wildlife information requirements for the Remediation Project Proposal.	No issues raised. Follow-on actions for Yukon Environment to confirm need for late winter moose survey and grizzly bear denning habitat survey.	Meeting notes	2A-9
January 17, 2013	Meeting	Pelly Crossing	SFN	To provide a project update (5-Year Plan, C&M Activities, Project Design Team [CH2M HILL], and Pelly Aquatics Study).	No issues or actions.	N/A	No attachment
January 21, 2013	Community Meeting with C&M Contractor	Ross River	RRDC	To provide a Q3 2013 project and C&M update.	No issues or actions.	N/A	No attachment
March 8, 2013	Meeting (TAC)	Whitehorse	SFN	A meeting to review of interim works project, particularly how site water affects the local environment.	No issues or actions.	N/A	No attachment
April 9, 2013	Meeting	Whitehorse (YESAB Office)	YESAB	To discuss the scope of the interim works project to confirm the level of assessment for the IWPP as AAM requested in a February 14, 2013, letter to YESAB.	No issues raised. Confirmed in meeting that, with the described scope, the interim works project appears to require a Designated Office-level Project Proposal.	February 14, 2013, letter from AAM to YESAB	2A-7
April 17, 2013	Meeting (TAC)	Whitehorse	SFN	A meeting to discuss Pelly Aquatics and water monitoring.	No issues or actions.	N/A	No attachment
April 22, 2013	Community Meeting with C&M Contractor	Pelly Crossing	SFN	To provide a project update on activities that had been completed on the site from 2010 to 2012 and on activities planned for 2013.	No issues or actions.	10-page presentation	2A-4
May 2, 2013	Meeting	Whitehorse	SFN	To provide a memory stick with data relating to water quality.	No issues or actions.	N/A	No attachment
July 23, 2013	Site Tour	Faro Mine	YESAB	To provide a site orientation and an overview of the IWPP.	No issues or actions. Several questions and comments for consideration in preparing the IWPP.	Agenda Site tour maps	2A-8
August 14, 2013	Site Tour	Faro Mine	KDC	To provide a site orientation and overview.	No issues or actions.	N/A	No attachment

Notes:
N/A = not applicable
Q3 = third quarter

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SECTION 4

Project Purpose and Alternatives

4.1 Project Purpose

As stated in Section 1.2, the purposes of the IW are as follows:

1. To control and reduce the effects of the existing FMC on human health and safety, and the environment.
2. To compile sufficient site and environmental information to support design, assessment and permitting for the FMRP.

The IW are temporary activities that are intended to minimize effects and manage risks at the FMC while YG and AANDC complete the design, permitting, procurement and implementation of the FMRP. The FMRP will be the subject of its own YESAA assessment and regulatory processes currently scheduled to begin in May 2017. The following sections discuss alternatives for each of the main IW components, including the following:

- Site operations
- Site investigations
- DVIHU

4.2 Alternatives

4.2.1 Site Operations

Site operations activities are the primary mechanism for addressing the first purpose of the IW, to control and reduce the effects of the existing FMC on human health and safety, and the environment. Because the conditions and facilities at the FMC present substantial chemical and physical stability risks, there is no alternative but to continue site operations. The operations, maintenance, and management activities are critical to controlling and reducing effects of contaminants from the site, and maintaining the physical integrity of site infrastructure. Without these measures, the FMC would cause unacceptable effects on the local environment.

4.2.2 Site Investigations

Site investigation activities are the primary mechanism for addressing the second purpose of the IW, to compile sufficient site and environmental information to support design, assessment and permitting for the FMRP. Implementation of the FMRP is the mechanism for addressing the long-term issues and risks at the FMC, and fulfilling the overarching objectives (Section 1.2). Failure to complete the proposed site investigations may compromise YG's and AANDC's ability to complete design, assessment and permitting for the FMRP. As such, there are no alternatives to completion of the site investigations.

As described in Section 5, the site investigations proposed for 2014 were defined based on the results of a detailed gap analysis. The gap analysis and subsequent field planning exercise considered alternative means of collecting the necessary environmental and engineering information. Methods were selected to maximize the effectiveness of data collection programs while minimizing adverse effects. For example, initial investigations of potential borrow areas use non-intrusive methods to narrow down the areas that may be subject to more intrusive investigations.

4.2.3 Down Valley Interim Hydraulic Upgrades

The DVIHU component of the IW is intended to address flood-related risks for the RCTA, thereby helping to reduce the likelihood of potential adverse effects on the environment. Section 5 provides a detailed description of the proposed DVIHU that entails upgrading the hydraulic capacity of both the Intermediate Dam spillway and the RCD to provide capacity for the system to convey a 1-in-500-year flood event.

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YG and AANDC considered three alternatives to addressing the flood risk before selecting the proposed DVIHU as part of the IW. Those three alternatives included:

- Maintain the RCD and Intermediate Dam spillway in their current configuration: Continue to maintain the existing facilities without substantial improvements in flood routing capacity.
- Construct the permanent flood routing facilities for the RCTA: As proposed in the FMRP, construct enhanced flood routing capacity for the RCTA to provide capability to convey the probable maximum flood (PMF).
- Construct the proposed DVIHU: interim upgrades to reduce flood-related risks for a period of several years, while planning and design for the FMRP are completed.

Based on annual operational risk assessments, YG and AANDC concluded that maintaining the current flood routing configuration for the RCTA presents an unacceptable risk. *Medium Term Plan, Faro Mine Remediation Project* (YG and AANDC, 2013b) describes the rationale for this conclusion:

> *"Despite the ID being rated as a "Very High" to "Extreme" risk dam based on the Canadian Dam Association (CDA) Dam Safety Guidelines 2007 (CDA, 2007), the existing spillway (capacity of 32 m3/sec) cannot safely pass a moderate or major flood event without potentially failing the dam. ID dam failure may cause an environmentally damaging discharge of metals-laden tailings to the Rose Creek Valley, Anvil Creek, and the Pelly River that would result in a significant or major loss of critical fish and wildlife habitat that would be impractical or impossible to restore. Failure of the Secondary Dam in 1975 within the Rose Creek Valley resulted in a loss of wildlife habitat, with little recovery evident more than 35 years later."*
>
> YG and AANDC, 2013b

YG, AANDC, and their design team have expended significant effort in evaluating options for permanent flood routing at the RCTA capable of conveying flows up to the PMF. Enhanced flood routing facilities constructed as part of the FMRP will have the capacity required for dams that have "Very High" or "Extreme" risk classifications. However, PMF spillway construction is a major undertaking that is impractical to implement within the timeframe necessary to respond to current flood-related risks, due to requirements for field investigations, design, funding and approvals.

YG, AANDC, the IPRP, the IE, and the design team met at a workshop in 2012 to review and evaluate alternatives for permanent routing the of the PMF flood through the Rose Creek Valley. While the group recommended construction of the permanent spillway facilities as soon as reasonably possible, they also agreed about the impracticality of timely completion of the permanent facilities and recommended interim upgrading of the hydraulic capacity of flood routing facilities. (YG and AANDC, 2013)

The DVIHU have been designed as an option that can be completed in a timely and cost-effective way, thereby providing suitable risk management for the IW period prior to construction of the permanent flood routing facilities. The proposed works are described in detail in Section 5, but generally include the following:

- Increase the existing ID spillway capacity by increasing the depth of the existing spillway channel.
- Relocate existing piping and lime mix tank that have been placed within the ID spillway.
- Increase the height of the ID embankment crest by installing a geomembrane layer to extend the core to the dam crest and by addition of gabion mattresses.
- Protect the ID spillway channel from erosion by installing gabion mattresses.
- Increase the RCD capacity to pass the 1-in-500-year flood event, by removing vegetation, repairing raveled slopes on the dike and cut slope, and by filling in low spots on the dike crest.

The work is proposed for completion as soon as possible because the DVIHU are intended to provide temporary protection of the ID until implementation of the final closure plan (YG and AANDC, 2013).

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SECTION 5

Project Description

5.1 Interim Works Project Scope

This section describes the components and related activities that make up the IW and identifies activities the scope of the proposed project excludes, and rationales for their exclusion. In general, the IW consists of works and activities that are required to protect human health and the environment from the ongoing effects associated with the legacies of mining activities at the FMC, and to manage risks associated with those legacies. The following four areas make up the IW environmental and socio-economic assessment scope:

- Site operations (Section 5.3)
- Site investigations (Section 5.4)
- DVIHU (Section 5.5 and detailed in Appendix 5I)
- Ancillary activities associated with completing site operations, site investigations and the DVIHU (e.g., worker accommodation and borrow source investigation and development) (Section 5.6).

As a fundamental part of the above activities, preventing and counteracting mining effects and managing site risks requires the ongoing implementation of comprehensive monitoring and adaptive management plans and of a risk assessment process. All of these project components are also described in this section. The monitoring and adaptive management plans are described in more detail in Appendix 5B, Environmental Monitoring, Surveillance and Reporting Plan, and Appendix 5C, the AMP.

In conjuction with the above activities, the project requires application of a series of management plans that are intended to mitigate potential effects. These are also described in this section and detailed in the following appendices:

- Appendix 5A Environmental Management Plan
- Appendix 5D C&M Risk Assessment Report
- Appendix 5E Spill Prevention and Response Plan
- Appendix 5F Emergency Management Plan
- Appendix 5G Access Management Plan
- Appendix 5H Heritage Resource Management Plan

The environmental and socio-economic assessment presented in subsequent sections considers the consolidated effects of all works and accessory activities.

5.1.1 Site Operations

Site operations are the ongoing site activities required to prevent the FMC from adversely affecting persons, property, or the environment, and to counteract, mitigate, and remedy adverse effects that do occur. The site operations scope for the IW includes the following components:

- Water management operations, including operating, maintaining, repairing, and monitoring water management systems and facilities at the FMC, as follows:
    - Fresh water conveyance diversions and facilities
    - Contaminated water collection, conveyance, and storage facilities
    - Water treatment at the Vangorda WTP and the Interim Water Treatment System at the Faro Mine Area, and associated sludge storage facilities
    - Dams and spillways

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- Operation, maintenance, repair, and monitoring activities required to understand and maintain safety and functionality, and manage the physical and chemical risks to the stability of site components, facilities, and equipment:
  - Pits, waste rock storage facilities, ore stockpiles, tailings (e.g., dust suppression), and tailings storage facilities
  - Ditches, culverts, and stream crossings
  - Roads, trails, and access routes
- Environmental management and monitoring, adaptive management, and risk management activities:
  - Adhering to the prescriptions of the Environmental Management Plan (Appendix 5A), which was developed so appropriate environmental management practices are carried out during the IW.
  - Conducting extensive monitoring programs to evaluate and understand environmental conditions, and the FMC's physical and chemical stability
  - Implementing an AMP to assure timely evaluations of site uncertainties, and equally timely responses, as necessary
  - Implementing a risk assessment program to continually re-evaluate risks to health, safety, and the environment

The site operations scope includes the implementation of interim responses that are identified in the AMP, provided those do not require major upgrades of site facilities or major changes to operational activities. For example, the assessment's scope includes the implementation of interim groundwater collection systems that the AMP triggers during the IW, providing implementing the system does not require major upgrades to the water treatment facilities.

5.1.2 Site Investigations

Developing the FMRP and designing remediation and closure elements requires extensive site investigation programs. These programs are anticipated to take place throughout the IW. The requirements for specific investigations will evolve as site conditions change, the results of sequential investigations become available, and design requirements are identified. Site investigations to be conducted during the IW include land use activities listed below.

- Sampling soil and rock and establishing monitoring wells and installations using various types of drilling equipment
- Conducting geotechnical investigation programs, including test pitting, reconnaissance, drilling, and sampling
- Constructing temporary access to investigation locations, including stream crossings.
- Using water for a variety of programs, including aquifer testing
- Establishing, maintaining, and operating various monitoring facilities, including wells, flow measurement facilities, and meteorological stations
- Establishing, maintaining, and operating test facilities to support reclamation research, including cover trials and vegetation trials
- Collecting vegetative material to support re-vegetation test programs
- Conducting reconnaissance programs, which may include use of helicopters
- Using heavy equipment to test remediation methods
- Test pitting, drilling, and sampling to support contaminated site assessment, and to identify and quantify borrow sources

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- Completing heritage and archaeological assessment programs
- Completing water treatment test programs
- Conducting field surveys for wildlife and habitat, as well as aquatic organisms and habitat
- Completing geophysics and seismic refraction programs
- Completing sampling programs including water, soil, rock, flora, fauna, and air
- Conducting surveying activities with associated line cutting, and establishing survey markers

5.1.3 Down Valley Interim Hydraulic Upgrades

The DVIHU provides improvement of flood routing capacity to the ID, where the current capacity does not meet the minimum standards specified in the CDA Dam Safety Guidelines (CDA, 2007). The RCTA contains approximately 55,000,000 tonnes of acid-generating tailings, whose release may cause adverse environmental effects. The existing ID spillway capacity (32 cubic metres per second [m^3/sec]) is smaller than the 1-in-500-year flood event (115 m^3/sec), required by the expired water licence. The DVIHU includes works to increase the capacity of the ID spillway. It also includes minor upgrades and maintenance to increase the capacity of the RCD to convey the 1-in-500-year flood event, with freeboard.

Upgrading the facilities to safely pass a 1-in-500-year event would provide acceptable risk management for the 10-year duration of the IW. The co-proponents acknowledge that planning for the FMRP has taken place on the basis of requirements established by the previous water licences. These have specified that the final remediation for the Rose Creek Tailings Area will (1) provide flood routing capacity for the PMF and (2) be able to withstand the maximum credible earthquake. The FMRP will include additional upgrades to achieve these design criteria. The co-proponents anticipate the FMRP flood-routing upgrades at the ID will require significant additional work.

It is likely that the interim upgrades at the ID will not experience flow during the IW because the design of the RCTA provides primary routing through the RCD for floods up to 1-in-500-year event. In addition, because the spillway will likely be redesigned to carry the PMF as part of the FMRP, the proposed interim hydraulic upgrade is designed as a temporary, rather than permanent structure.

The DVIHU scope includes the following:

- Increasing the capacity of the existing ID spillway by making it deeper and raising the crest height of the dam by addition of a geomembrane and gabions to raise the effective core of the dam
- Relocating piping and structures currently located within the ID spillway
- Constructing erosion protection in the expanded ID spillway (gabions and gabion mattresses)
- Increasing the RCD's capacity by removing vegetation, repairing slopes, and filling low spots on the dike crest

5.1.4 Ancillary Activities

The IW requires a number of ancillary activities associated with the activities presented in Sections 5.1.1 through 5.1.3. To address the environmental and socio-economic assessment of the IW, the IW includes the following ancillary activities:

- Maintaining site security by providing an ongoing site presence, establishing security facilities and programs, and managing site access as needed to secure the FMC and manage health and safety risks
- Maintaining and operating an office and gatehouse building at the FMC
- Providing emergency response capabilities and responding to emergencies
- Implementing preventative maintenance programs
- Maintaining buildings, site infrastructure, and utility systems (e.g., electrical distribution system maintenance and a waste-oil heating system)

- Maintaining stationary and mobile equipment
- Expanding existing borrow sources to supply aggregate and construction materials for C&M and DVIHU activities
- Providing onsite accommodations for site workers, including temporary camps (e.g. construction activities, field investigation programs)
- Maintaining and operating employee housing within the Town of Faro
- Maintaining existing roadways
- Procuring supplies and energy sources for the FMC (e.g. lime for water treatment and fuel)
- Transporting goods and equipment to and from the FMC (e.g., providing the materials listed herein and removing hazardous waste)
- Using existing solid waste disposal facilities at the FMC
- Managing special wastes (this includes operating a waste-oil heating system)
- Withdrawing and using fresh water for domestic purposes
- Using, maintaining, and repairing existing septic systems at the FMC
- Performing additional ancillary activities to complete the IW activities

5.2 Project Stages and Lifespan

As described in Section 3.2.4, a preferred closure option was selected in 2009 to provide the basis for the long-term closure and remediation of the FMC. These long-term closure and remediation activities make up the FMRP. However, more data are needed to further develop and design the remediation and closure elements. Therefore, planning efforts to design, assess, and permit the FMRP include additional site investigation programs to collect these data. The IW consist of these site investigation programs, as well as the existing operations and limited interim (i.e., DVIHU) activities to minimize risks at the FMC until the FMRP can be implemented. The IW are temporary activities, intended to minimize effects and manage risks at the FMC while the project team completes the design, permitting process, and procurement for implementation of the FMRP.

Site operations (Section 5.3) are ongoing and will be undertaken continuously throughout the IW. On an annual basis, activity levels generally increase between May and October and decrease between November and April.

Site investigations will take place throughout the IW period. An extensive site investigation field program is planned for the 2014 field season; however, additional site investigation activities will take place in subsequent years. The scope of the ongoing investigations will be determined based on the project's design requirements and the results of the initial investigations and studies.

The DVIHU is planned to be initiated and completed within 3 fiscal years. Final design will be completed during the 2014/2015 fiscal year, procurement will take place during the 2015/2016 fiscal year, and construction will be completed during the 2016/2017 fiscal year.

The IW is scheduled to take place over 10 years, from 2014 to 2024. This duration is based on an estimated 2 to 4 years to prepare the FMRP Project Proposal and another estimated 4 to 6 years to complete assessment and permitting processes, develop the final design, prepare contract documents, and initiate the implementation of the final closure measures.

FMRP construction will be initiated after the IW. The FRMP activities will have different effects than the IW activities; in the long-term, the FMRP will mitigate effects at the site. However, FMRP activities require additional planning before they can be defined sufficiently to predict their long-term effects.

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The FMRP will undergo a YESAA assessment before it proceeds, and YG and AANDC currently anticipate the Remediation Project Proposal will be submitted in 2017. The assessment for the FMRP will consider its potential effects, combined with the continuing effects of the IW after its proposed 10-year scope.

5.3 Site Operations

As described in Section 5.1.1, site operations are the ongoing site activities required to (1) prevent the FMC from having adverse effects on persons, property, or the environment and (2) counteract, mitigate, and remedy adverse effects. Site operations will be managed in accordance with the established Environmental Management and Monitoring Plans (Section 5.3.3 and Appendices 5A and 5B), the AMP (Section 5.3.4 and Appendix 5C), and the Risk Assessment (Section 5.3.5 and Appendix 5D).

The site operations activities have specific objectives:

- Minimize the amount of clean water that enters contaminated areas of the site and subsequently requires treatment
- Maximize the capture of contaminated water for treatment
- Store and treat contaminated water
- Manage treatment residuals (sludge)

The following major components of site operations are described in this section:

- Water management operations
- Routine operation, maintenance, and repair activities
- Environmental management and monitoring plans
- Adaptive management plan
- C&M risk assessment

5.3.1 Water Management Operations

Water management is the most important site operations activity at the FMC. These include:

- Conveying clean water around the FMC
- Collecting contaminated water
- Treating non-compliant water
- Providing storage capacity for non-compliant water and unforeseen events

Water management operations include operating, maintaining, repairing, and monitoring the following water management systems and facilities at the FMC:

- Fresh water conveyance diversions and facilities
- Collection, conveyance, and storage facilities for contaminated water
- Vangorda WTP
- Interim Water Treatment System
- Water treatment sludge storage facilities
- Dams and spillways

FMC water management operations establishes operational targets so that the contaminated water storage systems have capacity to store forecasted non-compliant water, and additional water resulting from unforeseen events, unusual environmental conditions, and operational upsets. To accomplish this, site water management and site operations are reviewed annually. These reviews note changes to water management systems and site conditions. A site water balance model is used to inform the annual assessment. Based on this review, end-of-season water operational targets are revised, if required.

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5.3.1.1 Faro Mine Area and the Rose Creek Tailing Area

Fresh Water Conveyance

Before mining development, several creek systems traveled through FMC. To facilitate development and protect these systems from mine-related contamination, these creeks were routed around the mine development areas via diversions, flumes, and ditches. There are three primary diversions in the Faro Mine Area (Figure 5-1):

- The FCD diverts Faro Creek around Faro Pit into the NFRC.
- The RCD diverts Rose Creek around the RCTA.
- The North Wall Interceptor Ditch collects runoff from the catchment areas north and northwest of the Faro Pit and routes it around the west side of the pit to Rose Creek downstream of the RCTA.

Faro Creek Diversion

The FCD will continue to be used and maintained during the IW to route Faro Creek water around Faro Pit and into the NFRC. The West Valley Interceptor Ditch is a component of the FCD that collects runoff from the west hillside above Faro Creek and directs the flow into the diversion. The FCD passes close to the northeast wall of Faro Pit.

Within the Faro Pit, the northeast pit wall is gradually ravelling into the pit. The rate of crest retreat is anticipated to be similar to the rates observed during the last few years. Only localized erosion, sloughing, and ravelling have been recently observed (Appendix 6C). During the IW, the crest of the pit wall is not anticipated to compromise the FCD. Water level targets in the Faro Pit consider water storage requirements in case the FCD does fail. The stability of the pit wall will continue to be assessed throughout the IW as part of the site geotechnical monitoring program described in the C&M Environmental Monitoring, Surveillance and Reporting Plan (Appendix 5B).

The following maintenance activities are proposed for the FCD:

- Clear ice, accumulated sediment, and debris, as necessary, so that flows are properly routed.
- Clear sloughed bank material.
- Upgrade portions of the channel to minimize leakage to Faro Pit and provide erosion protection
- Replace damaged geotextile and liners in the diversion channel and cover exposed liner material with rock armour.
- Repair or upgrading the containment dike.

North Wall Interceptor Ditch

The North Wall Interceptor Ditch will continue to divert runoff from Upper Guardhouse Creek and the slopes north of the Rose Creek Valley around the north abutment of the CVD. The following maintenance activities are proposed for the North Wall Interceptor Ditch:

- Clear ice, accumulated sediment, and debris, as necessary, so that flows are properly routed.
- Clear sloughed bank material.
- Clear vegetation along the upper and middle constructed channel reaches, as well as access roads and berms along the channel, to facilitate channel inspections.
- Clear excessive sediment accumulation upstream and downstream from the well access road crossing.
- Clear ice and debris from the twin culverts in the outfall section at Station X5.
- Maintain the Guardhouse Creek diversion dam.
- Maintain or upgrade the culvert road crossing near the CVD Pond.

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Rose Creek Diversion and Canal Dike

The RCD is the most significant water management structure within the RCTA, and routes the entire flow of Rose Creek around the south side of the RCTA and the CVD Pond. The diversion dike flanks the north side of the diversion channel and separates the RCD from the tailings, the ID Pond, the ID, and the CVD Pond. The RCD has a design capacity of 140 m^3/sec, without freeboard, which is slightly more than the 1-in-500-year flood event (Appendix 6B). Vegetative growth and other channel-maintenance-related issues have decreased the RCD flow capacity to less than the 1-in-50-year flood flow. The proposed DVIHU (Section 5.5) include modifications to the RCD that will provide capacity to allow the diversion to pass the 1-in-500-year flood event with freeboard. These include:

- Removing vegetation
- Repairing ravelled slopes on the dike and cut slope
- Filling in low spots on the dike crest
- Raising the fuse plug (overflow structure)

The following routine maintenance activities are proposed for the RCD:

- Clear ice, debris, and vegetation.
- Repair or upgrade the backslope.
- Install or replace new monitoring instrumentation, as required.

As discussed in Appendix 5B (the EMSRP), the proposed geotechnical monitoring program for the RCD includes semi-annual [spring and autumn] reading of the geotechnical instrumentation located at the RCD. These include thermisters, piezometers, and slope indicators. A professional geotechnical engineer will inspect the dike and backslope annually. This inspection will include a review of the geotechnical instrumentation data. The monitoring program will be updated annually, as necessary, in response to recommendations from a professional engineer.

Contaminated Water Collection, Conveyance, and Storage

Contaminated water is managed through collection, storage, and treatment at the Faro Mine and Vangorda/Grum Areas. At the Faro Mine Area, contaminated water is collected or stored in six areas: (1) the Zone II Pit, (2) the S-Wells SIS (3) the ETA, (4) the ID Pond, (5) the Faro Valley Dump Pond, and (6) the Faro Pit.

Zone II Pit

The backfilled Zone II Pit collects contaminated water from its immediate catchment area. If water in the Zone II Pit rises above 1,128 metres above sea level (masl), it will seep over the buried rim, towards the NFRC. In 1991, a water management plan was implemented for the Zone II Pit. This plan involved seasonal (summer) dewatering to the Faro Pit via a down-hole pump installed in a well (X26) within the Zone II Pit. Water was pumped, as needed, to maintain the water level below 1,116 masl and thereby reducing groundwater migration towards the NFRC. The pump intake was limited to an elevation of approximately 1,103 masl. However, operating to this target water level elevation left a hydraulic gradient from the pit towards NFRC (CH2M HILL, 2012a).

In 2012, a new well was installed (CH12-Z2-PW01) with a screened interval between 1,091.7 and 1,114.0 masl and a sump extending to 1,088.6 masl. In 2013, a submersible variable speed pump with a capacity of 5 litres per second (L/s) was installed. The pump discharge line is fitted with a digital flow meter with data logger, a sampling port for Zone II Pit water, and a gate valve so the pump discharge can be adjusted manually (if required). The pump controls and monitoring instruments at the well head are enclosed in a heated container (sea-can) to allow winter operation. Pumped water discharges to Faro Pit (30 m below surface) via an insulated and heat-traced high-density polyethylene (HDPE) pipeline, for year-round operations.

The water level in the Zone II Pit will now be maintained by operating the new Zone II pumping system year-round, with a target elevation of 1,096 masl. The old Zone II pumping well will remain available as a back-up system. The old pumping well will only operate during summers.

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S-Wells Seepage Interception System

The S-Wells SIS is located at the base of the Intermediate Dump, adjacent to the NFRC. It intercepts contaminated seepage and groundwater from the Main and Intermediate Dumps. The S-Wells SIS includes two main components (CH2M HILL, 2012a; SRK Consulting Engineers and Scientists [SRK], 2010a): (1) two pumping wells within the Deep Aquifer (SRK08-SPW1 and SRK08-SPW2) and (2) a shallow aquifer interception trench. The interceptor trench consists of a 25-m trench installed in February 2009 and a 15.4-m eastern extension installed in November 2009. A Bentomat liner was installed on the downstream face of the western 10 m of the trench and in the bottom and downstream faces of the eastern extension. An Enviro-liner was used for the remainder of the trench (SRK, 2010a). Within the trench, a 2.1-m-diameter central sump (PW3) cross-cuts the shallow aquifer, a 15-horsepower (HP) pump is positioned 0.6 m below the base of the shallow aquifer, at 1,083.3 masl (approximately 7.6 m below ground surface) (SRK, 2010a). Figure 5-2 provides a schematic of the S-Wells SIS.

Pumping well SRK08-SPW1 is not currently operational, because of excessive precipitate formation. The S-Wells SIS collects water year-round. This water is pumped to the Faro Pit, where it is discharged approximately 30 m below the pit lake water level. There are two pipes for conveying the water to Faro Pit:

- A 5.1-centimetre (cm) (2-inch) insulated HDPE pipeline (operating flow of 2.9 L/s) with heat–trace and a vacuum break at the pipeline high point
- A parallel uninsulated 10.3-cm (4-inch) HDPE pipeline, used during spring freshet (operating flow of 4.1 L/s)

An 8-foot-by-10-foot sea-can is installed over the sump, complete with all piping, valves, meters, controls, and discharge pipeline. Data loggers within the sea-can control housing record flow rates, cumulative pumped volumes, and water levels. An electrical line from the Faro Pit area provides the S-Wells area with power.

Since the system was modified in November 2009, the S-Wells SIS has intercepted, collected, and routed approximately 68,000 cubic metres (m^3) of water to the Faro Pit each year (Denison Environmental Services [DES], 2012; TEES, 2013a).

The S-Wells SIS does not have specific operational targets, but the general objective is to collect as much water as possible, based on the system capacity, to limit the amount of contaminated water entering the receiving environment. The S-Wells SIS will continue to operate this way during the IW. Contingency measures for the S-Wells SIS include repairing system components as soon as practical, when required.

Emergency Tailing Area Collection System

The ETA has been shown to contribute a significant contaminant load to the Rose Creek Alluvial Aquifer (RCAA) under the RCTA, through seepage and groundwater migration (Robertson GeoConsultants [RGC], 2007). In response, an SIS was installed in winter 2006/07 to collect waters on a seasonal basis draining to the ETA. The ETA collection system consists of the following components:

- Cut-off trench
- Sumps with 30-HP pumps
- Piping to pump to the Faro Pit or to the Interim Water Treatment System

The ETA collection system does not have specific operational targets, but the general objective is to collect as much water as possible, based on the system capacity, to limit the amount of contaminated water flowing downgradient to the ID Pond and potentially to the underlying RCAA. The ETA collection system will continue to operate seasonally during the open water season and will be activated as early as possible in the spring, pending suitable ice-free conditions. It will operate through the summer and autumn, until freezing temperatures occur. Typically, the ETA collection system will operate from May through October of each year, pumping up to 1,000 litres per minute (L/min) (CH2M HILL, 2012a). Contingency measures for the ETA include repairing system components as soon as practical, when needed.

During periods that the ETA collection system does not collect water, during operational upsets and during the winter season, it is routed to the ID Pond.

Intermediate Dam Pond

Water and tailings are retained behind the ID, and the ID Pond collects contaminated runoff water from the tailings, ETA, and Lower Guardhouse Creek. As part of the IW, water from the ID Pond will continue to be pumped seasonally to either the Faro Pit or Interim Water Treatment System. The water level in the ID Pond will be managed to maintain the water level elevation between 1,045.2 masl (top of the lower riprap) and 1,044.2 masl (bottom of the lower riprap). This will limit the potential for erosion to the upstream face of the dam. On a contingency basis only, operations may occur outside this range, to prevent uncontrolled releases of water from the ID Pond. When the dam operates below the bottom of the lower riprap (1,044.2 masl), its face will be monitored for erosion. If necessary, maintenance (i.e., erosion repair and riprap replacement) will be carried out. In addition, the stability of the riprap layer will be monitored and the water level drawdown will be suspended, if required.

Two 150-HP stainless-steel pumps, mounted on a floating barge, currently pump water via using a 350-millimetre (mm) -diameter HDPE pipeline. The current capacity of the ID Pond pumping system is 8,200 L/min. To provide sufficient storage capacity for snowmelt and spring freshet, the ID Pond will be pumped as early as practical in the spring. Pumping will continue throughout the summer and autumn to maintain the pond elevation within the recommended range. The ID Pond's drawdown is limited to a daily maximum of 40 mm to avoid potential instability related to rapid drawdown conditions. (Klohn Crippen Berger Ltd.[KCB], 2012a; CH2M HILL, 2012b).

Faro Valley Dump Pond

The Faro Valley Dump Pond is the area of ponded water that accumulates from local runoff along the alignment of the original Faro Creek channel, upstream from the Faro Valley Waste Dump. To reduce seepage into the Faro Pit, the ponded water will be periodically pumped to the FCD, provided it meets suitable discharge target water quality (currently set at 0.3 milligrams per litre [mg/L] for total zinc). Currently, data for the ponded water indicates the water quality does not meet the discharge target.

Faro Pit

The Faro Pit is an important reservoir for the active water management program at the FMC. It receives groundwater seepage, direct precipitation, runoff, FCD seepage, and water from managed sources such as the ID Pond, the S-Wells, the Zone II Pit, and the ETA. Until the fall of 2012, the water level in Faro Pit was maintained well-below the pit overflow elevation, within the prescribed operating range that has been in place since 1998. The purpose was to prevent an uncontrolled release of non-compliant water from Faro Pit to the receiving environment. Using this water management regime, the maximum recommended water elevation for the Faro Pit was set at 1,144.3 masl, which is approximately 14 m below the lowest point in the pit perimeter (1,158 masl), the point at which Faro Pit water could seep to the Zone II Pit.

The freeboard below the overflow in the Faro Pit was determined to provide sufficient storage capacity to prevent water from the Faro Pit from overflowing into Zone II Pit during an unforeseen event; specifically, a breach of the FCD for a 1-week PMF event (RGC, 1996). The minimum recommended elevation for the Faro Pit was set at 1,139 masl, based on the lower limit of the hinge range for the pumping barge. The Faro Pit water level was maintained within this prescribed range through a seasonal (summer) pumping program by pumping from the pit to the existing Faro Mill WTP. The objective of the summer pumping program was to draw the pit water level down to a pre-determined target elevation, set as 1,141 masl. This elevation allows capacity for seasonal recharge during winter, when pumping is not feasible. From 2004 until 2012, the water-level elevation in Faro Pit was maintained between approximately 1,140 m and 1,143 masl.

The Faro Pit pumping system included the following primary components (DES, 2011a):

- A floating steel barge with a walkway to the shore
- Three electric submersible pumps mounted on the barge
- Barge-mounted valving, flex hose, and header to combine flow from all pumps to one pipeline

- A 760-cm (30-inch) HDPE pipeline from the barge to the Faro Mill WTP, with flexible sections (flex hose) near the barge to prevent damage to the pipeline
- A transformer and electrical control house on shore, adjacent to the barge
- An overhead power line (4,160 volt), running from the Faro Mill substation to a transformer adjacent to the pumping barge

Each 225-HP barge-mounted pump could deliver between 7.6 cubic metres per minute (m^3/min) (approximately 2,000 United States gallons per minute [USgpm]) and 19 m^3/min (approximately 5,000 USgpm) of water to the existing Faro Mill WTP. On the barge, a manually operated valve controlled the flow rate. Typically, one pump was operated to deliver water, as the Mill WTP could only treat 19 m^3/min (approximately 5,000 USgpm). However, pumps could be run in tandem to supply more water to the Mill WTP, if required.

The existing Faro Mill WTP is located in the old Faro Mill Building and was constructed using existing ore-processing equipment adapted for water treatment. The existing Faro Mill WTP began to operate in 2001, and its original design life was intended to be 5 years (CH2M HILL, 2012c). In 2012, the existing Faro Mill WTP was assessed, and it was determined that there was an increasing risk of major equipment failure in the WTP (CH2M HILL, 2012c). In addition, a safety assessment of the existing Faro Mill WTP determined that the facility should not be operated until serious health and safety issues could be assessed and resolved (AMEC Environment and Infrastructure Limited, 2013). Consequently, the existing Faro Mill WTP ceased operations at the end of the pumping program in fall 2012. In spring 2013, the Faro Pit pumping barge was detached and relocated. Starting in summer 2013, contaminated water in the Rose Creek watershed was pumped to Faro Pit for storage.

Because the existing Faro Mill WTP was not used in 2013, the water-level elevation in the Faro Pit rose above the end-of season target (1,141 masl) to its water-level elevation of 1,148.3 masl as of January 27, 2014. The pumping system will be re-established as early as possible in 2014, and seasonal dewatering of the Faro Pit will resume through treatment at the Interim Water Treatment System when construction is completed in the summer of 2014.

The barge system will be replaced with a skid-mounted pump that will be moved as the water level lowers. The rate of dewatering will be set to a rate high enough to control and reduce the water level in the Faro Pit with the objective to achieve the end-of-season target of 1,141 masl as soon as practicable. Based on current site conditions, the water balance model predicts that the water level in the Faro Pit will return to the operational end-of-season target by summer 2016. For the remainder of the IW, the water-level elevation in the Faro Pit will be managed within the prescribed operating range outlined above.

Water Treatment at the Faro Mine Area

The Interim Water Treatment System will seasonally treat water from the Faro Pit, the ETA, the ID Pond, and other contaminated water sources at the Faro Mine Area and the RCTA. Treated effluent from the Interim Water Treatment System will discharge to the CVD Pond for clarification (solids removal) before discharge to Rose Creek. Water that complies with the proposed discharge limits (Table 5-2) will be discharged seasonally from the CVD Pond to Rose Creek through a siphon system located at Monitoring Station X5.

Interim Water Treatment System

The Interim Water Treatment System will be a modular lime-neutralization system that can treat up to 32,700 cubic metres per day (m^3/day) (6,000 USgpm). The system is expected to operate seasonally (May to September), though it could be operated at other times if necessary. As planned, the system will include modular equipment for the following operations:

- Lime storage, slurry makeup, and feed
- Mine-water neutralization and metal precipitation
- Primary clarification, with polymer- and microsand-assisted settling
- Sludge wasting to the tailings sludge ponds or into the Faro Pit

The Interim Water Treatment System will consist of mobile and skid-mounted equipment, connected by rigid and flexible piping. It will be located on the existing concrete pad in the Mill Yard, just south the Mill Building (Figure 5-3). This pad was used as a load-out area for zinc concentrate during mill operations.

Influent will be split between two 16,350 m^3/day (3,000 USgpm) treatment trains from a header pipe connected to existing pipelines from the Faro Pit, the ID Pond, and the ETA. Feed to the Interim Water Treatment System will consist of either a single, blended influent source from Faro Pit, or of influent from each individual source. Flow meters will be used to measure and record the flow split between the two treatment trains.

The treatment system described here is currently being developed to meet treatment requirements in early 2014. However, the system may be refined throughout the IW, as necessary, to provide effective water treatment.

Lime slurry will be made using a Porta Batch portable lime-slaking system from Lhoist North America. Either influent or effluent will serve as the water source for the slurry. A 20-tonne container of quicklime will be used each time a batch of lime is slaked. First, the Porta Batch will be filled with the required volume of water, and then a lime blower will pneumatically convey the 20 tonnes of quicklime into the Porta Batch while it mixes. Dust will be controlled because the lime will be discharged below the liquid surface. After slaking is completed, about 60 to 75 minutes, the slurry will be about 30 to 40 percent solids by weight. To maximize pH control, the slurry will be diluted in a mix tank to provide 10 to 15 percent lime slurry.

Figure 5-4 provides a process flow diagram of the Interim Water Treatment System. Once the influent is split between the two trains, it enters a mixed reactor tank configured into three compartments, in series. From there, it will flow into a second, similar mixed reactor tank, which in turn will flow into an Actiflo clarification skid. Polymer will be added to adhere the metal precipitates to microsand to facilitate rapid settling in the lamella clarifier. The settled sludge will be pumped to a cyclone, where the precipitates will be separated from the microsand. The microsand will be recirculated for reuse and the precipitates will be discharged to a sludge mix tank. Makeup microsand will be required periodically, as recovery is not 100 percent.

A variable-speed pump will be used to pump waste sludge via the existing piping to the tailings sludge ponds. The waste sludge is expected to be between approximately 3 and 4 percent solids by weight (Laliberte, 2013, Personal Communication). Wasting will take place as needed. Approximately 210 m^3/day of sludge will be wasted, based on a treatment rate of 32,700 m^3/day (6,000 USgpm). A portion of the sludge will flow by gravity to another sludge mix tank for mixing with lime slurry. The amount of additional lime slurry will be controlled automatically via pH feedback from pH probes in the two mixed reactor tanks. A variable-speed pump will pump the lime slurry from the lime slurry mix tank will take place via a recirculation loop. The lime/sludge mixture will then be pumped to the first compartment of the first mixed reactor tank. Figure 5-3 shows a preliminary layout of the Interim Water Treatment System.

Clarified overflow from the Actiflo clarifiers will flow by gravity to the CVD Pond. The turbidity of clarifier overflow will be continuously measured and recorded. Additional clarification will take place in the CVD Pond, similar to the existing Faro Mill WTP's operations. Lime slurry will be added to the clarified overflow as needed, to maintain a high pH in the CVD Pond. This will enhance solids removal before discharge. Effluent will discharge from the CVD Pond to Rose Creek via the CVD Pond siphon system at the X5 Monitoring Station. Using this approach, the Interim Water Treatment System effluent will meet the proposed effluent limits outlined in Table 5-2. If necessary, a flow baffle will be installed within the CVD Pond to increase settling time, or mobile filtration equipment will be used to supplement solids removal at the CVD Pond.

All tanks and vessels, except for the Porta Batch and Baker mix tank, will be housed within a heated building (i.e., a Sprung-type building). The Porta Batch and lime slurry mix tanks are designed for outdoor operation, and will be winterized. A construction-type trailer located outside the Sprung-type building will house the programmable logic controller and the human-machine interface, and will serve as a control room. The Sprung-type building will house 1,000-kg bags of polymer, as well as equipment to make and feed the polymer. Lime will be stored onsite in 20-tonne shipping containers to provide sufficient inventory for uninterrupted water treatment.

Interim Water Treatment System performance will be operated and monitored according to the FMC Operations Manual, under development. The Interim Water Treatment System will undergo routine maintenance and repairs, as required, to optimize its performance

Interim Water Treatment System Sludge Management

Sludge generated in the Interim Water Treatment System will either be deposited (1) in the existing tailings sludge ponds in the Original Impoundment or (2) in the Faro Pit via a new pipeline. For placement in the existing tailings sludge ponds, at the end of each treatment season, once partially frozen, the sludge will be excavated from the ponds and placed in windrows next to the ponds, similar to the past operations. After placement, water will be decanted off the solids as they thicken and routed to the ID Pond, where it will enter the treatment circuit. If the sludge is disposed in the Faro Pit, a new pipeline will be constructed. This pipeline will run from the Interim Water Treatment System to the pit ramp, down the pit ramp, and into the pit below the surface at sufficient depth to convey the sludge to the lower elevations of the pit lake.

Cross Valley Dam Pond

The CVD Pond will continue to be part of the active water management system at the FMC, by removing solids before effluent discharges to Rose Creek. Water that complies with the proposed discharge limits (Table 5-2) will primarily discharge seasonally (April to October) from the CVD Pond to Rose Creek at Monitoring Station X5. The existing siphon system has a maximum discharge capacity of 27,000 L/min. The current fall target water level elevation in the CVD Pond is 1,027.5 masl. This elevation provides maximum storage capacity, while considering the elevation of the sludge beds in the pond (670,000 m^3) (3.18 m freeboard), between the target level and lower spillway (1,030.68 masl). This elevation provides space to store typical winter inflows from October until March without the water level reaching the spillway elevation (approximately 173 days) Limiting the water level in the CVD Pond to 1,027.5 m also prevent its sludge beds from being exposed, potentially resulting in sludge re-suspension, which could impact the pond's water quality.

Water will be discharged from the CVD Pond to Rose Creek primarily during the open water season. Discharge will be initiated as early as practical in the spring and will continue throughout the summer and autumn, as necessary, until the target elevation is reached. Once the target elevation is reached, the discharge rate will transition to match inflow rates for the remainder of the discharge season. Between April and October, discharge from the CVD Pond is limited by a maximum drawdown of 100 mm per day to avoid rapid drawdown conditions at the dam (BGC Engineering [BGC], 2008). Winter discharges (October to March) will only take place as necessary and as conditions allow. Water quality in Rose Creek will further limit the volume of waster discharged from the CVD Pond. Specifically, the volume of water that can be released from the CVD Pond in winter is controlled to achieve acceptable water quality in Rose Creek at X14. Currently, a water quality target of 0.15 mg/L of total zinc is applied to Monitoring Station X14. If low-flow discharges last longer than 4 days, a lower internal target of 0.1 mg/L will be applied. As site conditions evolve, the water quality target at Monitoring Station X14 may be updated, as part of the AMP (Appendix 5C).

Dams and Spillways in the Faro Mine Area

Original and Secondary Dams and Impoundments

The dams that created the Original Impoundment are now almost entirely enclosed by the Secondary Tailings Impoundment. Today, only the Secondary Dam is functional. The Original and Secondary impoundments do not retain water near their surfaces. Surface runoff from these two upper impoundments, into the Intermediate Impoundment, is observed rarely, during extreme precipitation events.

During the IW, maintenance activities are not planned for the Original and Secondary Tailings Dams or Impoundments. The Secondary Dam will be monitored during IW as part of the geotechnical monitoring program described in Section 5.2.2 of Appendix 5B (Environmental Monitoring, Surveillance and Reporting Plan).

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Intermediate and Cross Valley Dams

The ID and CVD are critical to the protection of the downstream environment. The ID spillway will be upgraded during the IW to increase its capacity (as described in Section 5.5). Routine maintenance will be necessary, as well as additional maintenance recommended through dam safety inspections. Typical maintenance that may be required includes repairing erosion rills on its downstream face, removing granular material collected on the road surface covering the gravel drain, and maintaining rip rap and the gabion mattresses.

The major physical structure stability evaluation concluded the CVD meets the design criteria for earthquake and flood loading for the IW period (Appendix 6C). As such, the CVD will be monitored and maintained. Monitoring activities will focus on maintaining the water level in the CVD Pond within the operational range. The ID depends on the CVD Pond to provide a counterbalancing hydrostatic head, which contributes to its geotechnical stability. Monitoring is also required during discharge from the CVD, so that the maximum daily drawdown rate is not exceeded and discharge does not affect the geotechnical stability of the CVD.

Appendix 5B, the EMSPR, prescribes weekly and monthly monitoring protocols for the ID and CVD, which include the following activities:

- Monitoring the water level in the ID Pond so it remains within the operational range
- Monitoring the water level in the CVD Pond so it remains within the operational range
- Monitoring seepage flow and water quality at the toe of the CVD (X11, X12, X13, and Weir 3)
- Performing detailed inspections of dam crests and toes
- Monitoring the function of ID and CVD spillways and siphons
- Recording observations of dam instability (e.g. erosion, cracking, bulging, or wet spots)

The following maintenance and repairs may be required:

- Repairing surficial cracks
- Replacing rip rap and other erosion protection measures
- Repairing surficial erosion rills on the downstream slopes

The ID and CVD will undergo formal geotechnical inspections as part of the broader formal geotechnical monitoring program. A qualified engineer will complete the formal inspection program semi-annually (in the spring during freshet and in the fall). Section 5.2.2 of Appendix 5B describes the components of the formal geotechnical monitoring.

5.3.1.2 Vangorda/Grum Area

Fresh Water Conveyance

In the Vangorda/Grum Area, Vangorda Creek is diverted around the Vangorda Pit via the VCD (Figure 5-5). Diverted water is routed back to the original creek, downstream of the FMC. Onset runoff from the north side of the FMC, upstream from Grum Pit, is routed around Grum Pit via the Grum Interceptor Ditch (GID), through the SPP, and into Vangorda Creek. The Vangorda Northeast Interceptor Ditch and the Vangorda Northwest Interceptor Ditch capture and divert freshwater around the Vangorda Pit.

Vangorda Creek Diversion

The VCD is the major water management structure in the Vangorda/Grum Area. Before the Vangorda Pit was mined, Vangorda Creek flowed directly over the Vangorda deposit. The VCD was constructed in 1991 to capture the creek and route it along the northwest rim of the pit. The VCD currently consists of the following components (Appendix 6B):

- Headworks comprising an 8-m-high earth dam and a 1.5-m-diameter culvert within the dam that directs the water into an 800-m-long, 2,400- mm-diameter, half-round corrugated-steel pipe (CSP) culvert section
- A plunge pool or stilling basin located at the end of the culvert sections

- A 3,000-mm-diameter drop-box structure, a 2,000-mm CSP culvert, and a 600-mm outfall culvert conveying the discharge from the plunge pool beneath the Haul Road back into Vangorda Creek
- Two 1,000-mm-diameter culverts at the headworks to provide an emergency spillway (installed 2005) to the Vangorda Pit for events that exceed the 1-in-100-year flood event

The VCD was designed with capacity to divert a 1-in-100-year flood event, and since it has been constructed it has generally been successful in conveying Vangorda Creek flows around the pit during normal runoff events (Appendix 6B). In the last 10 years, the VCD has experienced two flood events that caused significant damage. It has also experienced slope failures and ice-build up, which have compromised its condition and resulted in extensive maintenance activities. Similar activities are expected as part of the IW:

- Clearing ice from VCD and defrosting it throughout winter months to prevent overflow
- Excavating ice from the drop box structure to maintain adequate flow
- Clearing debris at the trash racks (located at the entrance to the drop box inflow culvert) and at the flume headworks to maintain capacity
- Repairing flume sections, including cross-braces and holes in the structure after freshet, resulting from ice damage
- Repairing VCD rock and soil backslopes to prevent slope stability
- Removing debris from flume sections

Vangorda Northeast and Northwest Interceptor Ditches

The Vangorda Northeast Interceptor Ditch conveys uncontaminated surface runoff water that would originally have flowed directly to Vangorda Creek, around the east and south sides of the Vangorda Pit and the Vangorda Waste Dump. The diverted water is routed into Dixon Creek. Flow in the Vangorda Northeast Interceptor Ditch is intermittent. The Vangorda Northwest Interceptor Ditch is an open ditch. It was excavated from the native soils and surficial bedrock upstream from the VCD flume, at the top of the northwest wall of the Vangorda Pit. The water is routed around the northwest area of the pit and re-enters Vangorda Creek at the VCD plunge pool. The maintenance activities related to the Vangorda Northeast Interceptor Ditch and Vangorda Northwest Interceptor Ditch include clearing debris, vegetation, and sloughed material, as necessary, so flows are properly routed.

Vangorda Watering Hole

Natural runoff water collects in the old Vangorda Creek, immediately upstream from the Vangorda Pit. The Vangorda Watering Hole is a natural depression in the old Vangorda Creek channel. Without intervention, this surface runoff naturally flows into Vangorda Pit. Since 2002, a sump at this location has collected water and pumped it to the VCD during the open water season. The objective of this seasonal pumping program is to limit the volume of clean water entering Vangorda Pit. The Vangorda Water Hole is dewatered as early as practical in the spring and continues throughout the summer and autumn. Key activities related to the Vangorda Watering Hole include the seasonal installation, operation, and decommissioning of the pumping system.

Grum Interceptor Ditch

The GID passes runoff water and compliant effluent from the Vangorda WTP around the Grum Overburden Dump and into the SPP. The ditch consists of three sections:

- The upper 900-m section upslope of Grum Pit, used to divert clean water away from the pit
- The middle 900-m section along the northeast toe of the Grum Overburden Dump
- The lower 650-m section that conveys flow to SPP

The ditch includes some steep sections cut into the native soil, which can provide a source of suspended sediment. The ditch was upgraded in 2001 by excavating sloughed soil, widening the ditch, flattening the side slopes, and placing geotextile and rip rap. This type of maintenance and repair work will continue, as needed,

during the IW, to maintain the ditch in good operating condition. This work will be accompanied by routine inspections to monitor potential erosion of the Grum Overburden Dump into the GID.

Sheep Pad Ponds

The two SPP, are part of the active water management system at the FMC. They are located south of the Grum Overburden Dump. The SPP collect runoff from upslope areas, including the Grum Overburden Dump and the GID (which includes compliant effluent from the Vangorda WTP). Water from the SPP that meets discharge limits is discharged to the VCD at location V25BSP.

Runoff from the Grum Overburden Dump introduces a significant amount of suspended solids during spring freshet. To help mitigate this issue, a portion of the runoff from the Grum Overburden Dump is now routed to Grum Pit. This practice is expected to continue through the IW. In addition, during spring freshet (when SPP water contains total suspended solid (TSS) levels above discharge standards), water will be routed to Vangorda Pit via siphon instead of being discharged to receiving environment. General maintenance of the SPP includes placing rip rap on the upstream section of the spillway channel. Routine visual monitoring will take place for erosion, or potential erosion, from the Grum Overburden Dump into the SPP.

Contaminated Water Collection, Conveyance, and Storage

Within the Vangorda/ Grum Area, contaminated water is collected or stored at five locations: (1) the Grum Pit, (2) the GSC, (3) the V15/Moose Pond Area, (4) the LCD, and (5) Vangorda Pit.

Grum Pit

The Grum Pit is located near a drainage divide, and its catchment area is approximately 1.5 square kilometres (km^2). Approximately one-third of the surface drainage above the Grum Pit is directed around the east side of the pit in the GID, and then into the Vangorda Creek drainage (Appendix 6C). Grum Pit receives groundwater seepage, direct precipitation, and seepage from the GID. Since mining operations ceased, the water level in the Grum Pit has been steadily rising. On average, it increases by approximately 3 m per year (DES, 2012). The previous AMP for the FMC established a threshold level of 1,210.8 m (Gartner Lee Limited [GLL], 2004). This elevation was selected to provide 1 to 1.5 years to implement management strategy for Grum Pit water, before the water reached the maximum recommended level (1,213.4 masl). The maximum recommended elevation was selected to provide enough storage for a 1-week probable maximum flood before the water would reach the overburden-bedrock contact (1,216 masl) near the Grum Slot (DES, 2011b).

In October 2011, the water-level elevation in Grum Pit surpassed the AMP trigger level of 1,210.8 masl. This prompted the development of a response plan to actively manage in the Grum Pit. In 2013, the Grum Pit water was actively managed by pumping water from the Grum Pit to the Vangorda Pit on a seasonal basis. The Grum Pit water management aims to prevent contaminated water from reaching the downstream receiving environment. It does so by providing enough storage capacity to retain water in the Grum Pit and route excess water to the Vangorda Pit. Once the water reaches the Vangorda Pit, it undergoes treatment and discharges through the Vangorda WTP. The current target water-level elevation for Grum pit is 1,213.4 masl. The 2013 water transfer was initiated in August and shut down in mid-October. This transfer did not achieve the target water-level elevation. The water-level elevation of Grum Pit is 1,216.32 masl, as of January 27, 2014.

In 2014, water will be transferred from Grum Pit to Vangorda Pit as early as practical. The rate of dewatering will be set high enough to control and reduce the water level in the Grum Pit, to achieve the target of 1,213.4 masl as soon as possible. For the remainder of the IW, the water-level elevation in the Grum Pit will either be managed to the target-end-of season water level elevation (currently set at 1,213.4 masl), or to a revised target that prevents contaminated water from migrating to the downstream receiving environment.

Grum Sulphide Cell Sediment Control System

In 2010, an engineered cover was placed over the GSC to limit infiltration. Initially, runoff from the GSC discharged to Moose Pond, along with runoff from upgradient areas (CH2M HILL, 2013a). During the 2011 spring freshet, high flows eroded portions of the soil cover. As a result, a significant amount of silt was deposited in Moose Pond and

non-compliant, silt laden water was released to the receiving environment (CH2M HILL, 2012a). In response, a series of surface water management upgrades took place during autumn, 2011. These included implementing erosion mitigation measures and constructing the following sediment control structures, surface water storage and conveyance structures:

- HDPE-lined sediment pond (8,000-m^3 capacity (BGC, 2012)
- Unlined contingency storage area (9,000-m^3 capacity) (BGC, 2012)
- Skid-mounted diesel pump and 8-inch HDPE pipeline to pump water from the sediment pond to Vangorda Pit at a rate of 13,000 m^3 per day (Rainey et al, 2013)

In 2013, a ditch was constructed along the north and east perimeters of the GSC, to intercept and redirect runoff generated in the catchment upstream from the GSC. This runoff is directed to the ditch along the Haul Road, where it flows by gravity to Vangorda Pit.

The objective of water management for the GSC is to limit contact water from entering the receiving environment. Combined, the pumping system and the lined pond can manage 21,000 m^3/day (Rainey et al., 2013). A spillway in the lined pond provides more capacity by overflowing to the contingency storage area. When water starts to flow into the lined pond, the pumping system from the lined pond to Vangorda pit is activated as soon as practical.

V15 and Grum Creek Pumping System

Seepage and runoff from the Grum Waste Dump surfaces at V15 and Grum Creek, downgradient from the waste dump on the southeastern side. In 2007, a collection ditch was installed to convey seepage from V15 into an existing ditch that routes Grum Creek water to Moose Pond, away from lower Grum Creek. In 2011, in response to continued increasing contaminant levels at V15 and to manage peak spring runoff conditions, the V15 and Grum Creek Pumping System was installed. The pumping system is located east of the Grum Waste Dump and consists of an insulated and heat-traced 76-mm HDPE pipeline, a power supply, and pump. The system can redirect seepage from the Grum Waste Dump (V15, Grum Creek, or both) to the Vangorda Pit year-round. When the system is not operated, discharge flows to Moose Pond. The goal of the V15 and Grum Creek pumping system is to limit contaminated water from seeping to the downstream receiving environment. Currently, the system only operates during peak freshet and storm event flows; hence, Moose Pond receives “normal” (non-storm) flows. When the system is not operating, water flows to Moose Pond and exfiltrates to the ground, where downgradient monitoring confirms attenuation is occurring before the water is released into Vangorda Creek. Routine maintenance activities associated with the V15 and Grum Creek Pumping System include the prevention and removal of ice and sediment buildup, and upgrades to maintain the system’s conveyance capacity.

Moose Pond

Moose Pond is a natural depression on top of a gravel bank, on the northwest side of Vangorda Creek. In 1995, it was prepared for use as a settling pond for Grum Creek water. Seepage and runoff water from the Grum Waste Dump discharges into Moose Pond when the V15 and Grum Creek Pumping System is not operating. Water in Moose Pond infiltrates into the ground, ultimately discharging into Vangorda Creek. Downgradient monitoring confirms contaminant attenuation takes place along the groundwater flow path. Routine maintenance activities associated with Moose Pond include the prevention and removal of ice and sediment buildup in the inlet ditch to maintain the system’s conveyance capacity. Physical stability will be monitored, as described in Appendix 5B, the EMSRP.

Little Creek Dam Pond

The LCD Pond currently collects seepage and runoff from the Vangorda Waste Dump. Periodically, during the open water season, water is pumped from this pond into the Vangorda Pit for treatment. The dam crest is about 10 m above natural ground, ranging in elevation from 1,114.5 masl to 1,120 masl (Appendix 6C). The target end-of-season water-level elevation for the LCD Pond is 1,108 masl. Since 2010, the water-level elevation in LCD Pond has been managed around 1,106.5 (CH2M HILL, 2013a). Each spring, water will be pumped from the LCD Pond as

soon as practical after it begins to receive water. Active management will depend on seasonal constraints, but will take place until the target level has been reached.

The LCD is an important environmental protection structure. It retains water that would have a severe impact on the downstream receiving environment if it were released. Therefore, routine maintenance and repair is critical to maintain the LCD. The proposed C&M activities include monitoring for physical stability, as described in Appendix 5B, Section 5.2.2, the Formal Geotechnical Monitoring Program, and implementing maintenance activities required to maintain the structure in good condition, as follows:

- Investigating and repairing surficial cracks, if appropriate
- Upgrading or replacing riprap and other erosion protection measures
- Repairing surficial erosion rills on the downstream slopes
- Reconstructing or upgrading the crest, spillways, or other features to the initial design configurations where erosion and site related activities have altered those structures

Vangorda Pit

The Vangorda Pit receives groundwater seepage, direct precipitation, runoff, and VCD seepage, along with water from managed sources such as the LCD Pond and the GSC Pond. Starting in 2013, additional sources were routed to Vangorda Pit; these include Grum Pit water, inflows from the V15 and Grum Creek Pumping System, and discharge collected in the ditch around the northeast perimeter of the GSC. Vangorda Pit water is non-compliant with the proposed effluent discharge limits. To prevent an uncontrolled release of Vangorda Pit water to Vangorda Creek, the water level in Vangorda Pit is maintained well-below the overflow elevation of 1,122.5 masl through a seasonal pumping program. The maximum recommended water level elevation proposed for Vangorda Pit is 1,091.8 masl, approximately 30.5 m below the elevation at which water would overflow from the pit to Vangorda Creek. This elevation considers the elevation of the base of the surficial till, and the recommendation is based on providing enough freeboard to provide emergency storage of an unforeseen event such as a breach of the VCD. This emergency storage volume provides approximately 3 million cubic metres (Mm^3) of storage capacity. The operational end-of-season target for Vangorda Pit is 1,083 masl. This target elevation at the end of the pumping season allows enough storage to accommodate winter and spring inflows (natural and transfers).

As of January 27, 2014, the Vangorda Pit water-level elevation was at 1,086.6 masl, and above the end-of-season target of 1,083 masl. In 2014, pumping of Vangorda Pit will begin as soon as possible. Dewatering will be set to a rate high enough to control and reduce the water level in the Vangorda Pit. The goal will be to achieve the end-of season target of 1,083 masl as soon as possible. For the remainder of the IW, the water-level elevation in the Vangorda Pit will either be managed to the target-end-of season water level elevation of 1,083 masl, or to a revised target that achieves the objectives. When activated, the pumping program will typically run from May/June to late summer, pumping water from the pit up to the Vangorda WTP for treatment. A longer pumping season would be considered, if necessary, to address unusual, elevated inflow.

The current pumping system will pump water from the pit. This system includes the following primary components:

- A barge with fixed walkway and pivoting anchor point
- A pumping system comprising a 350-HP pump at the barge and a 350-HP pump at the booster station, each with a pumping capacity of 8,500 L/min
- Approximately 4 km of piping from the barge to the Vangorda WTP

Water Treatment including Sludge Storage Facilities

Vangorda Water Treatment Plant

The Vangorda WTP was constructed in 1990 as part of the initial development of the Vangorda/Grum Area. It is a conventional lime treatment system, designed to treat 10,900 m^3/day (2,000 USgpm). The system involves

agitation with lime slurry, the addition of flocculent, and the settlement of solids in an associated open air sludge pond. The WTP comprise the following primary components:

- A lime delivery and transfer system to deliver lime into the storage silo
- A lime storage silo
- A freshwater supply for reagent mixing
- A lime slurry mixing system (does not include any grinding or heat-controlled slaking), storage tank, and addition system
- Dual lime conditioning tanks, providing approximately 14 minutes of mixing at maximum design flow
- Flocculant mixing and addition systems (can be managed manually or by automated control circuitry)
- A flocculant agitation tank (provides 2 minutes' light mixing at maximum design flow)
- The Vangorda WTP Sludge Pond and influent pipe
- The Vangorda WTP Sludge Pond effluent discharge pipe

Compliant effluent from the WTP is discharged from the sludge pond into the GID and subsequently into Vangorda Creek at V25BSP, via the SPP.

During the IW, the Vangorda WTP will continue to be operated in this fashion to treat water pumped from the Vangorda Pit during the summer months. Operations and monitoring of the Vangorda WTP performance will take place according to the FMC Operations Manual. Routine maintenance and repairs of the Vangorda WTP will take place, as required, to optimize the WTP's performance.

Between 2004 and 2013, partially frozen sludge was removed from the sludge pond by suction truck or excavation. It was then deposited in an interim sludge disposal facility located within a containment berm on the Grum Overburden Dump. Starting in the 2014 treatment season, the sludge will be dredged from the pond and discharged into the southern end of the Gum Pit via pipeline. The annual volume to be deposited into Grum Pit is expected to range between 5,000 and 10,000 m^3 (average of about 7,500 m^3). Dredging will take place concurrently with treatment, as well as at the end of the treatment season.

Dams and Spillways at the Vangorda/Grum Mine Area

Little Creek Dam

The LCD is an important environmental protection structure. It retains water that would have a significant impact on the downstream receiving environment if it were released. Based on the observations from periodic dam safety reviews and the annual dam safety inspections, the LCD appears to be stable.

The proposed routine C&M activities are monitoring for physical stability (as described in Appendix 5B, the EMSRP) and implementing general maintenance activities to maintain the dam structure's condition, as follows:

- Investigating and repairing surficial cracks, if appropriate
- Repairing surficial erosion rills on the upstream and downstream slopes

5.3.1.3 Water Use and Proposed Discharge Effluent Limits

IW water usage is primarily related to pumping and treating contaminated water, and discharging compliant water to the receiving environment. Table 5-1 presents the estimated average annual water use for the IW site operations, based on the results of the FMC water quality model (GoldSim model V2.) as presented in Appendix 7B.

TABLE 5-1
Summary of Estimated Site Operations Water Use – 2014 to 2024
Faro Mine Interim Works

Water Use	Annual Volume Transferred/Discharged (m^3)
ID Pond to Interim Water Treatment System or Faro Pit	781,371
ETA SIS to Interim Water Treatment System or Faro Pit	99,961
S-Wells SIS to Faro Pit	80,245
Zone II to Faro Pit	73,002
FP to Interim Water Treatment System	2,815,937
X5 (discharge from CVD Pond)	4,356,117
LCD to VP	108,147
Grum Pit to Vangorda Pit	465,356
GSC – Vangorda Pit	19,255
Grum/V15 to VP	24,029
Vangorda Pit to Vangorda WTP	916,809

Table 5-2 presents the proposed effluent discharge limits for the IW. These are based on the expected future performance of the Interim Water Treatment System, and the past performance of the Faro Mill and Vangorda WTPs. For comparison, Table 5-2 also presents the predicted water quality at the discharge locations, V25BSP and X5, as well as the current site effluent discharge standards, based on the effluent limits set out in expired Water Licence QZ03-059.

TABLE 5-2
Median Water Quality Discharge Data
Faro Mine Interim Works

Analyte	Proposed Discharge Limit (mg/L)	Predicted X5 Discharge (mg/L)	Predicted V25 BSP Discharge (mg/L)	Current Effluent Discharge Standards (mg/L)
pH	6.5 – 9.5	6.5 – 9.5	6.5 – 9.5	≥6.5
TSS [a]	15	15	15	15
Ammonia-N[1]	1.3	1.0	0.4	1.3
Antimony	0.1	0.0002	0.0001	0.1
Arsenic	0.05	0.02	0.0003	0.05
Cadmium	0.005	0.0004	0.0003	0.02
Copper	0.05	0.03	0.004	0.2
Lead	0.05	0.02	0.01	0.2
Mercury [a]	0.005	<0.00005	<0.00005	0.005
Molybdenum	0.5	0.0003	0.0011	0.5
Nickel	0.25	0.06	0.002	0.5
Selenium	0.05	0.003	0.001	0.05
Silver	0.1	0.00001	0.00001	0.1
Zinc	0.5	0.3	0.2	0.5

Notes:

[a] Not modelled. 95th percentile of 2005 to 2012 data

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5.3.2 Routine Operation, Maintenance, and Repair Activities

In addition to site operations activities associated with water management, additional activities are required to maintain and monitor the functionality and performance of site components, facilities, and equipment.

5.3.2.1 Contaminated Water Pumping Systems

The FMC contaminated-water pumping systems described in Sections 5.3.1.1 and 5.3.1.2 will be operated and maintained to assure contaminated water is pumped to the WTPs. Currently, most pumping systems (including the following) are installed, operated, maintained, and decommissioned on a seasonal basis:

- ID Pond
- Faro, Grum, and Vangorda pits
- ETA
- GSC Pond
- LCD Pond
- V15 and Grum Creek Pumping System

The Zone II Pit pumping system, S-Wells SIS, and V15 and Grum Creek Pumping System are year-round pumping systems, although the latter is currently only operated to route peak flows. The contaminated-water pumping systems will be operated to meet the prescribed target water-levels or operational objectives. The seasonal pumping systems will be decommissioned before winter and commissioned in spring. Before commissioning in the spring, winter deterioration will be repaired so the systems are fully functional at start-up.

The contaminated-water pumping systems will be monitored to prevent the collective water inventory from exceeding the capacity of the treatment plant(s) and storage ponds. The water elevations of all pits and ponds will be measured on a weekly basis during the treatment season, to confirm freeboard is available. The pumping systems will be modified, as required, to manage new sources or extend the operating season.

Maintenance of the pumping systems will be implemented, as appropriate, on a preventative or repair basis. Maintenance activities may include the following:

- Inspection
- Repair or replacement of well pumps
- Installation of new pumping wells
- Repair or replacement of overland pipelines
- Repair or replacement of pumping barges, or modifications to barge anchor points
- Installation of an alternate pumping configurations
- Installation of automated switching and water level monitoring devices, or other appropriate activities.

5.3.2.2 Collection Ditches

In addition to the diversions and ditches described in the previous sections, there are several collections ditches at the FMC:

- Vangorda Waste Dump Seepage Collection Ditch
- Below the Grum Waste Dump, including along the V15 access road
- Along the north side of the S-Wells SIS access road
- Below the CVD

Collection ditches require regular monitoring and maintenance to assure flows are routed as intended. In addition to the maintenance measures described in previous sections, the following generic maintenance measures will be performed, as required:

- Clearing debris, accumulated sediment and excessive ice build-up
- Repairing any damaged or deteriorating channel lining, including flumes, culverts, geo-synthetic liners, rip rap and pipes, as necessary

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- Maintaining and repairing, as necessary, V-notch weirs including those at the Vangorda Waste Dump Seepage Collection Ditch
- Periodically re-armouring channels and side-slopes

5.3.2.3 Roads, Trails and Access Routes

All FMC roadways and associated infrastructure will be maintained to a standard that would prevent, counteract, or mitigate adverse effects to persons, property, or the environment. The following routine maintenance will be carried out as part of IW:

- Maintenance of road surfaces, including snow removal
- Maintenance of roadside safety berms as required by the Yukon Workers' Compensation Health and Safety Board
- Maintenance, including clearing of blockages and debris, of road-side ditches and culverts to maintain conveyance capacity and minimize the risk of road wash-out or sediment release to the environment
- Culvert steaming during winter, as required to prevent runoff from flowing over top of roadways

Two culvert crossings located on the mine Access Road are under the overall management of the Yukon Government Department of Highways and Public Works, but are monitored and maintained by site personnel because of their potential to impact water quality in the SFRC.

Haul Road

The Haul Road connects the Vangorda/Grum Area and the Faro Mine Area. It was developed for use by heavy duty off-road trucks hauling ore from the Grum Ore Transfer Pad to the Faro Mill. The road was constructed as a dumped rockfill structure, largely from mine waste rock selected for its non-acid generating characteristics. The road surface is approximately 30 m wide, with a 2-m-high safety berm on each side of the road.

Runoff from portions of the Haul Road enters the West Fork Vangorda Creek, and elevated sediment loads have been associated with precipitation events. Water quality is monitored in West Fork Vangorda Creek as part of the Pelly Aquatic Monitoring Program. In addition to the routine maintenance described herein, physical monitoring of the Haul Road consists of visual monitoring of drainage cutouts in the safety berms to identify and respond to surface runoff that may enter directly into creeks.

North Fork Rock Drain

The North Fork Rock Drain (NFRD) comprises clean waste rock at the base of the Haul Road structure, where the road crosses the NFRC. The NFRD has capacity to convey the flow of NFRC through the void space. The IW will include monitoring on a weekly basis, to confirm flows are passing normally and sediment build-up is not impeding flow-through. Sediment or debris will be removed, as required. Monitoring will also take place for sloughing that may affect the capacity of the NFRD, and material will be removed, as needed.

K-8 Rock Drain

The K-8 Rock Drain is located approximately 2.5 km east of the NFRD and drains water flowing from the northern reach of K-8 Creek through the Haul Road. The Haul Road at the creek crossing is approximately 55 m high, with a 25-m-wide crest, and is constructed of coarse waste rock fill (Appendix 6B).

The crest and side slopes of the mine Haul Road at the K-8 Rock Drain appear to be stable and the downstream drainage condition acceptable (KCB, 2012b).

The K-8 will also be monitored on a weekly basis to confirm flows are passing normally and sediment build-up is not impeding flow-through. Sediment or debris will be removed, as required. In addition, signs of sloughing will be monitored and will be maintenance as needed.

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5.3.2.4 Waste Dumps

Other than periodic physical inspections, as outlined in the EMSRP (Appendix 5B), there are no planned maintenance activities specifically associated with the waste dumps at the FMC. Routine monitoring of seepage and groundwater associated with waste dumps will be carried out as part of the EMSRP. As part of the AMP, the progression of waste rock chemistry will be assessed, as it relates to potential impacts to the receiving environment and need for intervention.

5.3.2.5 Grum Overburden Dump

The Grum Overburden Dump is not considered to present a risk of acid generation or metal leaching, as it contains primarily overburden materials. Monitoring and maintenance of the Grum Overburden Dump will be limited to routine visual monitoring of erosion, and potential for erosion to the GID.

5.3.2.6 Dust Management

Contaminant transport in dust from the exposed tailings surface is an ongoing issue at the FMC, particularly during periods of dry weather. To mitigate this, a dust control program has been implemented in portions of the RCTA since 2008, by applying a surface adhesive agent. Dust management at the FMC will continue as part of IW and will include the following activities:

- Monitoring of the surface tailings and identification of areas where tailings are being eroded by wind and dusting is occurring
- Monitoring of areas where surface adhesive agent has been applied previously to confirm treatment effectiveness
- Applying a surface adhesive agent to tailings surface, in accordance with the Dust Management Plan, to reduce wind erosion of the tailing surface

5.3.3 Environmental Management and Monitoring Plans

Site operations during the IW period will adhere to the prescriptions of the Environmental Management Plan (Appendix 5A), which was developed so that appropriate environmental management practices are carried out during the IW. The Environmental Management Plan is a framework document that outlines the key elements of monitoring and mitigation plans. These plans describe which measures should be applied to avoid or minimize adverse environmental effects and risk to public health and worker safety. The Environmental Management Plan will be refined, as required, during the IW to reflect site modifications, changes in environmental conditions or new management protocols arising from unforeseen events, or the implementation of adaptive management measures. The Environmental Management Plan currently contains the following plans:

- Sediment and Erosion Control Plan
- Environmental Monitoring and Surveillance Plan
- Emergency Response Plan
- Spill Contingency Plan
- Tailings and Water Management Structures Plan
- Emergency Response and Preparedness Plan
- Operations, Maintenance and Surveillance Manual
- Waste Management Plan
- Wildlife and Habitat Management Plan
- Heritage Resources Management Plan
- Occupational Health and Safety Plan

Source loads of environmental contaminants pose risks to the receiving environment, and so does the increasing risk of instability from certain FMC water and tailings-retaining earth structures. In light of these risks, along with the Environmental Management Plan, an extensive and comprehensive EMSRP (Appendix 5B) has been designed to monitor conditions at the FMC and in the receiving environment. By the consistently implementing the monitoring requirements of this program, environmental risks and hazards will be identified so they can be prevented or minimized. The EMSRP will provide data and site characterization information to assist in risk assessment and adaptive management activities.

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The EMSRP defines the monitoring objectives, monitoring design, and reporting to support the IW. The ERMSP outlines the anticipated environmental monitoring and reporting requirements for the IW related to water quality, meteorology, aquatic environment, wildlife, and vegetation. The primary objectives of the environmental monitoring program are as follows:

- Confirmation monitoring, to define environmental conditions for comparison with future monitoring efforts. It is also used to describe natural conditions in areas not impacted by mine site operations.
- Performance monitoring, to evaluate the changes in environmental conditions resulting from any action or operation carried out as part of the IW. The monitoring data collected in these areas will support the evaluation of system effectiveness, as well as support the design, of potential improvements to system operations. Performance monitoring also includes, where applicable, compliance monitoring to assure the site operations are meeting conditions set out in the Water Licence.
- Adaptive management monitoring, to understand how environmental conditions in a particular area are changing and whether a response is needed to address these changes and to protect human health and the environment.

The ERMSP also outlines portions of the Geotechnical Monitoring Program that will take place to protect the safety and integrity of the various physical site structures, including dams, diversions, and dikes.

The main site components will be monitored according to the EMSRP. Table 5-3 shows the monitoring program(s) associated with each FMC component.

TABLE 5-3
Site Operations - Component Monitoring Programs
Faro Mine Interim Works

		Monitoring Programs				
FMC Areas	**Site Operations Component**	**Surface Water (water quality and flow)**	**Pit and Pond Water Levels**	**Seepage**	**Groundwater**	**Geotechnical Stability**
Faro Mine Area	FCD	✓				✓
	North Wall Interceptor Ditch	✓				✓
	Faro Pit	✓	✓	✓		✓
	Zone II Pit		✓	✓	✓	✓
	Zone II Outwash				✓	
	S-Wells SIS	✓		✓	✓	
	ETA SIS	✓		✓	✓	
	Waste Dumps			✓	✓	
	West Valley Interceptor Ditch	✓				✓
	Faro Creek Canyon	✓				
	NFRD					✓
	K8 Rock Drain					✓
	Faro Valley Dump Pond	✓				
	Haul Road					✓
	Culverts and Stream Crossings	✓				✓
	Lower Guardhouse Creek	✓		✓		

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TABLE 5-3
Site Operations - Component Monitoring Programs
Faro Mine Interim Works

		Monitoring Programs				
FMC Areas	**Site Operations Component**	**Surface Water (water quality and flow)**	**Pit and Pond Water Levels**	**Seepage**	**Groundwater**	**Geotechnical Stability**
RCTA	Original Impoundment and Dam				✓	
	Secondary Impoundment and Dam				✓	
	ID				✓	✓
	ID Pond	✓	✓			✓
	Intermediate Impoundment				✓	
	CVD			✓	✓	✓
	CVD Pond	✓	✓			✓
	RCD	✓				✓
Vangorda/Grum Area	Vangorda Pit	✓	✓	✓		✓
	Grum Pit	✓	✓	✓		✓
	Vangorda and Grump Waste Dumps			✓	✓	
	Grum Overburden Dump					✓
	SPP	✓	✓			✓
	GID	✓				
	Vangorda Northeast Interceptor Ditch	✓				✓
	Vangorda Creek Diversion	✓				✓
	GSC Pond		✓			
	Moose Pond		✓			✓
	LCD					✓
	LCD Pond	✓	✓			✓
	K8 Rock Drain					✓
	Grum Ore Transfer Pad			✓		
	Vangorda Creek	✓				
	Grum Creek	✓				
	West Fork Vangorda Creek	✓				
	Vangorda WTP Sludge Pond	✓				✓
	V15 and Grum Creek Pumping System	✓		✓		

In addition to the main FMC components, the EMSRP sets forth water quality, biological, and flow monitoring requirements for reference sites not impacted by the FMC, and for receiving sites downstream from FMC and IW activities. This program includes internal and perimeter-type monitoring sites that are assessed to obtain early indications of deteriorating water quality or biological conditions. The EMSRP provides additional descriptions of these programs, including water quality monitoring parameters, and proposed study designs to monitor benthic

invertebrates and fish populations. The EMSRP also contains details of the proposed meteorological, wildlife, and vegetation monitoring programs.

5.3.4 Adaptive Management Plan

In addition to water and site facilities that will be actively managed during the IW, there are waters and facilities at the FMC that represent potential environmental risks but do not require immediate intervention. The IW includes an AMP (Appendix 5C) that will provide appropriate responses to these risks.

The AMP provides the site operator with a pre-planned framework within which decisions can be quickly and efficiently made. It also provides regulators with the security of a consistent and predictable approach to unforeseen events. The AMP framework has been developed to provide an overview of the AMP process for the IW.

The AMP takes the Precautionary Principle Approach: it provides a mechanism to identify potential environmental risks as they emerge, and to allow for a management response before an environmental effect occurs. To be effective, the AMP is linked to a monitoring program that is designed to indicate when management intervention is necessary. This assures the necessary data for the assessment of environmental conditions is being collected for evaluation against predetermined triggers or thresholds.

Because the specific environmental conditions addressed by the AMP are, by definition, unknown, the AMP does not provide detailed description of specific management responses. The AMP provides general descriptions of a range of possible responses that may be adapted or otherwise used to guide the design of an appropriate response that best suits the needs of the specific environmental conditions. This approach is inherent to the fundamental purpose of the AMP, which is to provide a framework for responding to unforeseen changes in environmental conditions.

Areas with uncertain site conditions, or where possible future conditions could lead to unacceptable environmental effects, have been identified. The AMP framework provides a strong adaptive management approach that will be used to monitor, detect, and respond to changing conditions. The AMP includes the following key components:

- Proactive monitoring to detect changing conditions in areas of expected uncertainty within a timeframe that allows for effective response
- Clear triggers that will ensure timely implementation of effective responses
- Appropriate measures that can be undertaken to address unacceptable conditions and performance

The following three broad types of uncertainty for the IW will be addressed through the AMP:

- When implementation of specific management responses will be required. For example, interception and collection of seepage water from the Zone II Outwash area is not required until water quality in the vicinity begins to show signs of deterioration. The timing of when this might occur is not known.
- Where implementation of specific management responses will be required. Depending on groundwater and seepage pathways, it is unclear where potential future contaminant sources could emerge.
- Performance adequacy of measures/mitigations that have been implemented. For example, the S-Wells SIS is currently intercepting contaminated water from the area immediately downgradient of the Intermediate Dump. Depending on downstream water quality, this system may not be performing adequately to ensure the ongoing protection of NFRC.

There are eight discrete events that comprise the AMP framework for the IW, which represent anticipated environmental conditions that may decline over the 10-year period of the IW to the point that they require a management response. These events specifically focus on areas where deteriorating water quality conditions may affect receiving environments. If required, additional events will be developed as part of the final AMP to incorporate issues/concerns raised during the Environmental Assessment process.

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The following eight events are included in the AMP framework:

1. Degraded groundwater quality in the RCAA
2. Degraded water quality in NFRC below S-Wells SIS
3. Degraded water quality in NFRC below NFRD
4. Degraded water quality in NFRC above NFRD
5. Degraded water quality in seepage from the Northwest WRDs
6. Degraded water quality in Rose Creek downstream of mine site facilities
7. Degraded water quality below the Grum/V15 Collection System
8. Degraded water quality in Vangorda Creek downstream of mine site facilities

Appendix 5C describes the conceptual AMPs for each of these proposed events individually. Table 5-4 summarizes the proposed events. The final IW AMP will be developed and finalized as part of the water licensing process; this will include defining the specific thresholds or triggers for each AMP event.

TABLE 5-4
Summary of Adaptive Management Plan Framework
Faro Mine Interim Works

AMP Event	Narrative Trigger(s)	Possible Consequences
1. Degraded groundwater quality in the RCAA	**Component 1:** Monitoring of the contaminant fronts in the tailings and underlying soils indicates that the zinc front has arrived at the tailings/aquifer interface. **Component 2**: Monitoring of indicator parameters indicates that the water quality in the RCAA is degrading and there is an increasing trend in contaminant concentrations in the aquifer, at target locations upstream from the ID. **Component 3**: Monitoring of indicator parameters indicates that the water quality in the RCAA is degrading and there is an increasing trend in concentrations of indicator parameters in the aquifer, at target locations downstream from the CVD.	Exposure of aquatic resources, terrestrial resources and human resource users to increased levels of contaminant in Rose Creek, Anvil Creek, and the Pelly River.
2. Degraded water quality in NFRC below S-Wells SIS	Monitoring of surface water downgradient of the S-Wells SIS in NFRC indicates that water quality is starting to degrade or change and contaminants are advancing towards receiving environments. Monitoring locations and indicators will be selected, where appropriate, for early detection.	Potential exposure of aquatic resources, terrestrial resources and human users of these resources to increased levels of contaminants in NFRC, RCD Channel, and, possibly, further downstream in Rose Creek, Anvil Creek, and the Pelly River.
3. Degraded water quality in NFRC below NFRD	*The development of AMP Event 3, as part of the IW AMP framework, is pending completion of the ongoing investigation of the source load.*	Potential exposure of aquatic resources, terrestrial resources and human users of these resources to increased levels of contaminants in NFRC, RCD Channel, and, possibly, further downstream in Rose Creek, Anvil Creek, and the Pelly River.
4. Degraded water quality in NFRC above NFRD	Monitoring of indicator parameters indicates that the water quality in NFRC is degrading with increasing concentrations of indicator parameters, and there is an increasing trend in concentrations at target seep and groundwater monitoring locations downgradient of the Zone II Outwash area and/or the Northeast WRDs.	Potential exposure of aquatic resources, terrestrial resources and human users of these resources to increased levels of contaminants in NFRC, RCD Channel, and, possibly, further downstream in Rose Creek, Anvil Creek, and the Pelly River.
5. Degraded water quality seepage from the Northwest Waste Dumps	Monitoring of indicator parameters indicates that water quality in seeps associated with the Northwest Waste Dumps is degrading and there is an increasing trend in concentrations at target seep locations associated with the Northwest Waste Dumps.	Potential future water quality effects associated with seepage from the Northwest Waste Dumps to Upper Guardhouse Creek, Rose Creek, Anvil Creek, and the Pelly River.

TABLE 5-4
Summary of Adaptive Management Plan Framework
Faro Mine Interim Works

AMP Event	Narrative Trigger(s)	Possible Consequences
6. Degraded water quality in Rose Creek downstream of mine site facilities	Monitoring of surface water quality in Rose Creek downstream from the FMC indicates that the downstream water quality is starting to degrade or change and acid rock drainage products are advancing towards receiving environments.	Potential exposure of the aquatic resources, terrestrial resources, and human resource users to increased levels of contaminants in Rose Creek, Anvil Creek, and the Pelly River.
7. Degraded water quality below V15 and Grum Creek Seepage Collection system	Monitoring of surface water, groundwater and seepage water quality at target locations downgradient of the V15 Grum Creek Seepage Collection System or Moose Pond indicates that water quality downgradient is starting to degrade or change and contaminants are advancing towards receiving environments.	Potential exposure of the aquatic resources, terrestrial resources, and human resource users to increased levels of contaminants in Vangorda Creek and the Pelly River.
8. Degraded water quality in Vangorda Creek downstream of mine facilities	Monitoring of surface water quality in Vangorda Creek downstream of the FMC indicates that the downstream water quality is starting to degrade or change and acid rock drainage products are advancing towards receiving environments.	Potential exposure of the aquatic resources, terrestrial resources, and human resource users to increased levels of contaminants in Vangorda Creek and the Pelly River.

5.3.5 C&M Risk Assessment

YG and AANDC conduct annual qualitative risk assessments to identify and characterize physical and operational risks at the FMC. The risk assessment approach is described in Appendix 5D. It consists of (1) ongoing identification and characterization of site risks and (2) development and implementation of appropriate responses to address the risks. Annual qualitative risk assessments are conducted to identify and characterize physical hazards and operational risks. The qualitative risk assessment approach is a form of Failure Modes Effects Analysis, which incorporates a systematic and comprehensive accounting of potential events and scenarios consisting of failure modes that could adversely affect human health and safety and the environment. The Failure Modes Effects Analysis characterizes the consequences of failure and the likelihood of failure for specific failure modes, thereby providing a framework for informed decision-making and prioritizing remedial activities.

The annual qualitative risk assessment is used as a guide to work planning efforts for site operations. YG and AANDC track ongoing risk evaluations and responses in a database that records changes in risks over time, as well as mitigation responses. The risk assessments provide rationale for annual work plan budgets associated with site operations (e.g., monitoring requirements and changes in water management approaches), site investigations to address evolving areas of concern (e.g., drilling programs in areas of evolving groundwater conditions), mitigation measures to address risks (e.g., replacement or re-alignment of piping), or equipment replacement (e.g., water treatment equipment or heavy mobile equipment).

5.4 Site Investigations

The IW site investigation activities are intended to collect additional data to support adaptive management during the IW, and to provide data to support the preparation of the FMRP. Site investigations proposed for the 2014 field season are well-defined and are described separately from site investigation activities that are likely to be undertaken subsequently. These subsequent site investigations, while similar to those proposed for the 2014 season, are not as well-defined and will depend on the results of the preceding investigations and studies. Over the timeframe of the IW, the scope of the field investigations will be refined as additional information is collected to further understand the site conditions or remedial design plans. In addition, field investigations could be required during the IW, in response to evolving geochemical conditions.

This section first describes the types of site investigation activities that will likely take place during the IW in preparation of the FMRP. Next, it describes specific site investigation activities planned for the 2014 field season. Figures 5-6 to 5-11 show field investigations planned for the 2014 field season, to illustrate their general locations.

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5.4.1 General Description of Proposed Site Investigations Activities

A range of site investigation activities are required to collect data to support the FMRP design. A large volume of borrow material will be required for the FMRP and investigations will take place to identify, delineate, characterize, and quantify potential sources of borrow material within or close to the FMC. Site-wide field investigations are also proposed to collect the data needed to further establish baseline conditions, and to enable assessment of effects on valued components in the FMRP proposal. Investigation activities will occur across the FMC both within the existing footprint in disturbed areas and in areas that have not been previously disturbed. Likely site investigation activities for the IW can be divided into two broad categories: (1) surface geotechnical and environmental investigations and (2) subsurface geotechnical and environmental investigations.

5.4.1.1 Surface Geotechnical and Environmental Investigations

Site investigation activities required to collect additional surface geotechnical and environmental information include reconnaissance programs and field surveys, monitoring and sampling programs, aquifer test activities, and reclamation test plots and trials, along with heritage and archaeological assessment programs. Each of these investigations is described in more detail in the following subsections.

Reconnaissance Programs and Field Surveys

Reconnaissance programs will generally involve field mapping geological and geomorphological features, or performing geological hazard identification, resulting in minimal land disturbance. Field surveys will be used to collect more detailed information to establish or further define baseline conditions of wildlife, aquatics, vegetation, soils, water, and air quality.

Wildlife and habitat surveys will focus on collecting data about the usage, timing, and location of wildlife species. For example, investigations may include the use of remote camera field study within key corridor areas to better define the characteristics of movements through the site (i.e., the timing, direction, seasonality, and group sizes/composition). Water birds and waterfowl studies will be aimed at documenting bird use, behaviour, and residency in the FMC area. Wildlife and bird surveys will be conducted in accordance with permit requirements.

Surveys will be undertaken to collect information on aquatic organisms and habitat, including data collection on periphyton, aquatic macrophytes, and benthic invertebrates. Sediment and fish tissue samples will be taken for analysis of metals, and water and sediment for toxicity testing, if and where possible. Fish and fish habitat survey activities may include electrofishing, seining, and angling in creeks within, upstream, or downstream of the FMC. All fish collection programs will be conducted in accordance with DFO permit requirements.

Surveys will likely be undertaken to collect information about vegetation and soil during the IW and, if required, are proposed to follow BC terrestrial ecosystem mapping protocols, or similar methodology. Vegetation and soil surveys may include sample collection for analyses and toxicity screening. Rare plant surveys may also be undertaken.

Field surveys will also include surface and groundwater monitoring and sampling programs. These programs may involve establishing, maintaining, and operating such various monitoring facilities as surface water flow gauging stations and meteorological stations. Air quality monitoring programs may be initiated for collection of particulates and metals data in specific areas or across the FMC.

Examples of other field studies that may be performed during the IW include human health and ecological risk assessment (HHERA) studies, hazardous material and waste characterization, and heritage and archaeological assessments. HHERA may include data collection from small mammals for tissue-chemical concentrations analyses, which would be undertaken only in accordance with any permit requirements. Hazardous material and waste characterization surveys will identify existing hazardous materials and wastes stored at the FMC. Heritage and archaeological assessment programs will evaluate heritage values for areas that may be disturbed by remediation related activities.

Reconnaissance programs and field surveys may include helicopter use to provide access to areas within the local or regional study areas. Helicopters will be operated in accordance with practices recommended in *Flying in Sheep Country* (YG, 2006).

Surface Geophysical Surveys

Surface geophysical surveys are conducted to non-intrusively identify subsurface conditions, including depth to bedrock and the depth of geologic unit contacts. Ground penetrating radar, electrical resistivity, and seismic refraction and/or reflection programs are among the geophysical surveys that may be used.

Seismic surveys require an energy source to generate a compression wave in the subsurface, which is commonly achieved by detonating a small explosive charge or impacting a strike plate with a sledgehammer. In areas where geophysical surveys are required that have not been previously disturbed, line cutting may be necessary. When necessary, line cutting will be performed with hand tools and trails cut will be less than 1.5 m in width. Lines require the removal of trees and shrubs along the route, but do not involve the removal or disturbance of the vegetative mat.

Bathymetric Survey

During the IW, bathymetric surveys may be performed from boat or barge on pits and man-made ponds within the FMC (e.g., CVD Pond, ID Pond, Faro Pit, Grum Pit, and Vangorda Pit).

Field trials of Remedial Measures

Field trials of remedial measures such as vegetation plots and cover trials are planned during the IW. Where used, field trials will occur in areas of the site that have already been disturbed (e.g., RCTA or WRD). Heavy equipment (e.g., excavator, bull dozer, or haul truck) will be used to construct remedial cover trials and re-grade surfaces before vegetation trials. Remediation trials will be maintained and operated to support reclamation research and evaluation. Cover trials may include use of different borrow material types and construction of lysimeters to monitor performance. Collection of vegetative material may be required to support revegetation test programs, unless commercial seed stock is used. Vegetation plots may receive application of different amendments to evaluate plant growth.

Aquifer Test Activities

Aquifer tests are planned during the IW. Aquifer tests typically involve installation of a submersible pump into an existing well and pumping the well for a set period of time while recording the aquifer response. Water extracted during aquifer tests will be managed to prevent environmental effects, in accordance with the Environmental Management Plan (Appendix 5A). Groundwater quality monitoring will be undertaken before, and during, the aquifer tests to identify the appropriate management practices for pumped water. If the water contains elevated concentrations of constituents of concern, such as zinc, it will be contained or directed in hoses to discharge in areas of the site where water is collected for treatment (e.g., ID Pond or Faro Pit), or to a storage tank for transfer to these areas or treatment facilities. If the water may contain suspended solids greater than the discharge criteria (i.e., TSS greater than 15 mg/L) in the absence of other constituents of concern, it will be directed to areas where these suspended solids can settle before release to the environment (e.g., a sump, a constructed sediment basin, or a vegetated areas away from a receiving water body). Erosion prevention measures will be in place to limit additional sediment entrainment in areas where discharge occurs. A generator will likely be used to run the pump; refueling practices will follow those described in the Environmental Management Plan, as discussed further in the section below on drilling activities.

Groundwater-surface Water Interaction Studies

Groundwater-surface water interaction studies are planned during the IW. Personnel will enter the stream on foot to hand-install temporary narrow diameter piezometers with a post pounder, to record vertical hydraulic gradients between the stream and shallow groundwater underlying the stream. Water samples may be collected from the piezometers installed into the shallow groundwater.

Water Treatment Test Programs

Studies to support the design of a new WTP will likely occur over the duration of the IW. Studies may include characterization of relevant water streams and bench or pilot tests (or both) to evaluate performance.

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5.4.1.2 Subsurface Geotechnical and Environmental Investigations

Subsurface geotechnical and environmental investigations will consist of advancing boreholes for the purpose of soil/rock classification, sample collection, and instrument installation, as well as excavating test pits for soil classification and sample collection. These investigations include drilling using a variety of different methods (e.g., roto-sonic, air rotary, hollow-stem auger, and rock coring), advancing test pits with excavators, and sampling soil and rock. Boreholes may be completed with monitoring well installations, or other data collection instruments such as vibrating wire or pneumatic piezometers, thermistors, soil-gas monitoring ports, or slope inclinometers. Whether instrumentation is installed or not, boreholes will be backfilled or sealed in accordance with best management practices to prevent surface water migration into the boring. Well development will be performed on monitoring and pumping wells following installation. Techniques used may include overpumping, bailing, air surging, or other practical methods. Water generated during well development will be managed in accordance with the practices for handing investigation-derived waste described in the Environmental Management Plan.

While excavating test pits in areas where there is a vegetative mat or organic soils, these materials will be segregated and replaced in the same sequence during backfill. Excavated test pits would typically be not more than 5 m long by 2 m wide and will extend less than 6 m in depth. Test pits will be backfilled immediately following logging and sampling activities.

Additional accessory activities which may be needed to support these investigations include access development, drill pad clearing, water usage, management of investigation-derived waste, fuel use, refueling, and spill prevention. Each of these activities are described in more detail in the following subsections.

Access Development and Drill Pad Clearing

Although many areas of potential investigation have been previously disturbed by mining activities, access trails and drill pad clearing may be required for investigation activities that are located in undisturbed areas. Access trails would be limited to the width necessary for drill-rig or excavator being used and would typically be less than 4 m wide. The area required for drill pads would also be dependent on the drilling equipment used, with the largest area to accommodate truck-mounted drill rigs requiring a pipe-truck support vehicle, such as roto-sonic, dual-rotary or air rotary drill-rigs. These activities would require a cleared area of about 30 m by 10 m. However, investigations in areas away from established roads would more likely be conducted with smaller track-mounted drill-rigs better suited to access conditions. The drill pad for a track-mounted drilling rig would require a cleared area of about 15 m by 10 m. Access trails and drill pad would require removal of trees and shrubs along the access route, but do not require the removal of the vegetative mat. It is anticipated that fill materials would be placed over the vegetative mat to provide access to the drill site. Before conducting clearing activities, heritage investigations and bird and rare plant surveys will be conducted or reviewed as necessary, in accordance with the Environmental Management Plan.

In selecting access trails, the priority will be to avoid stream crossings where possible. Alternatives will be explored before using a temporary stream crossing to access required investigation locations. Potential alternatives include using heli-portable drilling or excavating equipment, selecting longer access routes from a different approach, or timing investigations activities for winter when access impacts can be mitigated. If winter crossing is performed, a DFO operational statement regarding ices bridges and snow fills will be followed. In some instances, temporary stream crossings will be unavoidable. For example, design of a diversion channel east of NFRC will require subsurface investigation along the eastern slope as illustrated on (Figure 5-8). Any such temporary stream crossings will be conducted in accordance with best management practices and regulation (e.g., DFO operational statements for stream crossings [DFO, 2014] or water licence).

Water Usage

Drilling methods commonly require water to improve drill cutting recovery and productivity. If water is used for drilling, it will be pumped from onsite creeks. The volume of water potentially required will vary depending on the borehole diameter, borehole depth, and formation drilled. The volume of water used will be dependent on conditions encountered, but will be the minimum necessary to complete the work.

Investigation-derived Waste

Investigation-derived waste (e.g., soil cuttings, purge water, and equipment decontamination water) will be managed in accordance with the Environmental Management Plan. It is anticipated that waste generated during the investigation work will consist of excavated materials removed from boreholes and test pits, material generated during drill rig access pad construction, material excavated for installation of surface water monitoring structures, and water pumped from monitoring wells. A large majority of this work will be in areas previously disturbed during mining activities. In these previously disturbed areas, erosion-control measures will be implemented to prevent the migration of sediment or contaminated waters into adjacent water courses that are not part of the contaminated water circuit. These measures will occur in conjunction with run-on and runoff control, and will be put in place before the work being initiated. It is anticipated that earth materials removed during drilling activities for investigations in disturbed and undisturbed areas can be left onsite, adjacent to the boring. Tailings, waste rock, or other products will be replaced as practical in the borehole or test pit. These will be smoothed or blended into the existing topography once the investigation work is complete. Test pits will be backfilled with excavated materials in a similar order as removed and tamped in place.

Water quality data will be reviewed with respect to management of purge or well-development-derived water. This may involve reviewing historical water quality of nearby monitoring locations. Water that does not meet the effluent discharge criteria will not be discharged to water courses or areas where it can enter water courses. Instead, it will be discharged to an acceptable area such as one of the existing pits or a point where it will be captured and conveyed for treatment. Releases to non-contaminated surface waters will meet the effluent discharge criteria specified for the FMC.

Task-specific water management such as during aquifer test activities will follow specific effluent discharge procedures prepared in advance of these activities.

Fuel use and refueling

Refueling practices will include the use of the appropriate spill prevention equipment (e.g., drip pans and secondary containment), maintaining ready access to spill response supplies (e.g., spill kits), and will occur at least 30 m from water bodies.

5.4.2 2014 Site Investigations

Field investigations planned for the 2014 field season are shown on figures to illustrate the general locations of proposed field investigations (Figures 5-6 through 5-11). Field investigations are planned for the three main areas of the FMC, as follows:

- Faro Mine Area
- RCTA
- Vangorda/Grum Area

There are also site-wide investigations and investigations to support the regulatory process that are planned to occur across the entire FMC or in areas outside of the FMC. The following subsections present key field investigations proposed for the 2014/15 season.

Faro Mine Area

- Engineering geological field reconnaissance, geophysical and traditional surveys, along with subsurface investigations to collect data for design of surface water diversions at Faro Creek, North Wall Interceptor Ditch, and Lower Guardhouse Creek.
- Engineering geological field reconnaissance and subsurface investigations to support remedial planning and design for the WRDs (including the oxide fines and low-grade ore stockpiles). Investigations will support material delineation and characterization and will provide data to evaluate resloping or relocating material and cover design.

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- Engineering geological field reconnaissance, geophysical and traditional surveys, along with subsurface investigations in the ETA to support remedial planning and design, including potential re-location of tailings, installation of groundwater and surface water collection systems and cover design.
- Engineering geological field reconnaissance, geophysical and traditional surveys, along with subsurface investigations to evaluate groundwater collection system designs for the Zone II Outwash area and S-Wells area, as well as relocation of Zone II outwash material and design of a cut-off wall to limit contaminant migration to NFRC.
- Geophysical and traditional surveys, along with subsurface investigations to assess and characterize soil in the mill site and surrounding area.

Rose Creek Tailings Area

- Engineering geological field reconnaissance, geophysical, and bathymetric surveys, along with instrumented cover trials and subsurface investigations to support remedial closure planning and design for the dams and tailings in the RCTA.
- Engineering geological field reconnaissance, geophysical, and traditional surveys, along with subsurface investigations to support final closure design for the RCD.

Vangorda/Grum Area

- Engineering geological field reconnaissance and subsurface investigations (borings and test pits) to support remedial planning and design for the Vangorda WRDs (including in-pit WRD) and Grum WRDs (including Grum Ore Transfer Pad). Investigations will support material delineation and characterization along with providing data to evaluate resloping or relocating material and cover design.
- Engineering geological field reconnaissance, geophysical, and traditional surveys, along with subsurface investigations to support final closure design for the Vangorda Creek Diversion.
- Geophysical, traditional, and groundwater/surface water interaction surveys, along with subsurface investigations to support the design of groundwater collection systems downgradient of the Grum and Vangorda WRDs.

Site-wide

- Engineering geological field reconnaissance and subsurface investigations to support borrow material characterization, delineation, and development.
- Field surveys and studies to collect baseline data on soils, vegetation, aquatics, and wildlife.

The following provides a summary of the 2014 field investigation plan, providing an indication of the scale of the investigation activities. The numbers presented are approximate but were reached based on field planning for the proposed investigations. Proposed field investigations for 2014 include the following:

- Drilling of about 200 boreholes using various techniques, potentially including hollow-stem auger, diamond-drill coring, ODEX, air rotary, and roto-sonic, with boring diameters between 25 mm and 355 mm. Some of the borings are proposed to extend to depths of up to 100 m.
- Of these borings, about half are proposed to be completed as monitoring wells, pumping wells, or piezometers.
- In addition, about another 70 direct-push investigation locations are proposed to be advanced which includes the use of cone penetrometer tests, dynamic cone penetrometer tests, or similar.
- Excavation of over 200 test pits by an excavator, which generally would extend to a depth of about 4 to 5 m.
- There are an additional 50 shallow soil samples proposed to be collected by shovel or hand auger.
- Approximately 17,000 m of surface geophysical survey work is proposed; of this, about 10,000 m may require line cutting.

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These activities may require access road creation to allow access to borehole or test pit investigation locations. The majority of this work will occur within the disturbed areas of the mine site, but about 25 percent of the borehole and test pit investigation locations are located in undisturbed areas (Figures 5-6 through 5-11).

5.5 Down Valley Interim Hydraulic Upgrades

The DVIHU works and activities relate to the improvement of flood routing capacity for the RCTA. As summarized in Section 5.1.3, the current flood routing capacities for the ID spillway and the RCD do not meet the minimum standards specified in the CDA Dam Safety Guidelines (CDA, 2007). The existing ID spillway capacity (32 m^3/s) is much smaller than the 1-in-500-year flood event, which was the criterion specified in the now expired water licence. The RCD requires some minor upgrades and maintenance to restore its capacity to convey the 1-in-500-year flood event.

The proposed DVIHU include modifications to the ID and to the RCD, including increasing the capacity of the ID spillway, raising the height of the ID crest, and restoring the capacity of the RCD. Along with increasing the capacity of the ID spillway, erosion protection will be installed and current infrastructure within the spillway alignment will be removed or relocated.

These proposed activities provide an upgrade of the hydraulic capacity of the ID spillway and the RCD to allow both to safely pass the 1-in-500-year flood event, which is calculated as 115 m^3/s (including attenuation of flood flows through the NFRD and by the ID Pond). The work will be performed as part of the IW to provide temporary protection of the ID (and therefore the environment) until the FMRP can be implemented. The design criteria for the FMRP are further discussed in the Appendix 5I, Down Valley Interim Hydraulic Upgrades, which was prepared to support 60 percent design of the IW upgrades. The following paragraphs provide an overview of the activities to be completed as part of the DVIHU; additional details about the DVIHU project, including the current conditions, design criteria, hydrotechnical analyses, and modelling are presented in Appendix 5I.

Rationale for DVIHU

Approximately 28.6 Mm^3 of tailings were deposited in the RCTA between 1969 and 1998. The tailings are contained by a series of three dams (i.e., the Original, Secondary, and Intermediate Dams constructed across the Rose Creek Valley, with the ID (constructed in 1981) providing the final containment for the tailings and accumulated contaminated water (i.e., ID Pond) (Figure 5-12).

The ID has an emergency spillway channel on the right (north) abutment, constructed as a rock-lined channel in natural overburden material. The current capacity of the ID spillway is about 32 m^3/s when the ID Pond water elevation reaches the top of the core zone of the dam (Northwest Hydraulic Consultants Ltd. [NHC], 2006a). This is insufficient capacity to pass moderate or major flood events. The ID spillway discharges into the CVD pond. As the sulphide-bearing minerals remaining in the tailings oxidize, water with low pH (acidic) and elevated concentrations of sulphate, zinc, lead, copper, and other trace metals is released. The tailings and water contained within the tailings are potentially toxic to aquatic and terrestrial life. Failure of the ID as a result of not being able to safely pass a large storm event may cause discharge of metals-laden tailings, which would adversely affect water quality in the Rose Creek Valley and further downstream. This could result in a significant loss of fish and wildlife habitat. A failure of the Secondary Dam in 1975 within the Rose Creek Valley resulted in a loss of wildlife/aquatic habitat, with recovery ongoing for more than 35 years later.

An enhanced ID spillway will be constructed as part of the FMRP. That facility is expected to be designed to convey the PMF. However, the co-proponents of the project (YG and AANDC) wish to minimize risks associated with the current spillway capacity and condition because it is projected to require more than five years to design, plan and secure approvals for implementation of the FMRP. Therefore, the co-proponents propose to increase the capacity of the existing ID spillway and the RCD as soon as possible.

The RCD, on the south side of the valley, diverts water from Rose Creek around the RCTA (Figure 5-12). The total length of the existing diversion is approximately 4,700 m. The diversion was initially designed to carry a 1-in-50-year flood event (approximately 79 m^3/s) while maintaining 1 m of freeboard. It was subsequently modified to carry stream flows equivalent to slightly more than the 1-in-500-year flood event (BGC, 2006; NHC, 2006a). The

current condition of the RCD is such that vegetative growth and other channel maintenance related issues have decreased its flow capacity to less than the 1-in-50-year flood flow before overtopping.

5.5.1 Description of DVIHU

The main purpose of the DVIHU is to protect the ID until implementation of the FMRP, and it consists of the improvements to the ID spillway, the ID crest, and the RCD.

ID Spillway

The ID spillway capacity is proposed to be increased by:

- Increasing the effective depth of the existing spillway channel by excavating a maximum of about 2 m
- Increasing the effective height of the ID crest by about 0.5 m

Excavation of the existing ID spillway is estimated to require the removal of about 20,000 m^3 of soil and rock. The excavated ID spillway channel is proposed to be protected from erosion by installing gabion mattresses along the bottom and gabion retaining structures along the sides of the spillway, or other similar protective measures. Rock required for the gabions is proposed to be sourced from the existing Rose Creek Borrow Area (Figure 5-12). The initial estimates of the volume of rock required for the gabion mattresses and retaining structures is approximately 10,000 m^3. Section 5.6.16 provides additional detail on borrow requirements.

ID Crest

Modifications to the ID to increase the effective height will include installing a geomembrane to extend seepage cutoff to the dam crest from the dam core and adding a lined temporary crest berm to increase storage and freeboard. Glacial till will be placed in the installation trench, and the material excavated from the trench will be used for backfill where appropriate. The crest surfacing will be reinstated using a layer of gravel and sand at the crest. The temporary crest berm is proposed to be constructed from gabions.

Before excavation of the interim emergency spillway conflicting existing facilities require relocation, protection, or removal. The following existing pipeline and treatment systems located in or near the spillway construction zone will be affected:

- WTP effluent pipeline - Portions of the existing effluent pipeline will be removed and replaced to facilitate the interim emergency spillway channel. The replacement segment will be located on the north side of the access road then cross under the access road and spillway to reach the existing discharge structure at the CVD Pond.
- ID pond conveyance system – This conveyance system pumps water from the ID Pond to the WTP. Components of the conveyance system include floating barge pumps, pipelines, motor control center, and overhead power lines. A floating silt curtain will be installed to protect pumps during construction.
- Siphon Lime Mixing System - The mixing system is expected to be removed from service before construction of DVIHU and will be removed before construction begins.

RCD Modifications

The proposed RCD modifications will restore the capacity to allow the diversion to pass the 1-in-500-year flood event, with freeboard. The modifications to the RCD include removing vegetation, repairing raveled slopes on the dike and cut slope, filling in low spots on the dike crest, and raising the fuse plug.

Trees and other woody vegetation on the dike slopes can have a detrimental effect on the stability and function of the dike. It is therefore proposed that this type of vegetation be removed from the dike. Based on the results of hydraulic modelling (Appendix 5I) and considering that the left side of the channel is not a critical seepage barrier between the diversion and tailings impoundment, only the right side of the diversion is proposed to have vegetation removed.

Hydraulic modelling results (Appendix 5I) were used to determine the locations and extents of dike crest and overflow weir raises necessary to prevent overtopping of the overflow weir during a 1-in-500-year flood event (zero freeboard condition) and to prevent overtopping of the dike during a 1-in-500-year flood event (0.5 m

freeboard downstream of the overflow weir). The maximum required raise of the dike is about 0.8 m. The raise will be performed using sand and gravel for the upper 0.5 m, which is the freeboard distance. The required sand and gravel is proposed to be sourced from the existing Rose Creek Borrow Area. Compacted glacial till material is proposed to be used to extend the seepage barrier to the 1-in-500 year flood event elevation, and appropriate riprap erosion protection should be added to the top of the raised dike. The required glacial till material is proposed to be sourced from the existing Rose Creek Haul Road Borrow Area (Figure 5-12). Angular riprap required to repair the slopes along the RCD is proposed to be sourced from the Grum Dump Rock Quarry or the Granitic Outcrop Borrow Area.

Visual inspection of the existing RCD slopes and comparison with hydraulic modelling results confirmed the need for restoring the existing channel slope geometry and establishing uniform erosion protection to safely pass the 1-in-500-year flood event. It is anticipated that the most-common remediation technique will be removing vegetation and accumulated organic matter, performing localized minor regrading of the dike berm, and placing or augmenting riprap erosion protection material. The modifications do not include any in-stream work.

In summary, the specific activities associated with the proposed DVIHU are as follows:

- Install temporary silt and water management protection infrastructure
- Remove and relocate the existing pipeline
- Excavate and grade the existing spillway channel
- Screen and haul rock to build and set the gabion mattresses and sidewall supports
- Excavate trench on ID crest and install geomembrane and temporary berm
- Remove overgrown vegetation from RCD
- Remove bank slough from RCD and repair dike as required.

5.5.2 Design Components and Criteria

Until the closure conveyance strategy and structures are agreed upon and implemented, the DVIHU will upgrade existing conveyance structures so they are capable of safely conveying the 1-in-500-year flood event. This capacity is consistent with the requirements of the expired water licence (Water Use Licence QZ03-059), which states:

> *40. The Rose Creek Diversion shall have a capacity to carry a 1:500 year design flow.*
>
> *41. The spillways on the Intermediate Dam and the Cross Valley Dam shall have a capacity to carry a 1:500 year design flow of Rose Creek.*
>
> *42. The overflow structure on the Rose Creek Diversion Dam shall be maintained to ensure that peak flows can freely pass through it.*

The combined effect of deepening the spillway channel and raising the crest will allow the ID spillway to safely pass a 1-in-500-year flood event with about 1.0 m of freeboard. It is very unlikely that this flow rate would be reached during the IW because both of the following scenarios would have to occur at the same time in order for the full flow rate to be conveyed over the spillway:

1. None of the flood flow would continue down the RCD and all of the flow would be conveyed onto the tailings.
2. The duration of the 1-in-500-year flood event peak flow would be of sufficient length to fill the ITA to about elevation 1,049 m. Based on hydraulic modelling (Appendix 5I), starting from an assumed water surface elevation in the impoundment of 1,046.5 m, discharge over the spillway would reach 115 m^3/s while maintaining the minimum freeboard, during a 72-hour duration flood event that represents a peak input flow of 121 m^3/s.

Based on these considerations, it is unlikely that the flow over the ID spillway will reach the same magnitude as the inflow into the RCD during a moderate or major flood event. Additional discussion regarding the design criteria for each structure is provided in Appendix 5I.

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5.5.3 Schedule for Construction and Sequencing

The DVIHU construction scope includes the following items:

- Mobilizing to the site
- Performing surveying and layout
- Removing or relocating existing piping and structures that are within the existing ID spillway
- Increasing the depth of the existing spillway channel
- Protecting the excavated spillway channel from erosion by installing gabion mattresses
- Increasing the height of the ID crest by installing a geomembrane to extend the core to the dam crest and by adding a temporary berm
- Increasing the RCD capacity by removing vegetation, repairing raveled slopes on the dike and cut slope, and filling in low spots on the dike crest
- Performing demobilization

The work will be initiated and completed within 3 fiscal years. Final design is planned to be completed in the 2014/2015 fiscal year, procurement during the 2015/2016 fiscal year, and construction in 2016/2017 fiscal year. The RCD work is proposed to be accomplished during low water conditions in September through November. Further details on the schedule are presented in Appendix 5I.

5.5.4 Environmental Management Plans for Construction Period

Best management practices will be followed for construction works around water (Environment Yukon [EY], 2011). Relevant aspects of the Environmental Management Plan included in Appendix 5A will be adhered to during all construction activities part of the DVIHU. The specific requirements will be defined in a project-specific environmental management plan prepared before construction begins.

5.6 Ancillary Activities

The completion of the works and activities associated with the IW requires a number of ancillary activities that are associated with one or more of the main undertakings described in the preceding sections. The ancillary activities described in the following subsections will take place at the FMC to support the IW.

5.6.1 Site Security and Access

A security gate is present at the Guardhouse to control access according to the Site Security and Health and Safety Plan. Active security personnel are onsite 24 hours a days, 7 days a week from April to October. From October to March, the security personnel are present 8 hours a day, 7 days a week. The gate is locked at all other times. The site operator is responsible for the following:

- Maintenance of security systems (e.g., gates, fences, locks, and building access)
- Conducting security training/meetings
- Ensuring all visitors are approved, sign-in, and have the required Personal Protective Equipment (PPE)
- Maintenance of security records (i.e., staff, visitors, equipment, and materials)
- Updating the Site Security Plan, including reporting of site visitors, incidents, or issues
- Conducting an annual review and audit of the Site Security Plan

AAM is responsible for the management of the FMC and, as such, needs to be able to ensure the health and safety of those that use the area, while maintaining environmental protection. As outlined in Section 3.1.3, the FMC area is covered by O.I.C. 2008/168, as well as covered by a land reserve. AAM recognizes that there are many traditional and contemporary activities that take place in the O.I.C. and reserve, or that require people to pass through them en route to other areas. An Access Management Plan has been developed to maintain access to the FMC for those with legitimate access requirements, while restricting access for unauthorized users (Appendix 5G).

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Authorized users are members of the public (such as hunters, hikers, all-terrain vehicle riders, and snowmobilers) who wish to access the FMC for existing known uses, providing they are within identified known areas or crossing the site at designated points to access areas beyond. People holding or using trapping and guiding concessions are also considered authorized users. Non-authorized users are those that either do not have a specific purpose or are not accessing an area known for recreational, traditional, or big game outfitting purposes within or outside the area. Further details on the specifics of the Access Management Plan are provided in Appendix 5G. The Site Access Crossing Points map provided in Appendix 5G identifies the designated crossing points and known use areas.

5.6.2 Preventative Maintenance Plan

The FMC Preventative Maintenance Plan sets out a process designed to minimize equipment failures and breakdowns and retain the value of the assets to the extent possible considering requirements for service. The PMP applies to the following:

- Mobile and stationary equipment
- Infrastructure
- Faro Housing

The Preventative Maintenance Plan sets out a program of work activities that includes, but is not limited to, the following:

- Monitoring and inspecting equipment to determine the need for preventative maintenance
- Scheduling maintenance tasks
- Conducting all scheduled preventative maintenance
- Conducting all repairs and replacement of consumable components
- Provision of a monthly summary of maintenance activities
- Maintaining Preventative Maintenance Plan records and documents

The Preventative Maintenance Plan will continue to be implemented as part of IW.

5.6.3 FMC buildings and infrastructure

There are a number of buildings at the FMC that are currently used to support operational activities of the mine located at the Faro Mill site and at the Vangorda/Grum site. Site operations personnel operate, maintain, and repair, as required, the following buildings at the Faro Mill site:

- Mill Building
- Warehouse
- Norcan shop
- Lube storage building
- Cold storage
- Reagents building
- Crusher and coarse ore storage
- Guardhouse
- Dry and lunch room
- Concentrate load-out building
- FMC Laboratory

The majority of these buildings have been in place for more than 40 years, and several have been secured against access. The Mill Building, which houses the existing Faro Mill WTP, was deemed unsafe for workers in 2013 and has since been closed and barricaded against public or worker access. Similarly, the primary crusher and coarse ore storage areas are also closed and barricaded against access. The concentrate load out has mostly been removed, with only the foundation remaining.

The Guardhouse is located at the entrance to the FMC. It is occupied by security staff year-round with offices that are used during the week. There are three trailers attached to the Guardhouse: the Dry facilities, lunch room, and

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FMCL. The Dry trailer contains a men's and women's dry with ten showers, three toilets, and a small laundry facility with one washing machine.

The office and warehouse facility located adjacent to the Mill Building is generally not used except for storage. Although the whole warehouse is accessible, only the garage bays are used for storage. The second-floor offices are not used or maintained.

A heavy duty equipment repair shop, tire shop, and light vehicle repair shop are used on a regular basis for onsite equipment maintenance and repairs.

The following buildings are located in the Vangorda/Grum mine area:

- Grum office/dry complex
- Grum shop building
- Vangorda WTP

The office/dry complex is a 735 square metre (m^2s) two-storey wood frame construction on a concrete slab with a total floor space of approximately 1,500 m^2. The exterior cladding is sheet steel. The adjacent shop building is approximately 1,092 m^2 and of similar construction. These two buildings are owned by the Town of Faro.

The Vangorda WTP is housed in a steel-frame building on a concrete pad. The site also includes a lime bin and related structures and a few small temporary buildings or shed used for storage, office, and lunchroom space. The Vangorda WTP building and associated accessory buildings are the only buildings in the Vangorda area that are operated, maintained, and repaired by site operations personnel.

All site buildings and related infrastructure currently used will be operated, maintained, and repaired as required as part of IW.

5.6.4 Faro Mine Complex Laboratory

Operational water quality samples are analyzed at the FMC Laboratory, which is located in a trailer attached to the FMC Guardhouse. The use of the onsite laboratory provides for quick turnaround of water quality results to support operational needs. The FMC Laboratory contains an Inductively Coupled Plasma dual-view Optical Emission Spectrometer, which is used as the primary instrument for metals analysis. The laboratory also contains an Atomic Absorption Spectrometer, which is currently used as a backup method for analysis.

The FMC Laboratory is operated in accordance with very stringent contamination procedures and a quality assurance/quality control program implemented to help ensure the accuracy of results and ongoing compliance with Canadian Association for Laboratory Accreditation proficiency requirements.

5.6.5 Lime Delivery and Storage

Lime, specifically calcium oxide or quicklime, is used for the treatment of water at the FMC. Lime is delivered to site and stored in 20-tonne sea containers pending emptying of the containers at the Interim Water Treatment System and Vangorda WTP. At the Vangorda WTP, there is a lime silo with approximately 36 tonnes storage capacity. The specific method of delivery and storage may vary through the IW period, depending on the costs and other aspects of delivery. For example, lime may be delivered in bulk trailers that are offloaded directly into the treatment systems or that are stored onsite and exchanged for an empty trailer. Regardless of the specific delivery and storage method, lime will be handled onsite according to operational procedures that provide for worker health and safety. The handling and storage of lime is also subject to contingency spill response procedures described in the site Spill and Response Plan (Appendix 5E). Annual lime consumption for the IW period for the Interim Water Treatment System and Vangorda WTP is estimated to be approximately 780 tonnes and 350 tonnes, respectively.

5.6.6 Temporary Camp

A temporary camp may be required in order to provide facilities for accommodation of workers for various components of the IW including construction activities and field investigation programs. If required, the proposed location for this temporary camp is the old Pelly Camp area, located off the Grum Access Road. Potable water

supply for this temporary camp would be provided by a well located adjacent to the Grum Office Building. There is an existing septic system in place at the old Pelly Camp that has sufficient capacity to handle potential sewage flows generated by the temporary camp.

5.6.7 Town of Faro Housing

The site operator is responsible for the maintenance of four houses in the Town of Faro. Maintenance personnel are required to report the condition of each house on an annual basis.

5.6.8 Drinking water and septic system

Potable water for the FMC is shipped to the site from Yukon Springs in Whitehorse. There is a potable water system onsite, but it is currently not used for drinking water because of the conditions of the pipes in the Guardhouse. Water for this system is provided by a 66-m well located approximately 350 m northeast of the Guardhouse. This water system is currently only used for water for showering and washing in the Dry facility.

In 2005, a new septic system was installed to treat an increased volume of wastewater discharge from the Guardhouse/Dry facilities associated with additional seasonal activities. The septic system is comprised of a septic tank and siphon, and an absorption bed north of the Guardhouse. The existing septic system will continue to be used for IW period. The septic system is permitted under the *Sewage Disposal Systems Regulation* pursuant to the *Public Health and Safety Act.*

5.6.9 Fuel transport and storage

There are three aboveground storage tanks on the mine site used for storing and dispensing diesel and gasoline at the FMC. There are two single-walled diesel tanks, each with a 40,000-litre (L) capacity. The diesel tanks are located inside a lined, bermed containment area that is sized to store 110 percent of the tank volume, in accordance with the Yukon Government's *Storage Tank Regulations* and *Environmental Code of Practice for Aboveground storage Tank Systems Containing Petroleum Products*. The gasoline tank is a double-walled enviro-tank with a capacity of 30,000 L. The tanks are permitted under the Yukon Government's *Storage Tank Regulations,* and operating procedures are in place that provide for monitoring of storage tank levels and security control of dispensing. Gasoline and diesel fuel are handled according to applicable regulations (i.e., Transportation of Dangerous Goods) and diligently managed for protection of the environment, public safety and worker health and safety. Mobile tanks will be used to fuel equipment remotely or during special projects where procedures for additional tanks are expressly incorporated into the project work plan. Any active mobile tanks will be located within secondary containment berms. The handling and storage of fuels is also subject to contingency spill response procedures described in the site Spill and Response Plan (Appendix 5E).

5.6.10 Electrical distribution system

Electrical power is supplied to the Faro site via a 38-kilovolt power line connected to the Whitehorse-Aishihik-Faro grid. Transformers at the Faro Mill step the power down for onsite distribution. A 27-kilovolt overhead power line runs from the Faro Mill site to the Vangorda/Grum site, and there are electrical substations located at both sites. If required, backup power can be provided using the diesel generator located in the Town of Faro.

5.6.11 Access route and trails construction and maintenance

The mine access road from the Town of Faro to the FMC is maintained by Yukon Government Department of Highways and Public Works. This has included localized resurfacing, grading, patching, steaming culverts, and snow clearing, activities which will continue throughout the IW period.

All FMC roadway and associated infrastructure will be maintained to a standard that would prevent, counteract, or mitigate any adverse effects on persons, property, or the environment. The following routine maintenance will be carried out as part of IW:

- Maintenance of road surfaces in a condition that is suitable for travel that is commensurate with the frequency of use and type of vehicle commonly used

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- Maintenance of road side safety berms as required by the Yukon Workers' Compensation Health and Safety Board
- Maintenance of roadside ditches and culverts to minimize the risk of road wash-out or sediment release to the environment
- Culvert steaming during winter, as required to prevent runoff from flowing over top of roadways

5.6.12 Solid waste management

Solid waste disposal is authorized by Waste Management Permit No: 81-001 and is managed in accordance with the terms therein. The permit is currently held by TEES and is effective until December 31, 2014. Under this permit, there are two permitted facilities at the FMC: the Demolition Dump, located directly southwest of the Faro Pit, and the Operations Dump, located directly south of the Demolition Dump. Both dumps are located within the area of the Main and Intermediate Waste Dumps.

The scope of authorization of the Waste Management Permit includes the following:

- Operation of the dumps for the disposal and burial of solid waste generated at the FMC
- Generation, storage, and handling of waste oil, waste batteries, waste antifreeze, and waste lubricants
- Operation of equipment for the incineration of special waste (waste oil) for the purpose of space heating
- Offsite transfer of solid waste

Solid waste generated at the FMC is disposed of in these two permitted facilities, other than domestic-type waste and material containing contaminants in excess of the industrial land use standards in the *Contaminated Sites Regulation*, O.I.C. 2002/17. The domestic-type waste is taken for disposal at the Town of Faro dump. This includes food waste and garbage associated with routine operations at the Guardhouse and Dry facility.

The handling and storage of solid and special waste is also subject to contingency spill response procedures described in the site Spill and Response Plan.

5.6.13 Waste-oil heating

The FMC warehouse, welding, and maintenance building is heated by means of incineration of waste oil. Site C&M personnel are responsible for commissioning, operating, maintaining, and decommissioning the waste-oil heaters. Waste oil is consolidated from equipment maintenance and from a number of storage tanks in a safe and environmentally secure manner and processed in the waste-oil burners as necessary to provide heat.

Incineration of waste oil is conducted in accordance with the terms of the FMC Waste Management Permit No. 81-001. Specifically, the permit sets out limits on contaminant levels of waste oil and prohibits the incineration of waste oil that exceed these thresholds.

5.6.14 Special/Hazardous Waste Management

Special (including hazardous) wastes are stored and handled onsite in accordance with Section 7 of FMC Waste Management Permit No. 81-001. Section 7 sets out a list of mandatory criteria that includes specifications for storage structure and location, segregation of special waste from other wastes, storage container labeling, mixing and dilution prohibition, and standards for storage containers.

The permittee is prohibited from transporting or transferring special wastes, other than within the site. Special waste is transported offsite by a carrier permitted in the Yukon, to an appropriate special waste management facility.

5.6.15 Borrow Sources for IW

Borrow material is required for various components of IW. The following provides a summary of the borrow material requirements for two components of IW: site operations and DVIHU. In addition, the proposed investigations for the identification of borrow sources for the FMRP are summarized.

Borrow Material for Site Operations

Site operations will required borrow material for activities such as road repair, erosion protection, or minor construction purposes. The current borrow material available and its source area is as follows:

- Gabbro rock from the Grum Dump Rock Quarry located west of the Grum waste rock dump
- Sand and gravel from the Haul Road Borrow located south of the Haul Road at NFRC
- Sand and gravel from the Rose Creek Borrow Area located northwest of the RCTA

Heavy equipment is used to extract and transport the borrow material sourced from these areas. Material is screened to acquire a specific grain-size fraction if required.

Borrow Material for DVIHU

Borrow material requirements for the DVIHU are described in Section 5.5. The DVIHU requires approximately 10,000 m^3 of rock to construct gabion mattresses and retaining structures. The proposed source of this material is the existing Rose Creek Borrow Area. Heavy equipment will be needed to extract and transport the required borrow material. Material will be screened to acquire the grain-size fraction specified in the engineering design.

Minor amounts of angular rip rap (1,500 m^3) are required to repair the slopes along the RCD. The Rose Creek Borrow Area does not provide a suitable borrow source of angular riprap. The Grum Dump Rock Quarry or the Granitic Outcrop Borrow Area, have been identified as potential source areas of angular riprap. The Grum Dump Rock Quarry is an active quarry at the site. Heavy equipment is used to extract the borrow material. The Granitic Outcrop Borrow Area would be developed in an existing cut on the south side of the Haul Road. The quarry will be drilled and blasted to meet rip rap size requirements. The blasted rock will then be sorted and loaded into trucks using hydraulic excavators or with large loaders. If the Grantic Outcrop Borrow Area is used, best management practices for rock quarries will be followed and all required permits and certification for storing and using explosives will be in place.

Borrow Material Requirements and Investigation

Additional borrow material will be required for elements of the FMRP. Various material types are required for specific reclamation uses, including the following:

- Low permeability silt and clay (till) for covers and as a growth medium
- Organic rich soils for top cover to improve vegetation growth
- Granular sand and gravel for concrete aggregate, drainage, backfill, and grading/ fill
- Coarse rip-rap (competent cobbles and boulders) for lining watercourses

As described in Section 5.4, Site Investigations, additional investigation of potential borrow areas is required to identify, delineate, and quantify potential borrow material sources. This investigation work will also help to determine geochemical/ geotechnical characteristics of source materials at each potential deposit and to determine fertility/salinity parameters of low permeability and organic soils that affect vegetation for use as potential growth medium, or evapotranspirative cover, or both. Borrow materials must be relatively non-reactive and free of potential leachable contaminants.

Potential priority borrow areas, and material type(s) within the Faro Mine Area, RCTA, Haul Road, and Grum/Vangorda Area include the following:

Faro Mine Area

- Rose Creek Borrow (Granular)
- Rose Creek Haul Road (Low permeability/growth medium)
- RCD Quarry (Schist bedrock)
- Haul Road Borrow (Granular)
- Pump House Borrow (Granular)

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Haul Road Area

- Faro Mine Access Road Granitic Outcrop (Granite bedrock for rip-rap)

Vangorda/ Grum Area

- Grum Overburden Dump (Low permeability/growth medium)
- NE Area of Grum Pit (Low permeability/growth medium)
- Grum Creek Borrow/Moose Pond Borrow (Granular)
- Grum Dump Rock Quarry (ripable Gabbro bedrock)

As part of the IW, targeted areas will be evaluated for their potential to be developed into an economically feasible borrow source, but only the sources specifically identified in above and in Section 5.5 will be used during the IW. Many potential borrow locations are located in undisturbed areas. As part of the FMRP, plans to rehabilitate the selected borrow areas will be completed. Reclamation planning of borrow sources will include a revegetation plan, which requires input from baseline data collection, volumes of borrow material to be removed, and information about fertility and salinity parameters. This planning work is ongoing; therefore, it is included for context but not described in further detail at this time.

5.7 Workforce Requirements

5.7.1 Employment Expectations

Employment expectations for the components of the IW, including the timing the labour force is required, skill level of workers and number of positions, are provided in this section. This includes details on the employment levels, broken down by month and job type.

Site operations are ongoing and are expected to continue with similar staffing levels as in the recent past. Site operations occur year-round; however, between about April and October, the staffing levels increase (Figure 7-1). Average monthly employment is expected to range between 36 and 52 employees for site operations from April until October.

Currently there are no significant changes anticipated to the number of site operations staff during the IW. Staffing requirements are indicated on Figure 7-1, and include WTP operators, environmental technologists, security/safety personnel, skilled labourers/equipment operators and unskilled labours, along with supervisors and forepersons.

As has been described in the preceding sections, extensive site investigations will occur in 2014, with reduced levels of investigation activities likely to occur in subsequent years. Average monthly employment during 2014 is expected to range between 13 and 41 employees for site investigations from May to October (Figure 7-2) and are anticipated be at the lower end of that range in subsequent years. Staffing requirements are indicated on Figure 7-2, and include drillers, field engineers/scientists, surveyors, and managers.

Activities at the FMC to construct the DVIHU are limited to one season (anticipated to be in 2016), and average monthly employment is expected to range from 6 to 26 employees from April to September (Figure 7-3). Staffing requirements are indicated on Figure 7-3, and include equipment operators, labourers, engineers, and forepersons.

5.7.2 Accommodation Requirements

There is one hotel in the Town of Faro (the Studio Hotel) and at least three bed and breakfasts (B&Bs) (Bears Den B&B, Far-O-Way Guest House, and the Valley B&B) that offer potential accommodation for the seasonal-workforce. During the IW, there are several periods when staffing levels may exceed the supply of rooms available in Faro. In addition, it is understood that there are competing demands for the available accommodations. Visitors and service providers who travel to the community, such as health care providers or non-FMC related construction workers (e.g., highways crews or forest fire crews), also require lodging.

This competition for accommodation is highlighted by the same seasonal use requirements by the IW workforce as the seasonal use for tourism and non-FMC construction work. Therefore, the seasonal non-local workforce will likely be housed in a mix of hotel/B&B accommodation and leased or rental housing in the Town of Faro.

Consultation with the Town of Faro is occurring to assess the availability of possible rental units and other housing accommodation solutions to the anticipated accommodation needs. One additional option to meet the accommodation requirements is the construction of a temporary camp, as described in Section 5.6.7.

5.7.3 Worker Health and Safety Programs

The site operations contractor is required to have a site-specific Occupational Health and Safety (OHS) manual to manage health and safety at the site and protect the health and safety of the employees. TEES, the current site operations contractor, has prepared a FMC OHS manual, last updated in 2013. In addition to the OHS manual, all employees are responsible for complying with the requirements of the Yukon Occupational Health & Safety Act and Regulations and the Yukon Workers' Compensation Health and Safety Board.

The FMC OHS manual provides a means to communicate the health and safety culture, rules, regulations, policies, procedures, and criteria for site operations employees, as well as other contractors, subcontractors, and visitors. The OHS manual includes information on the following:

- Policies
- Roles and responsibilities
- Hazard identification and risk control
- Safe work practices and job procedures
- Company rules and enforcement
- PPE requirements
- Preventive maintenance
- Training
- Inspections
- Incident investigation
- Emergency preparedness
- Occupational health and hygiene
- Joint health and Safety Committee

5.7.4 Yukon and Local Opportunities

As referenced in Section 5.1, one of the overarching objectives of the FMRP closure and remediation work is to maximize local and Yukon socio-economic benefits. This objective is carried through the IW. Yukon and local opportunities will be developed or identified and implemented for AYFN and Yukoner participation with a view to build capacity toward longer-term participation and socio-economic benefits for the project. Opportunities and socio-economic benefits for AYFN and Yukoners will include opportunities for direct employment and for the provision of services, goods, and supplies from AYFN and Yukon businesses. Opportunities for engagement will continue to evolve during the IW based on participation, lessons learned and as new opportunities are identified.

A wide range of Yukon-based contractors, suppliers, and vendors were engaged to support 2012 and 2013 site operations, site investigations and development of the IW, and similar or other opportunities will continue to be available during the IW. This includes engagement of external technical consultants, drilling contractors, surveyors, electricians, truck rentals, piping and pumping supplies, transport and expediting services, potable drinking water, communication systems, and accommodations.

Table 5-5 provides a detailed list of the Yukon-based subconsultants, suppliers, and vendors retained for the 2013 field programs and development of the IWPP. Similar engagement is anticipated to support activities during the IW.

In general, IW activities likely provide limited long-term employment opportunities for the local communities (Town of Faro, Ross River, Pelly Crossing, and Watson Lake), beyond the current employment opportunities needed to sustain site operations. While the three main IW activities potentially provide employment opportunities for a range of job types, many of these jobs require specialized skillsets. As a result, the local area is expected to capture a relatively small portion of the employment opportunities. The workforce is anticipated to combine non-local technical experts with Whitehorse-based and local support.

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Similarly, beyond current opportunities for purchase of materials and supplies, the activities conducted as part of the IW offer limited additional local business development opportunities. As most of the materials and equipment will be imported into the project area, limited potential for economic diversification is anticipated. However where possible and practical, local resources will be used. It is expected that for some supporting services and suppliers demand will exceed the existing local capacity. Opportunities for potential engagement by local business include house rental, shuttle services, catering, housekeeping, restaurant, grocery, and fuel supply.

TABLE 5-5
Yukon-based Subconsultants, Local Suppliers, and Vendors for Field Programs and development of the IWPP
Faro Mine Interim Works

Name	Service Provided
A-1 Delivery	Shippers
Acklands Grainger	Field supplies
Air North	Air transport and freight
Alkan Air	Air charter transport
Aurora Geosciences	Geophysical surveys
Bill Slater Environmental Consulting	Technical consulting services (Regulatory Lead role)
Bears Den B&B	Faro Accommodation
Challenger Geomatics	FMC surveys and aerial photography targets
Capital Helicopters	Helicopter transport
The Chocolate Claim	Catering
Driving Force	Truck rentals
Dynamic Electric	Electrician
EDI Environmental Services, Inc. (EDI)	Fish tagging and telemetry
ELR	Technical consulting services
Energy North	Technical consulting services
Faro Studio Hotel	Accommodation
FMTX	Field suppliers
Glacier Water	Potable drinking water
Hemmera (Whitehorse Office)	Technical consulting services
Laberge Environmental Services	Pit Lake Sampling
northSense	Technical consulting services
NorthWest Vacuum Service	FMC portable toilets
Northwestel	Cable and internet
Midnight Sun Drilling Ltd.	Drilling services
SLR (Whitehorse Office)	Technical consulting services
Sunset Septic Services	Septic service
Tait Custom Trailer	Trailer rental
The Brick	Lab equipment
Territorial Expediting	Expediting
Total North	Radio and satellite communications hardware and setup
Trans North Helicopters	Helicopter transport
Valley B&B	House rental and Faro accommodations

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5.7.5 Training and Skills Development Programs

Various programs to provide training and skill development have been offered in the past and will likely continue during the IW. Training and capacity building initiatives are intended to develop skills and capabilities that will meet labour resource needs during the IW and ultimately for the FMRP. The training and education strategy will preferentially support AYFN work force development and training opportunities.

Examples of training programs that occurred recently include the following:

- The site operations contractor offers a training and development program for AYFN residents. Training and development initiatives include work experience opportunities, job shadowing, role cross-training, and formal training courses. In 2012, six AYFN trainees (including participants from Ross River and Watson Lake) and in 2013, eight AYFN trainees (including participants from Faro, Ross River, and Watson Lake) completed this training program.
- CH2M HILL participated in the YG-sponsored Student Training and Employment Program (STEP), which provides summer employment opportunities to full-time post-secondary students or recent post-secondary graduates who were Yukon residents before attending school.

Table 5-6 provides a list of AYFN participation activities planned for 2014. It is anticipated that these, or similar activities, will continue during the remainder of the IW. Table 5-7 provides a list of Yukoner participation activities planned for 2014. It is anticipated that these, or similar activities, will also continue during the remainder of the IW. Lessons learned related to local skill development and training opportunities from the IW activities will be applied to the FMRP.

TABLE 5-6
Proposed November 2013–November 2014 AYFN Participation Activities
Faro Mine Interim Works

Opportunity	Description	Participation Type	Schedule
Visit First Nation Communities	Road trip to Pelly, Ross River, and Watson Lake to discuss opportunities for training employment and contracting opportunities	Training and capacity building	November–December 2013
Youth Job Fairs	CH2M HILL attendance at local job fair-type information sessions (Pelly, Ross River, Watson Lake)	Training and capacity building	February 2014
Dechen La' Youth Program Support	Meeting with N. Barichello to discuss the 2014 summer program	Training and capacity building	February–June 2014
Project Delivery Assistant for the FMC Field Office	Direct-hire 2 AYFN candidates to work in FMC Field Office as key team members	Direct employment	Summer 2014
AYFN Trainee Program/TEES	Coordinate work with TEES to use job training and mentoring for apprentices CH2M HILL to offer specialized 'young worker' health and safety training programs that are more age-sensitive	Training and capacity building	2014 field season
Contracting	Award field support services to local vendors, including heavy equipment services, vending, and logistics	Contracting and Procurement	2014 field season

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TABLE 5-7
Proposed November 2013–November 2014 Yukoner Participation Activities
Faro Mine Interim Works

Opportunity	Description	Participation Type	Schedule
Identify New Opportunities	Cooperation with the Town of Faro	Direct employment and contracting opportunities	November–December 2013
STEP Student	Environmental intern	Direct employment	June–August 2014
STEP to Employment Transition	Offer full-time position to STEP student following program	Direct employment	2014
CH2M HILL Whitehorse Office Recruitment	Various positions	Direct employment	Ongoing
Yukon College	Work with Yukon College on ways that CH2M HILL employees can maximize use of College training	Training and capacity building	November–December 2013
Yukon Schools	Work with key high schools (Whitehorse and Watson Lake) to provide career orientation to appropriate classes; find school “champions”	Training and capacity building	Spring and Fall 2014

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SECTION 6

Description of Existing Environmental and Socio-economic Conditions

This section describes the existing conditions at the FMC and the assessment study areas, as follows:

- Existing Site Conditions (Section 6.1)
- Environmental Conditions (Section 6.2)
- Socio-economic Conditions (Section 6.3)

The existing conditions serve as the baseline for the assessment of effects presented in Section 7.

6.1 Existing Site Conditions

This section describes existing site conditions at the three main areas of the FMC: the Faro Mine Area, the RCTA and the Vangorda/Grum Area (as illustrated in Figures 5-1 and 5-5), and the associated main facilities. It focuses on issues and components that result in requirements for the proposed IW. It describes the existing geochemical and physical stability conditions associated with the FMC facilities. As stated in Section 3.3.2, the FMC presents long-term chemical and physical stability risks that require on-going monitoring and long-term management. Current geochemical and physical stability conditions are characterized by the following documents, provided as appendices to this document:

- Appendix 6A, Geochemical Characterization Report
- Appendix 6B, Hydraulics Characterization of Existing Facilities
- Appendix 6C, Stability of Major Existing Facilities

6.1.1 Faro Mine Area

An overview of the Faro Mine Area and RCTA is provided in Figure 5-1. It shows the following main facilities:

- Freshwater diversion systems
- Faro Pit and backfilled Zone II Pit
- Faro WRDs
- S-Wells area, ETA, and associated SIS
- The Faro Mill WTP
- The RCTA

6.1.1.1 Freshwater diversion systems

Historically, a number of streams and creeks conveyed runoff through the Faro Mine Area. However, to prevent potential surface water contamination associated with mining activities, many of these systems were re-routed via diversions, flumes, and ditches. North of the Faro Pit, runoff drains through Faro Creek, a natural channel carrying unimpacted surface water to the southwest. Faro Creek was diverted from its original flow path and now flows around the northeast side of Faro Pit through the FCD, to the NFRC natural channel. Clean runoff is collected from the hillsides northwest of the Faro Pit and redirected to the FCD via the West Valley Interceptor Ditch. The NFRC flows southwest and adjacent to the Northeast WRD and Intermediate Dump, and through the Haul Road via the NFRD to its confluence with the SFRC. Water from the NFRC and SFRC flows into the upper section of the RCD, a straight constructed channel that diverts water around the south side of the RCTA. The RCD is described in detail in the section below describing the RCTA. Rose Creek ultimately flows to Anvil Creek, a tributary of the Pelly River.

The North Wall Interceptor Ditch intercepts runoff from the north side of the Rose Creek Valley and diverts it around the CVD to Rose Creek. Upper Guardhouse Creek, a natural channel located northwest of the Faro Pit, collects runoff from the catchment north of the FMC, as well as seepage from the Faro Northwest Waste Dump (Northwest WD), and conveys the flow to the North Wall Interceptor Ditch.

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Throughout the FMC, clean surface water continues to be managed using various fresh water conveyance diversions and facilities to minimize the amount of clean water that enters the impacted areas of the site and subsequently requires management and treatment.

6.1.1.2 Faro Pit

The Faro Pit was mined from 1969 until 1982, and from 1986 until 1992. Excavation began along the northwest side of the pit and expanded to the west and south until the pit reached its maximum open length of approximately 1,600 m and maximum width of approximately 975 m, crest to crest. The top of the slope at the northwest end of the pit is approximately 1,320 masl, and the top of the slope along the east side of the pit is approximately 1,296 masl. The bottom of the pit is currently under water, but is estimated to be 975 masl (RGC, 1996). The side slopes are intact where benched, with overall slopes varying between 30 and 45 degrees. The steepest slopes are located around the northwest end of the pit, and the gentler slopes are located along the eastern wall. Two slope failures have been identified along the east slope of the Faro Pit: the North and South Instability Zones (Golder, 2013). For the interim period, there is a low risk of the Faro Pit slopes experiencing a large-scale failure (Appendix 6C). The Faro Pit Instability Zones are monitored periodically.

Underground mining also took place through the southwest wall of the Faro Pit, but its extent is not well-defined. During these operations, approximately 3.4 million m^3 of mine rock were dumped into the Faro Pit. The pit also contains approximately 15 million tonnes of net acidic, alkaline-bearing tailings received from the Mill starting in 1992. Portions of the pit's south and east walls are covered by waste rock and contribute a significant amount of contaminants to the pit lake.

Faro Pit is part of the active water management program at the site and receives groundwater seepage, direct precipitation, runoff, FCD seepage, pit wall seepage, and water from managed sources such as the ID Pond, S-Wells, Zone II Pit, and ETA. The Faro Pit has the capacity to store water pumped by various water interception systems year-round, making it possible to operate the WTP seasonally. Until the fall of 2012, to prevent an uncontrolled release of non-compliant water from Faro Pit to the receiving environment, the water level in Faro Pit has been managed through seasonal pumping and treatment. Each year the water level was maintained at least 15 m below the elevation at which water could overflow into Zone II Pit, through seasonal (summer) pumping and treating of water from the pit in the Faro Mill WTP.

In 2012, the Faro Mill WTP was assessed and it was determined that there was an increasing risk of major equipment failure in the WTP (CH2M HILL, 2012c). In addition, a safety assessment of the existing Faro Mill WTP determined that the facility should not be operated until health and safety issues could be assessed and resolved). Consequently, operation of the Faro Mill WTP ceased at the end of the pumping program in the fall of 2012. During 2013, without operation of the Faro Mill WTP, the water-level elevation in the Faro Pit rose above the end-of season target (1141 masl) to its current water-level elevation of 1148.3 masl (as of January 2014). In 2014, as early as possible, seasonal dewatering activities will resume at the Faro Pit using the Interim Water Treatment System, with the objective to manage the water-level elevation in the Faro Pit within the prescribed operating range. Based on current site conditions, it is anticipated that the water level in the Faro Pit will return to the operational end-of-season target in 2016.

6.1.1.3 Zone II Pit

A smaller pit, the Zone II Pit, was excavated immediately southeast of the Faro Pit. This pit was mined from 1969 until 1982, and was approximately 100 m deeper than the original ground surface (RGC, 1996). During the 1980s, this pit was backfilled entirely with waste rock; however, there is a continuing need to extract contaminated water from the backfilled pit. The back-filled Zone II Pit collects contaminated water from its immediate catchment area. If water in Zone II Pit rises above 1,128 masl, it will seep towards NFRC. Since 1991, a water management plan for Zone II Pit has been in place involving seasonal (summer) dewatering into the Faro Pit via a down-hole pump installed in a well (X26) located in Zone II Pit on an as-required basis to maintain the water level and to minimize the migration of groundwater from the pit towards the NFRC. In 2013 a new well (CH12-Z2-PW01) replaced X26, enabling groundwater levels in Zone II Pit to be managed to lower levels, below the elevation of water in the NFRC. In addition the system was upgraded to enable year-round operation.

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6.1.1.4 Faro Waste Rock Dumps

Within the Faro Mine Area, waste rock was deposited in a series of dumps surrounding the Faro Pit. There are approximately 260 million tonnes of waste rock in the Faro Waste Rock Dumps, covering approximately 335 hectares of surface area. There are roughly 30 separate dumps, each with a unique history and composition.

The Faro Waste Dumps' geochemistry has been studied extensively in the recent past (SRK 2004a, 2006a) and most recently to as part of the current assessment (Appendix 6A). The main waste dumps at the Faro Mine Area include Northwest, Faro Valley, Main, Intermediate, Northeast, Zone II, and near pit dumps, and the Low-Grade and Oxide Stockpiles. The Faro Mine Area waste dumps are shown in Figure 6-1.

At the broadest level, it is helpful to characterize three groupings of waste rock. The most mineralized material occurs in a series of low-grade ore and oxide fines stockpiles. Although that material represents less than 10 percent of the total volume of waste, it has a high metals content and is therefore a significant source of contaminants. The next most mineralized material is found in three sulphide cells, which are areas within the Main Dump, Intermediate Dump and Northeast WRD, where some sulphide waste was purposefully segregated. The sulphide cells are not as well-delineated as the low grade ore and oxide fines, so volumes are more difficult to estimate. But the material's relatively high metals content and acid-generating potential suggest the sulphide cells are also disproportionately large sources of contaminants. The remainder of the waste rock dumps are variable in composition. In general, most dumps contain areas of acidic and metal-leaching waste, and none of the dumps can be considered completely benign.

Geochemical loading from the FMC WRDs is largely controlled by the waste rock material's composition, as well as how it was placed, relative to the paleotopography. Previous borehole data and historical geological information indicate the FMC WRDs are underlain by generally thin (less than 10-m-thick), discontinuous deposits of glacial till, glaciofluvial sediments, and low-permeability bedrock (RGC, 1996). When the FMC WRDs were established, the relatively coarse waste rock material (which has a fairly high hydraulic conductivity) was placed over the native soil, which is less permeable. As a result, water infiltrating the waste rock either continues to infiltrate into the native soil or will travel along the paleosurface at the base of the WRD until it daylights at the toe of the waste rock. Contaminated water which infiltrates the native soil and into the groundwater leads to groundwater contamination in the Faro Mine Area. Groundwater contamination is expected to increase significantly in the future (Appendix 6A).

Seepage water that emerges at the toe of the WRDs can impact surface water quality directly. Currently, the majority of poor-quality seepage water is collected through interception systems for treatment. Most of the seepage occurs at these locations after freshet or large precipitation events. It takes place over a fairly short timeframe, based on observations during the CH2M HILL 2012 field program (CH2M HILL, 2013b), as well as the historical seep sampling program (SRK, 2010b). However, several seeps (generally located in pre-mining drainage channels), flow year-round. As part of the FMRP, the seepage from perennial seeps at the toe of the waste dumps will likely be managed further by placing covers to minimize infiltration through the waste dump. SISs will control seepage that still emanates from the toe of the waste dumps (i.e., after the covers are in place).

6.1.1.5 S-Wells and Emergency Tailings Area Seepage Interception Systems

The S-Wells area is an area of identified groundwater contamination. It is located at the southernmost extension of the Main WRD, where it branches off to the Haul Road (Appendix 6A). Groundwater and surface water quality investigations in the S-Wells area indicated high levels of contaminants near the NFRC, with a component of the contaminated groundwater discharging to the creek. Increasing trends in contaminant levels were also evident within the creek, particularly in the winter low-flow period. In early 2009, a first-phase groundwater interception system was installed in the S-Wells area and upgraded in the autumn of 2009. Since then, the collected water from the S-Wells has been pumped to the Faro Pit on a year-round basis.

Significant groundwater contamination has also been identified in the ETA, located downgradient of the Mill and stockpiles (Appendix 6A). The ETA has been shown to contribute a significant contaminant load to the RCAA under the RCTA through seepage and groundwater migration. As the name suggests, the area was used for emergency deposits of tailings, but studies have shown that groundwater contamination results at least in part from the

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waste rock located upgradient of the tailings. The ETA is also the only portion of the Faro Mine Area with significant surface water seepage from the waste rock (other seeps are ephemeral or internal). Measures to capture the ETA surface and groundwater and send it directly to water treatment were implemented in 2007, providing for seasonal collection and treatment. Flow not captured by the ETA SIS flows into Faro Creek Canyon, the pre-mine Faro Creek channel located downgradient of the Mill Area and ETA. Most of this flow discharges to the Intermediate Impoundment of the RCTA, where it is pumped to the Faro Pit or directly for treatment when the WTP is operating. A small percentage of this flow, however, seeps into the RCAA through the unlined conveyance ditch draining Faro Creek Canyon to the Intermediate Impoundment.

6.1.1.6 Faro Mill Water Treatment Plant

The Faro Mill WTP, which began operation in 2001, is located in the old Faro Mill Building and was constructed using existing ore-processing equipment adapted for lime water treatment. Treated effluent from the Faro Mill WTP was discharged to the CVD Pond for polishing clarification (solids removal) prior to discharge, via siphon, to Rose Creek.

In 2012, the Faro Mill WTP was assessed and it was determined that there was an increasing risk of major equipment failure (CH2M HILL, 2012c). In addition, a safety assessment of the Faro Mill WTP determined that the facility should not be operated until health and safety issues could be assessed and resolved. Consequently, operation of the existing Faro Mill WTP ceased at the end of the pumping program in the fall of 2012.

Since 2006, sludge generated in the Faro Mill WTP was deposited in a series of cells (ponds) excavated in the Original Impoundment. At the end of each treatment season, once partially frozen, the sludge is excavated from the ponds and placed in windrows next to the ponds. During operations, water decanted off the solids is routed through existing ditches to the ID Pond, where it blends with those waters and is eventually pumped back for treatment.

6.1.2 Rose Creek Tailings Area

6.1.2.1 Rose Creek Tailings Area Dams

Figure 5-1 shows the RCTA, which consists of four dams; the Original Dam, Secondary Dam, ID, and CVD. The RCTA contains about 28.6 million m^3 of tailings (about 55 million tonnes). Throughout most of the operating periods at the FMC, tailings were deposited in the three impoundments that make up the RCTA:

- The Original Impoundment was used from 1969 to 1975; it has a surface area of 41.7 hectares, and holds approximately 6,300,000 m^3 of tailings.
- The Secondary Impoundment was used from 1975 to 1982 and again in 1986; it has a surface area of 54.5 hectares and contains approximately 10,400,000 m^3 of tailings.
- The Intermediate Impoundment was used from 1986 to 1992; it has a surface area of 99 hectares and contains approximately 11,900,000 m^3 of tailings.

Between 1992 and 1998, tailings were deposited in the Faro Pit as described previously.

The tailings impoundments were created by the series of dams and associated dam raises. The dams that created the Original Impoundment are now almost entirely enclosed by secondary tailings and no longer function as dam structures. The Secondary Dam and ID function as tailings and water retention structures.

The Secondary Dam comprises an East and a West Limb. The East Limb of the Secondary Dam is a low retention dike constructed of compacted fill. It runs parallel to the south Rose Creek Valley wall, and only rises about 4 m above the natural topography. The West Limb of the Secondary Dam is a curved portion of the dam that crosses the Rose Creek Valley in a roughly north–to-south direction. It was raised using centerline construction and compacted fill to a maximum height of 27 m, about half of which is now covered by the intermediate tailings. Tailings were deposited behind this dam from 1975 until 1982, and again for approximately five months in 1986.

The ID is a zoned earthfill embankment with a sloping upstream low-permeability core and a downstream random fill shell. In 1981, the ID was constructed across the Rose Creek Valley to contain supernatant water and tailings

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solids. It was raised in 1988, 1989, and 1991 to a final crest elevation of 1,049.8 masl, to a maximum height of about 32 m above the old Rose Creek channel. The ID spillway on the right (north) abutment is a rock-lined channel in natural overburden material. The ID spillway discharges into the CVD Pond.

The CVD is located about 500 m downstream from the ID. It has a maximum height of about 19 m, is approximately 500 m long, and creates the CVD Pond which holds treated water prior to discharge to Rose Creek. The embankment is a zoned dam with core and filters, constructed as a conventional water-retaining dam with no retained tailings. A toe berm was constructed at a later date (after the original construction was completed) to address seepage that appeared near the toe of the dam. The crest of the dam is 1,034 masl and the downstream toe is 1,016 masl (nominal).

Sampling to date has identified contaminants migrating from the acid-generating Rose Creek tailings to the RCAA, an essentially continuous aquifer of sand and gravel outwash that underlies the tailings. The tailings contain an excess of acid-generating sulphide minerals, with very high levels of soluble metals and acidic conditions. Precipitation picks up some of the soluble contaminants and transports them down into the underlying tailings and soils. However, groundwater contamination is limited and is not ecologically significant at this time because the contamination has not reached surface receiving waters. Testing of soil and water from the RCAA demonstrates that the metal contaminants are being temporarily held within the organic and alluvial sediments underlying the tailings. In the future, groundwater contamination is expected to increase significantly below the tailings (Appendix 6A).

6.1.2.2 Rose Creek Diversion

The RCD is located about 2.5 km southwest of the Faro Pit and was designed to convey Rose Creek around the RCTA. The RCD is approximately 4,700 m long, with a slope ranging from 0.23 to 5.0 percent. Numerous drop weirs are present at the downstream portion of the diversion.

The RCD was developed in two stages: the upper section and the lower section. The upper section was constructed in 1974, in conjunction with the construction of the Secondary Impoundment, and is approximately 900 m long. It is predominantly a straight channel constrained by natural slopes on the south side and by a constructed dike on the north side. The channel includes drop weirs, as well as rip rap for erosion protection.

The lower section of the RCD was constructed in 1980 and 1981, in conjunction with the Intermediate Impoundment development. It passes water along the south side of the Intermediate Impoundment and returns flow into the natural Rose Creek Channel, downstream of the CVD. The lower section includes a series of boulder-lined drop structures and a sharp bend at the downstream end. It is constrained by natural slopes on the south side and by a till dike on the north side.

The crest of the diversion dam (also known as the overflow weir) which diverts flow from the upper section to the lower section of the RCD, was constructed approximately 1 m lower than the crest of the adjacent diversion canal dike, and was armoured with rip rap. This was done to facilitate overflow at this location to the Intermediate Impoundment during an event in excess of the 1-in-500-year flood design capacity. In 2004, the containment dike (roadway) was rebuilt along portions of the lower RCD to restore freeboard to safely pass the design flood. Slumping and encroachment of excessive vegetation in the containment dike has limited the success of this rebuild, and the RCD's capacity remains below the intended design flood capacity.

6.1.3 Vangorda/Grum Area

An overview of the Vangorda/Grum Area is provided in Figure 5-5. It shows the following main facilities:

- Fresh water diversions and facilities
- Vangorda and Grum Pits
- Vangorda and Grum Waste Dumps (including the GSC)
- Little Creek Dam
- V15 and Grum Creek Pumping System
- Grum Overburden Dump
- Vangorda WTP and Sludge Pond

6.1.3.1 Fresh water conveyance diversions and facilities

The Vangorda/Grum Area is characterized by two localized groundwater sinks (the Grum and Vangorda Pits) and regional groundwater flow toward Vangorda Creek, which drains the area and flows south toward the Pelly River. The major water management structure in the area is the VCD. Before mining began, Vangorda Creek flowed directly over the Vangorda deposit. Vangorda Creek is now diverted from its original path via a 1,200-m-long flume that flows west of the Vangorda Pit and discharges back into Vangorda Creek downstream of the Vangorda Pit. Design of an upgraded VCD is currently underway because the current diversion only has capacity for a 1-in-100-year flood event, and it requires extensive ongoing maintenance to maintain performance.

There are also a number of small ditches and sediment ponds around both the Grum and Vangorda Pits. The GID diverts Grum Creek in a rip rapped channel around the upper perimeter of the Grum Pit. It discharges the flow into the sedimentation SPP built to capture sediment from the GID before discharging into Vangorda Creek.

6.1.3.2 Little Creek Dam

The LCD is located directly south of the Vangorda Pit. The LCD was constructed in 1992 to collect water pumped from the Vangorda Pit, and runoff and seepage from the Vangorda Waste Dump. During operations, water stored in the LCD Pond was conveyed to the water treatment plant. Once mine operations ceased, water management at the FMC changed. Currently, only runoff and seepage from the Vangorda Waste Dump collects behind the LCD. Runoff and seepage are conveyed to the LCD Pond by the Vangorda Waste Dump Seepage Collection Ditch; an open ditch along the south, west and north sides of the Vangorda Waste Dump which intercepts runoff and seepage that would otherwise enter Vangorda Creek directly. Several transverse drains were constructed beneath the till berm surrounding the Vangorda Waste Dump to direct the seepage toward the perimeter collection ditch and LCP. Water accumulates in the LCD Pond and is pumped seasonally to the Vangorda Pit and eventually to the Vangorda WTP for treatment.

6.1.3.3 V15 and Grum Creek Pumping System

Seepage and runoff from the Grum Waste Dump surfaces at V15 and Grum Creek, downgradient from the waste dump on the southeastern side. A collection ditch, installed in 2007, conveys seepage from V15 into a ditch that routes Grum Creek water to Moose Pond, away from lower Grum Creek. In 2011, site operators installed the V15 and Grum Creek Pumping System in response to continued increasing contaminant levels at V15, to manage peak spring runoff conditions, and to protect the physical integrity of Moose Pond. The pumping system, located east of the Grum Waste Dump, consists of an insulated and heat-traced, 76-mm HDPE pipeline, a power supply, and pump. The system can redirect seepage from the Grum Waste Dump (V15, Grum Creek, or both) to the Vangorda Pit year-round. Currently the system is operated during peak freshet and storm event flows only, with Moose Pond receiving ‘normal” flows. When the system is not operated, discharge flows to Moose Pond, where it exfiltrates to ground. Sampling of Moose Seep and Moose Well No. 2, downgradient of Moose Pond, confirm that losses from Moose Pond (via exfiltration) flow towards Vangorda Creek with contaminant attenuation provided along the groundwater flow path.

6.1.3.4 Vangorda and Grum Pits

The Vangorda Pit is about 1,150-m-long and 375-m-across at its widest point. The southeast half of the pit is narrower and shallower, and includes a ramp, and ore and waste stockpiles. The deepest point in the pit is about 150 m from the crest. Vangorda Pit receives groundwater seepage, direct precipitation, runoff, VCD seepage, along with water from managed sources such as LCD Pond and the GSC Pond. Starting in 2013, additional sources were routed to Vangorda Pit including Grum Pit water, inflows from the V15 and Grum Creek Pumping System, and discharge collected in the ditch around the northeast perimeter of the GSC. Pit wall rock and waste rock release contaminants to the pit lake. Vangorda Pit water is currently non-compliant with the proposed effluent discharge limits.

The water level in Vangorda Pit is maintained through a seasonal pumping program. When activated, the pumping program typically runs from May/June to late summer/autumn, pumping water from the pit up to the Vangorda WTP treatment.

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The Vangorda Pit walls are considered stable and with a low risk of large-scale failure. Slope movement, however, has been identified along the southwest pit wall and could eventually affect the safety berm along the Haul Road.

The Grum Pit is oval in shape, oriented with the long axis in a north to south direction. The pit is approximately 1000 m in length (north to south), and 625 m wide (west to east), measured crest to crest. The Grum Pit receives water from surface runoff within the Grum Pit catchment, as well as groundwater inflow from the surrounding thalweg aquifer (Appendix 6A). Since the mine operations were shut down, the water level in the Grum Pit has been steadily rising. In 2013, active management of water Grum Pit was initiated through seasonal pumping of water from Grum Pit to Vangorda Pit. The Grum Pit was operated as an in situ biological treatment system (algal-based bioreactor) by adding nutrients over approximately 8 years. However, the treatment process was discontinued in 2012 due to limited effectiveness.

Slope failure within the glacial till materials overlying the rock of the Grum Pit East wall occurred during a temporary shutdown in 1997/98. The slope failure has since increased in size and has potential to affect the GID and electrical substation. Continuing displacement is occurring within the instability zone, but the rate and the magnitude of these displacements are unknown. There is a risk that the blocks of soil hanging at the top of the slope could break free at any time (Appendix 6C). In addition, the North wall of the Grum Pit is a till slope that is gradually sliding into the pit.

6.1.3.5 Vangorda and Grum Waste Dumps

Figure 6-2 shows the three waste dumps in the Vangorda/Grum area: the Vangorda Dump, the Grum Waste Dump, and the Grum Overburden Dump. There are a number of much smaller waste deposits in the area, such as above the Vangorda Pit ramp and on the Ore Transfer Pad northwest of the Grum Pit. Depending on the sub-catchment location, seepage from the waste dump may flow to the Grum Pit, the Vangorda Pit, Vangorda Creek, or West Fork Vangorda Creek.

The Vangorda Waste Dump was constructed on a topographic high point south of the Vangorda Pit. It contains about 16 million tonnes of material and covers about 40 hectares. Despite more rigorous segregation practices followed when the Vangorda Pit was mined, the waste dumps associated with the Vangorda Pit generally contain sulphide-rich waste rock with little neutralization potential available to buffer acid generation processes. Waste rock generated from the Vangorda Pit area contains some of the greatest percentages of sulphide at the FMC (SRK, 2006b). As a result, water draining from its waste dump can be poor quality (SRK, 2010b). The contaminant load from the Vangorda Waste Dump is expected to continue increasing over the next few decades, and water will require treatment for several centuries.

The Grum Waste Dump contains about 28 million tonnes of waste that covers about 128 hectares. The south-central portion of the Grum Waste Dump contains sulphide-dominant waste rock in an area called the GSC, and has some of the greatest potential at the FMC for generating acid and leaching metals. To minimize downgradient impacts, the GSC was strategically placed during active mining, and in 2010 it was capped with a low-permeability cover (60-mil single-sided textured HDPE liner covered with 1 m of till [Rainey et al, 2013]). Although the GSC contains strong acid-generating material, the remainder of the Grum Waste Dump contains only pockets of acidic material. Seepage water quality downgradient of the Grum Waste Dump has begun to deteriorate. Groundwater contamination downgradient of the Grum Waste Dump is expected to increase in the future (Appendix 6A).

The Grum Overburden Dump is southeast of the Grum Pit. It covers about 46 hectares and contains overburden and till that was stripped from the surface of the Grum deposit.

6.1.3.6 Water Treatment Plant

The Vangorda WTP, located north of the Grum Pit, was constructed in 1990 as part of the initial development of the Vangorda/Grum Mine Area. Annually, during the open water season, water is pumped from Vangorda Pit to the Vangorda WTP for treatment. The Vangorda WTP is a conventional lime treatment system with discharge to a sludge disposal pond. Compliant effluent is discharged from sludge pond into the GID and from the GID into Vangorda Creek at V25BSP via the SPPs. Prior to 2013, sludge from the Vangorda WTP Sludge Pond was removed from the sludge pond by suction truck or by excavation, when partially frozen, and deposited in an interim sludge disposal facility located on the Grum Overburden Dump. In 2013 the sludge was hydraulically dredged and piped

into Vangorda Pit. Starting in the 2014 treatment season, the sludge will be dredged from the pond and discharged into the southern end of the Grum Pit.

6.1.4 Site-wide Conditions

6.1.4.1 Geochemical Characterization of Waste Materials

The Geochemical Characterization Report, (Appendix 6A), presents the geochemical conditions at the FMC in detail. The report provides cumulative results of historical and recent field characterization programs and describes geochemical processes with the potential to impact water quality at the FMC during the IW. Characterization results not otherwise cited in the following section are sourced from the Geochemical Characterization Report (Appendix 6A). All other source information and data is cited appropriately.

The following section provides a broad summary of the results of analyses, and highlights sources of contaminant-loads requiring management throughout the proposed IW period. It also includes general information about predicted water quality effects on receiving subcatchment zones in the FMC.

There are three main contaminant-load contributors at the FMC:

1. **Waste Rock Dumps (including the backfilled Zone II Pit)**

- The main source of contaminants in the FMC is sulphide-containing waste rock stored in several waste dumps. Oxidation and leaching of the mineralized waste rock results from precipitation, which migrates through relatively coarse waste rock material. The resulting contaminated seepage water either infiltrates through the less permeable underlying native soil to groundwater or flows to the toe of the waste dump, where it can impact surface water directly. The infiltration of precipitation through waste dumps has led to the contamination of certain groundwater aquifers, and is causing increasing contaminant levels in some surface waters. Groundwater contamination is expected to increase significantly in the future. This contamination will impact surface water quality if the waste dumps and seepage are not adequately managed.

2. **Faro Pit, Grum Pit, and Vangorda Pit (including discrete inputs into the pits [i.e. pit walls, surface runoff])**

- A secondary source of contaminant load is confined to the lake waters of the three open pits. Each pit lake has unique geochemical properties. Predicting future water quality conditions in each of the pits is an ongoing process.
- The main controlling factors in the Faro Pit water chemistry is seepage through pit walls, the FCD and Faro Waste Dumps, and water pumped from the S-wells SIS, ETA SIS, the Zone II Pit, and the ID Pond. The Faro Pit also contains tailings received from the Mill. Tailings are not expected to become acid-generating or a significant source of metals, because subaqueous disposal limits contact with oxygen.
- The Vangorda Pit chemistry is driven by seepage and runoff water from within its catchment and water pumped from the Grum Pit, the LCD Pond and the V15 and Grum Creek Pumping System.
- The Grum Pit future chemistry will be mainly controlled by sulphidic pit wall oxidation and the composition of the influent seep chemistry.
- Additional remedial system waters that may be pumped to the pits in the future, would further impact the lakes' water quality (SRK, 2010b).
- Disposal of WTP sludge into Grum Pit will begin in 2014. The sludge will have a higher pH than the pit water. Metal leaching from the sludge is not expected to be significant. Any leaching that may occur would be treated along with the Vangorda and Grum Pit water in the WTP.

3. **Tailings (RCTA)**

- Approximately 55 million tonnes of tailings generated from ore processing at the mill were deposited in the RCTA. The rate of oxidation within the tailings was evaluated testing samples from the RCTA. The results showed an oxidation front moving through the tailings deposits over time (RGC, 2012). As this oxidation front migrates through the largely sulphidic tailings material, acidity and high concentrations of metals will be

released to the pore water. Over time, the pore water will be displaced by precipitation infiltration, driving impacted water into the underlying RCAA.

- Once the tailings-impacted water reaches the RCAA, it reacts with the alluvial aquifer sediments and attenuation occurs. The alluvial material's attenuation results in a delayed, sequential release of contaminants. Sulphate, which is largely unattenuated, is the first contaminant to migrate from the RCTA source area. Zinc, iron, and other metals are retained through changes in pH that cause precipitation, coprecipitation, and adsorption. As the aquifer material's attenuation capacity declines, either by metals occupying adsorption sites or through decreased pH (which can result in metal desorption), metals (e.g., zinc) are transported downstream of the RCTA, arriving later than the sulphate front.
- Recently, elevated sulphate has been observed in groundwater at the downstream end of the RCTA, at the toe of the CVD. However, trace metals such as zinc, lead, and cadmium are being actively attenuated by existing and newly precipitated oxyhydroxides and by organic material, maintaining concentrations well-below levels of concern in the downgradient portion of the RCTA.

Concentrations of sulphate and zinc were used to assess relative levels of contamination at the FMC. Sulphate is a good indicator of acid rock drainage and zinc represents the metal leaching potential of other trace metals released during the drainage. The relative levels of contamination are categorized according to the concentrations listed below for use in illustrating figures and differentiating areas of impact within the text.

- Not impacted or minimally impacted: sulphate less than or equal to (≤) 40 mg/L and zinc ≤ 0.05 mg/L.
- Slightly impacted: sulphate greater than (>) 40 mg/L and ≤400 mg/L, or zinc > 0.05 mg/L and ≤ 0.5 mg/L.
- Moderately impacted: sulphate > 400 mg/L and ≤ 4,000 mg/L, or zinc >0.5 mg/L and ≤5 mg/L. This corresponds to sulphate and zinc concentrations one order of magnitude greater than the "slightly impacted" range.
- Highly impacted: sulphate >4,000 mg/L or zinc >5 mg/L. This corresponds to sulphate and zinc concentrations one order of magnitude greater than the "moderately impacted" range.

Faro Mine Area Constituent Loading

Depending on the subcatchment location of a waste dump, seepage from the waste dumps near the Faro Pit may flow to the Faro Pit, Zone II Pit, NFRC, Faro Creek Canyon, Upper Guardhouse Creek, Lower Guardhouse Creek, RCAA, RCTA or Rose Creek.

Constituent Loading to the Faro Pit

The following sources contribute influent waters that affect water quality in the Faro Pit:

- Seepage from the Faro Valley Waste Dump (Faro Valley North [FVN] and Faro Valley South [FVS])
- The Northeast Faro WRDs (Upper Northeast [NEU], Lower Northeast [NEL], East Sulphide Cell [NELS], and Outer Northeast [NEO])
- Pumping from the Zone II Pit (X26)
- Pumping from the S-wells area
- Pumping from the ID Pond and ETA

Faro Pit lake water quality can be described as buffered acid rock drainage. It has a neutral pH and is highly impacted based on concentrations of zinc. Dissolved sulphate concentrations have been consistent in recent years, and zinc concentrations have been increasing over time (Appendix 6A). As the alkalinity is consumed, the acidity will rise, resulting in an increase in acid-mine drainage products.

Seepage flowing through the Faro Valley Waste Dumps (FVN and FVS) enters the Faro Pit through the north pit wall. Flow through the area of the dumps is high, and the high flux of oxygenated water may be causing relatively acidic conditions in this area, relative to other seepage areas. The seepage water is highly impacted with a low pH

and moderate concentrations of sulphate (545 mg/L) and high concentrations of zinc (47.3 mg/L). The observed general decrease in alkalinity over time and increased sulphate concentrations indicate much of the available NP in this area has been consumed. The data also indicate a net acid generation effect on seepage from the monitoring location on the north pit wall (A30) reporting to the Faro Pit lake.

Seepage from the Northeast WRDs flows either to the Faro Pit or to the NFRC along a pre-mine surface drainage divide. The most highly impacted waters are generally downgradient from the NELS, located towards the centre of the Northeast WRD. Two main flows from the Northeast WRDs report to the Faro Pit lake. The first flow originates west of and topographically lower than the NELS, and is characterized as highly impacted water with high concentrations of iron (10.8 mg/L), zinc (40 mg/L), and sulphate (1,060 mg/L). The second flow is a moderately impacted, higher volume flow that follows a pre-mine drainage just north of the former Zone II Pit. Geochemical characterization of the Northeast WRDs' waste rock materials indicates substantial potential for long-term acid generation.

In general, very little seepage flows from the south and west pit walls into the Faro Pit. The only other main inputs into the Faro Pit are from groundwater pumped from the Zone II Pit and the S-wells SIS area. Groundwater from the Zone II Pit is highly impacted, with high sulphate (3,320 mg/L) and zinc concentrations greater than 20 mg/L. Seepage water collected by the S-wells SIS is highly impacted and the S-Wells area is expected to be a large contributor to increased contaminant loads through time with sulphate and zinc concentrations greater than 5,000 mg/L and 300 mg/L, respectively, in water quality observed in SRK08-SPW3. Alkalinity in SRK08-SPW3 has decreased over time, from 587 mg/L to 401 mg/L, but has remained present to neutralize acidic drainage. The numerous contaminant sources that contribute to the S-Wells area are attributed to the pre-mine topography. The current conceptual site model (CSM) indicates pre-mining drainage patterns are focusing seepage water from the Intermediate and Main Dumps, towards the S-Wells SIS area and ETA, respectively (CH2M HILL, 2012e).

Although surface water quality downgradient of the S-Wells SIS improve, groundwater quality in the S-wells area downgradient of the SIS did not improve as expected with the installation of the SIS, with no notable change in groundwater quality (better or worse). Contaminant concentrations were neither shown to increase, nor to decrease, in groundwater downgradient of the S-wells SIS. Increased concentrations of sulphate and zinc in groundwater monitored by wells southeast of the S-wells SIS indicate the SIS may not be capturing a portion of the waste dump seepage.

The ETA is also a source of contamination to the Faro Pit. A seasonal pumping system located above Faro Creek Canyon captures 80 percent of contaminated surface water seepage and groundwater, and pumps this flow to the Faro Pit. Water quality is monitored at station X23, and is characterized as highly impacted. The most recent (September 2013) concentrations of sulphate (8,750 mg/L) and zinc (1,380 mg/L) were some of the largest concentrations measured at the FMC. Concentrations of iron at X23 were also indicative of highly impacted water, at 613 mg/L. As described above, this contaminant load is unique to the site in that the source of contaminants are both from waste rock surface water seepage and from groundwater contaminated by waste dumps in the ETA.

The ID Pond is part of the active water management program on site and functions as a reservoir for contaminated water held for pumping to the existing Faro WTP for treatment or, in 2013, to the Faro Pit for storage. The ID Pond receives flows not captured by the ETA SIS via Faro Creek Canyon, as well as Lower Guardhouse Creek, a catchment area adjacent to the Intermediate Impoundment.

Constituent Loading to North Fork Rose Creek

Seepage water that flows east from the Northeast WRDs and from the former Zone II Pit area (i.e. water that is not captured by the pumping well) contributes to the NFRC, upstream of the NFRD and is represented by the water quality measured at monitoring stations SRK- FD21, SRK-FD05, SRK-FD06, NE1, NE2, and NE3. Seepage from SRK-FD21 (located within the NEL waste dump) is highly impacted, with concentrations of sulphate and zinc at 3,200 mg/L and 36.7, respectively. Highly impacted seepage water has also been observed emanating from the west side of the Northeast Waste Dump at SRK-FD05. SRK-FD05 and SRK-FD06 represent a widespread perennial seep located near the base of the west face of the Northeast Waste Dump. Observed water quality at SRK-FD05

indicates seasonal fluctuations in concentrations of sulphate (692 mg/L [September 2012] to 904 mg/L [June 2013]) and zinc (5.9 mg/L [September 2012] to 8.3 mg/L [June 2013]), with greater concentrations observed in the spring than in the fall, and an overall trend of increasing concentrations through time (SRK, 2010).

Seepage water in the waste dumps adjacent to the Zone II Pit that is not captured by the Zone II pumping well continues along a flowpath toward the Zone II Outwash and is further influenced by waste dump seepage (RGC, 2012). Wells in this area indicate that highly impacted groundwater is flowing toward the NFRC with sulphate concentrations of approximately 3,000 mg/L and zinc concentrations greater than 100 mg/L.

Downstream from the Zone II Outwash, the NFRC flows southwest at the base of the Intermediate Dump, underneath the Haul Road through the NFRD, and past the S-Wells area. The S-wells area is characterized by highly impacted water that is collected and pumped to the Faro Pit. However, water not captured by the S-wells SIS continues down the flowpath toward NFRC and its confluence with the SFRC.

In the autumn of 2013, a new load source to the NFRC developed in the area of the NFRD, which resulted in zinc concentrations in the NFRC (NF2, X2) and at X14, above concentrations previously measured at these locations. Consistent with the current site AMP, a detailed monitoring program was implemented to delineate the source of this new load. Based on the results of that program, the source of the increased zinc loading to the NFRC is believed to be seepage from the Intermediate Sulphide Cell. The increased loading associated with this source is most likely due to breakthrough of a natural seep, possibly due to depletion of attenuation along the flow path, in a drainage channel beneath the NFRD (YG, 2013). As per the site AMP, a response plan has been developed and is currently being implemented to locate and intercept this source.

Constituent Loading to Faro Creek Canyon

Water quality at Station X23, which is the surface expression of groundwater flow along the pre-mine Faro Creek Canyon, is characterized as highly impacted mine water. Seepage water from X23 flows across the eastern edge of the ETA and into old Faro Creek Canyon, just south of the Haul Road. Drainage from the Mill area also contributes to flow across the ETA. Along these flowpaths, water interacts with the ETA tailings material before discharging into Faro Creek Canyon. The ETA SIS at the head of Faro Creek Canyon, just below the Access Road, is designed to seasonally capture the bulk of X23 and Mill area flows, as well as subsurface flows from the ETA, before the flow reaches Faro Creek Canyon, the ID Pond, and seeps into the RCAA. The intercepted flow is pumped to Faro Pit or directly to the treatment facilities. Flow not captured by the ETA sump (approximately 20 percent of the flow when operating in the summer, and 100 percent of the flow in the winter) flows through Faro Creek Canyon and continues down an unlined earthen ditch along the northern side of the Intermediate Impoundment, flowing out over the western end of the Intermediate Impoundment and into the ID Pond, or seeping into the RCAA.

The most recent (September 2013) concentrations of sulphate (8,750 mg/L) and zinc (1,380 mg/L) were some of the largest concentrations measured at X23. The highly impacted water quality at X23 is not unexpected as the pre-mine Faro Creek Canyon south of Faro Pit includes waste dumps with some of the highest metal and sulfide content in the Faro Mine Area, such as the Low-grade Stockpiles “A” and “C” (LGSPA, LGSPC), the Oxide Fines Stockpile (OXSP), Medium-grade Stockpile (MGSP), Stockpiles Base (SPB), Chrusher Stockpile (CHSP), and the Main Dump (MDE, MESC, MDW).

Constituent Loading between S-Wells and X23

The S-wells area and the X23 seepage area are hot spot seepage areas south of the Main and Intermediate Dumps. While there are no significant surface seepage locations between these two areas, one well (SRK08-P9) provides an indication of the groundwater conditions flowing from the Faro waste dumps towards the RCAA in this area. Samples collected in 2012 suggest this area is moderately impacted with sulphate (1,160 mg/L), but not impacted with zinc (0.01 mg/L).

Constituent Loading to Upper and Lower Guardhouse Creek

Upper Guardhouse Creek flows through mainly unimpacted terrain, yet collects several seeps originating from the Northwest WRDs. These seeps have maintained a slightly impacted status over the past 10 years, with sulphate

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concentrations generally less than 50 mg/L and zinc concentrations of about 0.1 mg/L. Increasing concentrations from these seeps indicate the possibility of future water quality impacts to Upper Guardhouse Creek.

Lower Guardhouse Creek collects mine-influenced seepage emanating from waste dumps, draining to the ID Pond. Concentrations of sulphate (3,020 mg/L) and zinc (87.7 mg/L) observed at SRK-FD01 are increasing and reflect highly impacted water.

Contaminant concentrations have been steadily increasing in Lower Guardhouse Creek, with seepage from the south toe of the Northwest Lower waste dump contributing 50 percent of Lower Guardhouse Creek flow. This seepage is highly impacted, with trends of decreasing alkalinity (from 386 mg/L [September 2002] to 151 mg/L [September 2013]) and increasing sulphate (from 3,810 mg/L [September 2002] to 6,300 mg/L [September 2013]) and zinc (from 51 mg/L [September 2002] to 257 mg/L [September 2013]).

Constituent Loading to Rose Creek Tailings Area, Rose Creek Alluvial Aquifer, and Cross Valley Dam

The RCTA generally receives clean groundwater from the south and southeast, and receives impacted waters from the Faro Mine Area to the north (Appendix 6G, Groundwater Baseline Report). Locally, tailings contribute to groundwater contamination in the RCTA. Contaminant loads may be mobilized by precipitation infiltrating through the tailings, or by discharge from the ETA migrating downward into the underlying RCAA (Appendix 6G). The unlined ditch that conveys ETA water not captured in the ETA sump may also be contributing a substantial source of contamination to the northern RCAA underlying the RCTA. This possibility is supported by increasing trends in sulphate (from about 1,000 mg/L [January 2006] to about 3,500 mg/L [June 2012]) and zinc (from about 0.1 mg/L [January 2006] to about 11 mg/L [June 2012]), observed in the RCAA underlying the Secondary Impoundment downgradient of the Faro Creek Canyon. The greatest concentrations of sulphate and metals of interest were observed in tailings porewater in the southeastern and northwestern sections of the Secondary Impoundment. Conversely, the lowest concentrations of contaminants occur in groundwater in the southwestern section of the Secondary Impoundment (Appendix 6G, Figure 6G-28) (RGC, 2012). In the RCAA area, downgradient from the Faro Creek Canyon and towards the ID Pond, observations over the past 10 to 12 years have noted a gradual increase in sulphate, followed by a lagging increase in zinc (RGC, 2012).

The southern portion of the RCAA is generally less impacted than the northern portion because of “clean” water leaking from the RCD. The exception is the southeastern corner of the RCTA, where oxidation appears to be more rapid in the Secondary Impoundment and seepage from the tailings appears to be impacting the RCAA. Significant increases in sulphate and zinc concentrations were observed in wells in the Secondary Impoundment: P03-03 (sulphate from about 1,000 mg/L to about 5,000 mg/L and zinc stable at about 0.01 mg/L in P03-03-06) and P03-05 (sulphate from about 400 mg/L to about 800 mg/L and zinc from about 0.01 mg/L to about 10 mg/L in P03-05-02) (RGC, 2012). Site operations personnel have observed iron stains in the ice covering the RCD during the low-flow winter months when groundwater input contributes the most flow. This suggests metal-rich groundwater from the RCTA is reaching the RCD during this time.

In addition to the impacts to the RCAA, groundwater in the underlying weathered bedrock downgradient of the CVD shows signs of impact by magnesium and sulphate, especially on the northern side of the valley (RCG, 2012). Metal plumes (i.e., zinc and iron) currently remain upgradient of the CVD (RGC, 2012). Zinc, lead, and cadmium concentrations in alluvial groundwater, downgradient of the Secondary Impoundment and beneath the ID and CVD, however, are being actively attenuated by adsorption to iron oxyhydroxides and carbonates and also to adsorption to organic matter near the CVD (CH2M HILL, 2013c).

Vangorda/Grum Area Constituent Loading

Depending on the subcatchment location of a particular waste dump in the Vangorda/Grum Area, seepage from waste dumps may flow to the Grum Pit, the Vangorda Pit, or Vangorda Creek.

Constituent Loading to Grum and Vangorda Pits

The Grum Pit receives water from surface runoff within the Grum Pit catchment, as well as groundwater inflow from the surrounding thalweg aquifer. Seepage water quality is characterized by alkaline pH, and is slightly impacted with sulphate concentrations and zinc. The Grum Pit lake’s water quality is characterized by alkaline pH

(7.84) and moderately impacted mine water, based on sulphate and zinc concentrations (435 mg/L and 3.14 mg/L, respectively) from June 2013.

The Vangorda Pit lake is largely the product of surface runoff within the pit catchment area and groundwater flow. The Vangorda Pit also receives constituent loading from pumped water from the Grum Pit, as well as water collected by the V15 and Grum Creek Pumping System, and LCP. The current water quality is characterized by a slightly acidic pH (6.24) and highly impacted mine water, based on concentrations of sulphate and zinc (857 mg/L and 52.5 mg/L, respectively) measured in June 2013. Concentrations of sulphate and zinc in the Vangorda Pit lake have been increasing steadily during the period of record (CH2M HILL, 2013b). Seasonal fluctuations were observed in the water quality of the Vangorda Pit lake, with decreased sulphate and zinc concentrations during freshet and increased concentrations during low-flow conditions (DES, 2012; CH2M HILL, 2013a).

Grum Waste Dump

The easternmost flank of the Grum Waste Dump was built over the former Grum Creek channel, whose drainage water flows toward two contiguous perennial seep locations (SRK-GD01 and SRK-GD02). These two seeps indicate moderately impacted water quality, based on sulphate (1,578 mg/L) and zinc (2.3 mg/L) concentrations.

Water quality at V15 showed moderately impacted water, based on zinc concentrations (4.1 mg/L) measured before the low-permeability cover was installed on the GSC; concentrations have somewhat stabilized (to observed 2010 concentrations) since the cover has been placed (DES, 2012).

Seepage water quality at the southern toe of the Grum waste dump, differs from other seepage water at the FMC because of its abundant algal growth and hard-white, crusty deposits. This seepage is characterized by neutral to alkaline pH and is moderately impacted with sulphate (2,330 mg/L) and zinc (2.95 mg/L).

Westward-flowing seepage from the western toe of the southwest Grum Waste Dump ultimately flows to West Fork Vangorda Creek drainage. This seepage indicates neutral to alkaline pH and moderately impacted drainage, based on concentrations of sulphate (1,140 mg/L) and zinc (0.23 mg/L).

Seepage from the Ore Transfer Pad, which is northwest of the Grum Pit, ultimately flows into the West Fork Vangorda Creek drainage via AEX Creek. Seepage water quality is characterized by neutral pH and minimally to moderately impacted drainage, based on concentrations of sulphate (522 mg/L) and zinc (0.45 mg/L) (Appendix 6A).

Vangorda Waste Dump

The Vangorda Waste Dump is composed of sulphide-rich waste rock. Four monitoring wells monitor seepage beneath the Vangorda Waste Dump drainage ditch (Appendix 6G). Water quality at these locations is characterized by high pH with slightly-to-moderately elevated dissolved sulphate and zinc concentrations (Appendix 6A). Observed increases in sulphate concentrations in all four wells suggest that some groundwater from the Vangorda Waste Dump is bypassing the seepage collection system (Appendix 6A and Appendix 6G).

Several transverse drains extend beneath the till berm surrounding the waste dump; these direct the seepage toward the perimeter collection ditch and LCD Pond. Water quality in the LCD Pond is highly impacted, based on sulphate and zinc concentrations. Water quality in the five transverse drains is also highly impacted, with low pH and elevated concentrations of sulphate and zinc. Values of pH in the transverse drains range from 2.71 to 5.84. Concentrations of sulphate and zinc range from 1,740 mg/L to 87,400 mg/L, and 0.73 mg/L to 87.3 mg/L respectively. These concentrations identify the till berm area around the waste dump as one of the most mine-affected areas of the FMC. Monitoring of the Vangorda transverse drains will continue to support future water collection and treatment options.

Currently, Vangorda Creek and its tributaries are monitored at nine monitoring stations. Water quality is characterized by pH ranging from neutral to alkaline, with minimal impacts to water quality. These characteristics suggest Vangorda Creek has experienced minimal impacts from mining activities to date. However, increasing concentrations of mine-related contamination and evidence of affected waters bypassing the seepage collection system indicate future impacts are possible (Appendix 6G and CH2M HILL, 2013e).

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6.1.4.2 Physical Stability of Dams

The major civil structures at the FMC are part of an ongoing program monitoring and evaluating physical stability. The results of these evaluations have recently been compiled in Appendix 6C, which describes the current conditions of the major civil structures at the FMC, and provides recommendations to for interim measures to reduce associated potential risks to human health and safety, and the environment during the IW period. The following sections provides a summary of this compilation. Due to the potential for detrimental consequences from the release of contaminated water and tailings to the receiving environment associated with dam failure, this section focuses on the stability assessment of the dams and hydraulic conveyance structures. Appendix 6C describes the physical stability of additional FMC major physical structures.

The following subsections summarize the main findings of this evaluation, focussing on the recommended design criteria for dams for the IW. Also summarized is a stability evaluation of major conveyance structures and dams under various hydraulic and seismic loading conditions.

Hazard Classification of Dams

Each dam at the FMC poses a different level of hazard; the RCTA dams are considered the most hazardous. Based on the potential incremental losses associated with environmental and cultural values, each of the dams at the FMC were assigned a hazard rating according to the CDA Dam Safety Guidelines (CDA, 2007). For reference, the CDA dam classification is provided in Table 6C-1 of Appendix 6C.

Intermediate Dam

The most severe consequences of a dam breach are associated with the ID, which contains more than 11.9 Mm^3 of tailings and water that are toxic to aquatic and terrestrial life. The total tailings volume in all three impoundments (Original, Secondary, and Intermediate) is 28.6 Mm^3 (RGC, 1996). Failure of the ID could result in a significant or major loss, or deterioration of critical fish or wildlife habitat downstream of the FMC within Rose Creek, Anvil Creek, and possibly extending to the Pelly River.

Currently it is estimated that the ID has a High risk classification, although this estimate was made in the absence of a formal dam breach and inundation study. A dam breach and inundation study for the ID and the CVD will be carried out in conjunction with the 2014 dam safety evaluation. These studies will assess downstream consequences of dam failure and may result in a modification of the hazard classifications for these facilities. Considering the CDA dam safety guidelines and noting that a large spill would likely make restoration or compensation impractical or impossible, it is likely that the hazard classification may change once these updated studies have been completed.

Cross Valley Dam

The CVD has the same hazard classification as the ID: High risk classification. The main hazards from a CVD breach include the uncontrolled release of water from the CVD Pond, as well as a sudden release of the polishing pond, which could cause significant danger to the ID. The ID does not have filter and drainage systems in the lower part of the embankment, below the downstream bench. It depends on the polishing pond to provide a counter balancing hydrostatic head to reduce seepage and the need for filtering. A sudden drawdown of the pond is likely to result in significant seepage from the saturated ID downstream slope. This could lead to progressive sloughing, even more seepage, possibly backward erosion, and could eventually result in piping or loss of the crest from larger slope stability failures.

Secondary Dam

A breach of the Secondary Dam could also lead to a loss of tailings into the environment, but the magnitude of such a tailings loss would be much smaller and more contained than the tailings loss associated with an ID breach. Whereas the ID and CVD need to accommodate hydraulic (flood) loading, as well as seismic loading, the Secondary Dam only needs to be designed for seismic loading. Seismic loading could cause liquefaction of the dam foundation, specifically where Rose Creek sediments occur. At the West Limb, which is the curved portion of the Secondary Dam that crosses the valley roughly north to south, there are intermediate tailings on the downstream toe of the Secondary Dam. These intermediate tailings would prevent the dam from failing during seismic loading,

even if the foundation soils liquefy. Even if some tailings are lost along this portion, the Intermediate Impoundment is likely to contain the tailings.

A breach of the East Limb of the Secondary Dam, which is parallel to the RCD and does not contain tailings at the toe, could result in tailings flowing into the RCD. Note, the upper layers of the secondary tailings are not saturated and the East Limb's crest is relatively low, at about 4.6 m. Given that a breach of the East Limb of the Secondary Dam could result in tailings loss into the RCD and from there into the areas downstream of the tailings areas, it can be conservatively assumed that the Secondary Dam has the same risk classification as the ID, which is High.

Little Creek Dam

The LCD is typically not operated at full supply level. Because it contains a small volume of potential water release, it is assigned a Low risk classification, based on the fact that (1) there would be relatively small economic loss, (2) there is limited infrastructure or services downstream, and (3) there would be loss of marginal habitat only or restoration or compensation in kind would be possible.

Stability Evaluation of Dams

The dam stability evaluation includes two components: (1) the adequacy of the associated conveyance structures (such as spillways and diversions) to pass the inflow design flood (IDF) and (2) the structural stability of the dams under normal, flood loading, and earthquake loading conditions.

Structural Stability of Dams under Hydraulic Loading Conditions

The general approach to assess whether the existing dams could withstand the design hydraulic loads for each conveyance structure during the IW included the following steps:

1. Assemble the 1-in-500-year IDF estimates for each conveyance structure based on routing scenarios and area-based hydrologic estimates.
2. Compare the existing capacity of the specific conveyance structure with the IDF. The existing capacity is determined by hydraulic modelling and the development of rating curves for the structures.
3. Identify required modifications to address insufficient conveyance capacity.

The following sections describe the capacity of conveyance structures and indicate proposals for interim modifications.

<u>North Fork Rock Drain</u>

Based on review of the design and construction records, uncertainty exists pertaining to the flow-through capacity of the rock drain and its hydraulic capacity during extreme storm events. Flood routing of a 500-year storm event indicates that, assuming low flow-through capacity and some debris accumulation, a significant flood pool may form against the Haul Road embankment and NFRD, possibly destabilizing the haul road (Appendix 5I). In such a case, the performance of the rock drain and the embankment, and their stability under these conditions, is uncertain. Concerns exist with respect to piping of materials, internal erosion, and destabilizing resulting in erosion of the downstream face of the embankment.

<u>Rose Creek Diversion</u>

Hydraulic modelling results predict the existing configuration of the RCD does not provide adequate capacity to convey the 1-in-50-year flood flow of 71 m^3/sec before overtopping the overflow structure. Design criteria dictate that the RCD maintain 0.5 m freeboard at the 500-year flow. As such, the crest of the RCD dike must be raised to meet freeboard criteria. In addition to raising the crest of the RCD dike, vegetation needs to be removed from the dike and rip rap, and slope sloughing needs to be repaired at some locations. These activities are proposed as the DVIHU component of the IW.

<u>Overflow Weir in Rose Creek Diversion Dike</u>

To prevent flows in excess of the 500-year event from damaging the RCD downstream of the overflow weir, the elevation of the overflow weir must be raised to 1,057.82 masl, which corresponds with the predicted water

surface elevation to convey the 500-year flow (elevation 1,058.0 m) plus a 200-mm thick layer of native sand and gravel covering the crest to provide a road surface (i.e. the structure will have a freeboard of 0.2 m).

Intermediate Dam Spillway

The existing ID spillway does not have the capacity to safely pass a moderate or major flood event without overtopping and potentially failing the dam and releasing tailings to the downstream environment.

Planned improvements of the ID spillway capacity are part of the DVIHU.

The ID is a secondary flood-routing facility; therefore, there is a considerable chance that it will not experience flow during the IW. As a result, the Interim Hydraulic Upgrades design for the ID does not focus on permanent capacity. Permanent capacity will be designed into the FMRP.

Cross Valley Dam Spillway

According to NHC (2006b), the CVD spillway has a capacity of 300 m^3/sec, which is sufficient to convey the IDF.

Structural Stability of the Dams Under Seismic Loading Conditions

Numerous studies have been undertaken by different firms over the last 10 years to assess the stability of the dams. These included seismic stability assessments by Golder (2004) and Klohn Crippen Consultants (later Klohn Crippen Berger) for the tailings dams and the CVD; other studies (NHC, 2006b, etc.) were performed to assess the flood vulnerability of the ID and CVD. The results of these studies formed the basis for evaluating the embankment slope stability under static and seismic loading conditions, for the interim period.

Intermediate Dam

Extensive seismic stability assessments were performed to determine the liquefaction potential in the ID foundations and to evaluate seismic slope stability (KCB, 2006a; KCB, 2006b). Results showed that the terrace or glaciofluvial deposits that form most of the uppermost foundation soils of the ID (Appendix 6C, Figure 6C-23), the northern foundation of the West Limb of the Secondary Dam, and most of the foundation of the East Limb of the Secondary Dam, are not liquefiable.

However, it was found that the recently deposited Rose Creek sediments were generally liquefiable under MCE loading (for example, beneath the West Limb of the Secondary Dam and the southeast corner of the East Limb). The only exception was beneath the maximum section of the ID, where the recent Rose Creek alluvial sediments were found to be not liquefiable.

Since the design earthquake for the interim period has a recurrence interval of 1-in-500 years, with ground motions much smaller than the MCE motions (1-in-10,000-year motions), the ID should be stable for this level of shaking, and permanent seismic displacements should be small.

Cross Valley Dam

KCB (2007) performed seismic stability analyses of the dam for the 1-in-500-year earthquake. Ground motions from the Atkinson (2004) study were used for those analyses. The results of the analyses showed that the foundation soils do not liquefy under the 1-in-500-year motions, and that the dam would be able to withstand the 1-in-500-year earthquake. KCB (2007) noted that there will still be seismic deformations of the dam during an earthquake event of this magnitude. Such movements will be permanent but should be small and will not lead to the release of the reservoir, provided the freeboard is more than 1.5 m.

The analyses performed in 2007 (KCB, 2007) used the ground motions from the Atkinson (2004) study, which are significantly higher than the ground motions of the recent updates to the seismic hazard assessment (Atkinson and Assatourians, 2013). It is therefore concluded that the CVD is stable under the design seismic loading for the interim period.

Secondary Dam

Analysis results showed no liquefaction in the foundation soils (including the recent Rose Creek sediments) for a 500-year seismic event. Results also showed that the dam will be stable with factors of safety of 1.5 or greater

under all considered load cases, including static, pseudo-static and post-seismic loading. It is anticipated that small deformations will occur and such deformations would be tolerable; the dam will not breach and no tailings would be released.

Little Creek Dam

Based on the observations from periodic dam safety reviews and the annual dam safety inspections, the LCD appears to be stable.

In summary, most of the major existing facilities meet the design criteria for physical and hydraulic stability during the IW. However, some of the existing flood conveyance structures are undersized and inadequate to convey the IDF for the interim period (500-year return period flood event). The current flood routing capacities for the ID spillway and the RCD should be improved so that they can safely convey the inflow design floods. Planned improvements for the ID spillway capacity and RCD are part of the DVIHU.

6.2 Environmental Conditions

This section describes the environmental conditions of the FMC and assessment study areas, including the physiography, geology and soils, atmospheric environment, water resources, aquatic ecosystems, terrestrial resources and heritage resources. Details are documented in the following appendices:

- Appendix 6D Climate Baseline Report
- Appendix 6E Air Quality Baseline Report
- Appendix 6F Hydrology Baseline Report
- Appendix 6G Groundwater Baseline Report
- Appendix 6H Aquatic Baseline Characterization Report
- Appendix 6I Vegetation and Soil Baseline Report
- Appendix 6J Wildlife and Wildlife Habitat Baseline Report
- Appendix 6K Heritage Resource Impact Assessment

6.2.1 General Physiography

The FMC is located in the Yukon Plateau-North Ecoregion in the Boreal Cordillera Ecozone. The Yukon Plateau-North Ecoregion is the largest ecoregion located entirely in the Yukon Territory (YT) and it encompasses the Stewart Plateau, the Macmillan Highlands, and the Ross Lowlands (Smith et al., 2004). This ecoregion was once entirely glaciated by the Cordilleran Ice Sheet, as well as local glaciers from the South Ogilvie Mountains and cirque glaciers from other peaks in the ecoregion. This intense glaciation has resulted in rolling highlands, till-covered plateaus, thermokarst lakes, and discontinuous permafrost.

The FMC is located on the Vangorda Plateau, a northwest-to-southeast-oriented rolling upland located between 1,000 and 1,400 masl, and is surrounded by the Anvil Range to the north and east, and Rose Mountains to the south. The Anvil Range rises to a series of peaks over 2,000 masl, including Mount Mye (east of the Vangorda/Grum area) and Mount Aho (north of the Faro Mine area). Faro Peak and Sheep Mountain are two key features occurring to the south of the FMC. Generally, the FMC area is typical of a mountainous region that has been influenced by multiple past glaciations, consisting of broad U-shaped valleys, rounded hills, rough mountain peaks, as well as deposits of glacial till and glaciofluvial materials.

The Vangorda Plateau parallels the Tintina Trench, which is a regionally dominant feature of the Tintina Fault that lies just south of the FMC. This ancient fault contains deposits from at least seven Pleistocene glaciations and numerous wetlands and sloughs (Smith et al., 2004). The Tintina Trench, in the vicinity of the FMC, lies at approximately 600 masl.

Two local watersheds encompass the FMC: Rose Creek and Vangorda Creek, both of which form part of the Pelly River drainage. The Pelly River is regionally dominant and flows northwesterly within the Tintina Trench. The Pelly River is a major tributary to the Yukon River and drains more than 49,000 km^2 of land.

The Rose Creek watershed encompasses the Faro Mine Area portion of the FMC and drains west to the Pelly River via Anvil Creek. Rose Creek is fed by two tributary forks that join within the FMC: the NFRC and the SFRC. The NFRC drains south from the Anvil Range and is partially fed by Faro Creek and other small tributaries. The SFRC originates further east and drains northwest along the Vangorda Plateau, joining the NFRC just east of the RCTA. From 1969 to 2003, the Freshwater Supply Dam held back the flow of the SFRC, retaining water for mine operations. That dam was removed in 2003, and the SFRC again flows in its original channel. Downstream from the confluence of the NFRC and SFRC, the main stem of Rose Creek was diverted around the tailings impoundment in 1974. The subsequent expansion of tailings facilities in 1982 required a further extension of the Rose Creek Diversion. Rose Creek still flows via the Rose Creek Diversion to beyond the RCTA, where it rejoins its original channel just northwest of the CVD. Rose Creek flows into Anvil Creek approximately 13 km northwest of the FMC; Anvil Creek then flows into the Pelly River, approximately 33 kilometres west of the Faro Mine Area.

The Vangorda Creek watershed encompasses the Vangorda/Grum Area of the FMC, with a total drainage area of approximately 90 km^2. Vangorda Creek is fed by Grum Creek and several smaller tributaries within the FMC, and drains to the Pelly River to the southwest, near the Town of Faro.

The Pelly River, Anvil Creek, Rose Creek, and the lower reaches of Vangorda Creek all provide fish habitat. Species recorded in these watercourses include Arctic grayling (*Thymallus arcticus*), slimy sculpin (*Cottus cognatus*) and Chinook salmon (*Oncorhynchus tshawytscha*). Anvil Creek, Rose Creek and lower Vangorda Creek provide habitat for juvenile Chinook salmon, as well as some occurrences of spawning adults. The NFRC and SFRC provide a variety of spawning, rearing, and overwintering habitat for slimy sculpin and Arctic grayling.

Vegetation in the FMC area is typical of the boreal and subalpine zones of the encompassing ecoregion. Vegetation in the boreal zone largely consists of forest and wetland associations, most of which are linked to morainal and glacio-fluvial terrain and are influenced by fire. The dominant forest type in moist and cool aspects is typically black spruce (*Picea mariana*) with moss dominating in moist understories, which is often associated with permafrost soils, and lichens dominating in drier areas. Drier slopes and warmer aspects frequently are dominated by white spruce (*Picea glauca*) with occasional stands of trembling aspen (*Populus tremuloides*), and less frequently lodgepole pine (*Pinus contorta*). Vegetation in the subalpine zone is largely dominated by tall shrub vegetation, with some scattered open spruce and fir forests. Dwarf birch (*Betula nana*) and scattered white spruce and subalpine fir (*Abies lasiocarpa*) dominate the overstory, with lichens occurring in drier sites and mosses and graminoids in wetter areas. In the wetlands, bogs, and lakes, various willows, sedges, and aquatic plants are typical with riparian areas being comprised of black spruce.

The FMC supports many of the typical boreal forest wildlife species, including a wide variety of resident and migratory birds, moose (*Alces alces*), woodland caribou (*Rangifer tarandus caribou*), grizzly bear (*Ursus arctos*), and Fannin sheep (*Ovis fannini*). The Tintina Trench is an important migratory corridor for large numbers of sandhill cranes (*Grus canadensis*) and waterfowl that breed on the North Slope of the YT and the northern tundra. Many of the wetlands, lakes, and ponds in and around the FMC are valuable breeding and staging areas for a variety of waterfowl, including American wigeons (*Anas americana*), surf scoters (*Melanitta perspicillata*), and horned grebes (*Podiceps auritus*), as well as several species of mergansers.

6.2.2 Geology and Soils

Introduction and Study Areas

The following sub-sections describe bedrock geology, surficial geology, terrain and soils of the FMC. These descriptions are based on information obtained from previous CH2M HILL studies, geological and geochemical data gathered during the CH2M HILL field programs of 2012 and 2013, published technical papers, and documents prepared by others, including SRK and RGC. Further information is also available in Appendix 6G, Groundwater Baseline Report, which provides a description of the geologic setting, and in Appendix 6I, Vegetation and Soils Baseline Report, which provides details on the soil conditions at the FMC.

The local study area (LSA) is illustrated on Figure 6I-1 (Appendix 6I) and is defined as the area encompassing all FMC facilities, infrastructure, and road corridors, with the addition of a 1- km buffer. The resulting LSA area is 8,122 hectares.

A regional study area (RSA) was established within which to describe more broad geographic features of surficial geology, bedrock geology, and terrain features. The RSA is shown on Figure 6I-2 (Appendix 6I) and includes geological units of the YT interior that are separated by the northwest trending, right-lateral Tintina Fault Zone, with distinct geological properties: a relatively homogeneous region to the northeast composed of a thick, older sequence of sedimentary rocks (miogeocline), and a more heterogeneous region to the southwest comprising several younger, litho-tectonic terranes of varying rock types that amalgamated and accreted to the stable sedimentary package. In addition, the northern component of the RSA includes portions of the Anvil plutonic suite, which forms the core of the Anvil Arch, a structural high within the RSA.

6.2.2.1 Bedrock Geology

Regional Bedrock Geology

The FMC is located within the Anvil District, between the Rose Mountains and the Anvil Range. The Anvil District contains the westerly exposures of the Selwyn Basin, a large area of central Yukon in which deep-water clastic rocks, chert, and minor carbonate accumulated along the ancient North American continental margin (convergent plate boundary between the oceanic Pacific Plate and the continental North American Plate) during the Neoproterozoic and early Paleozoic eras (miogeocline) (Lowe et al., 1994; Wheeler et al., 1991). Locally, the Anvil District consists of a structurally thickened sequence of late-Precambrian to upper Paleozoic poly-formed, poly-metamorphosed, meta-sedimentary, and meta-volcanic schists and phyllites (Jennings and Jilson, 1986) of the miogeoclinal assemblage.

The northwest trending, right-lateral Tintina Fault Zone separates the older relatively homogeneous miogeoclinal geology of the Selwyn Basin from several younger, litho-tectonic terranes of varying rock types (locally the Slide Mountain and Yukon-Tanana Terranes). These younger, heterogonous, litho-tectonic terranes likely once formed a Paleozoic-to-early-Mesozoic fringe to North America before accretion to the stable continent (Colpron et al., 2007). Regionally, the Tintina Fault Zone is mapped for over 1,000 km, trending northwest from Watson Lake at the Yukon/British Columbia border to its termination into a series of splay faults in the Yukon Flats area of Alaska (Snyder et al., 2005).

During the Cretaceous Era, the southwestern portion of the miogeoclinal Selwyn Basin meta-sediments of the region were intruded by two large intrusive suites: the Anvil and Tay plutonic suites. The Anvil plutonic suite (104 to 109 million years ago [Ma]) are the oldest recognized granitic intrusive rocks in the Anvil District and consist of biotite±muscovite granite of sedimentary protolith-derived geochemical affinity. The Anvil plutonic suite forms the Anvil Batholith that cores the northwest-trending Anvil Arch (Pigage, 2004). The Anvil plutonic suite is cross-cut by the Tay River plutonic suite (97 Ma), consisting of intrusives of biotite-hornblende granodiorite to granite composition (Pigage, 2004). The igneous protolith-derived Tay Suite forms the large Orchay Batholith at the southeast margin of the District and numerous dikes and sills throughout the District. The plutonic suite's geochemical signature and age indicate it is the subvolcanic equivalent of the South Fork volcanics that outcrop immediately to the northeast.

There are 108 mineral occurrences listed in Yukon Minfile (a database of mineral occurrences in the Yukon) for the 1:250,000 NTS Mapsheet Index 105K (Tay River) map area (as listed by the YGS Online Map Viewer on November 15, 2013), which encompasses the FMC. The majority of the occurrences are strataform lead-zinc showings and deposits that occur in Selwyn Basin sedimentary rocks. Most of these occurrences are found within a broad belt, parallel and adjacent to the Tintina Fault Zone. The dominant deposits are the significant zinc-lead-silver-barite pyritic sulphide sedimentary-exhalative-type deposits of the Anvil Range (Jennings and Jilson, 1986; Pigage, 1990), of which the FMC deposits are a component.

Local Bedrock Geology

Locally, the Mount Mye and Vangorda formations represent the lower part of the late Proterozoic and early Paleozoic sequence and are the most important with respect to the FMC site geology as the mineral deposits of the FMC occur on or near the geological contact between these formations. The Cambrian-aged Mount Mye formation is the oldest unit exposed in Anvil District (Jennings and Jilson, 1986). It is extensively exposed on the lower slopes of both the north and south sides of Mount Mye. Cross sections on the north side of Mount Mye

indicate a minimum present-day thickness of approximately 2,000 m (Pigage, 2004). Typical Mount Mye formation is a medium to dark grey, noncalcareous, moderately soft to soft, fine-grained, micaceous phyllite; close in composition to an average shale. Interbands of marble, calc-silicate rock, and chloritic phyllite or hornblende amphibolite occur in lesser amounts.

The Cambrian- and Ordovician-aged Vangorda formation is a widespread unit in the Anvil District that overlies the Mount Mye Formation. It is characterized as a pale silvery grey, calcareous, recessive phyllite (Jennings and Jilson, 1986). Lesser interbedded rock types include limestone/marble, carbonaceous phyllite/schist, dolomitic siltstone, and chloritic phyllite/amphibolite. At higher metamorphic grade, the Vangorda formation consists of thinly banded, resistant, pale cream and dark brown calc-silicate rock. The unit is exposed both north and south of intrusions that make up the Anvil Batholith. Thickness estimates for the Vangorda formation from cross sections range from 700 to 2,200 m. Jennings and Jilson (1986) suggested an average thickness of 1,000 m.

The Ordovician-aged Menzie Creek formation is present as a thick, resistant, grey-weathering, basaltic volcanic unit that conformably overlies the Vangorda formation (Jennings and Jilson, 1986). Massive and pillowed, locally amygdaloidal flows are interbedded with volcaniclastic rocks, which consist dominantly of monolithic basalt breccia with lesser conglomerate, sandstone, and siltstone. South of the Anvil Batholith, the Menzie Creek formation consists of a medium green, pervasively foliated, noncalcareous to slightly calcareous chloritic phyllite (Pigage, 2004). The phyllite commonly contains pale tan to white calcite amygdules.

Overlying the Menzie Creek formation is the Duo Lake Formation. It is present onsite as a black, carbonaceous, silty argillite with lesser siltstone, sandstone, and limestone. It is documented as generally poorly exposed, but with significant continuity along strike (Pigage, 2004).

A higher degree of metamorphism is generally observed in the local miogeoclinal lithology with proximity to the Anvil Batholith contact. The strata of the metamorphic sequence dip northeast and southwest, away from the Anvil Batholith. The degree of metamorphism within sedimentary and volcanic strata range from moderate (schist) to low (phyllite).

Locally, the zinc-lead-silver deposits of the FMC occur as stratiform horizons within a 150-m stratigraphic interval that straddles the geological contact between the Vangorda and Mount Mye formations. The Faro deposit is in the phyllite and schists of the Mount Mye formation. Numerous local structural faults intersect this ore body.

The Grum and Vangorda Mine deposits are predominantly hosted in the Vangorda Formation, which consists predominantly of calcareous phyllite and calc-silicate rocks banded with meta-igneous greenstone and chloritic phyllite, carbonaceous phyllite, and minor limestone (AECOM, 2009). The Grum deposit intersects the Mount Mye Formation at its base.

6.2.2.2 Surficial Geology and Soils

Regional Surficial Geology

The FMC is located within the Yukon Plateau physiographic subdivision, bound by the Pelly Mountains and Tintina Fault to the southwest, and the Tay River to the north. The local physiography is dominated by the northwest trending Tintina Fault Zone, which coincides with a linear valley known as the Tintina Trench. The surficial geology of the area is controlled by three physiographic features: the Anvil Arch, the intermediate upland surface of the interconnected valleys known as the Vangorda Plateau, and the Tintina Trench (Bond, 2001).

As many as six glaciations during the Pleistocene are recorded in the stratigraphy of Tintina Trench near Dawson City (Bond, 2004). The last glaciation to affect central Yukon is the late Wisconsinan McConnell Glaciation, which began sometime after approximately 25 to 15 thousand years ago (Bond, 2001). The Anvil District is overlain by sediments originating from this glacial period.

Ice flow through the district was controlled by topography, except in areas of low relief. Glacial ice advanced into the Tintina Trench and followed the topographic lineament northwest into central Yukon. Ice flow was largely from east to west, becoming more northwesterly upon intersecting the Vangorda Plateau. With the exception of a few unglaciated summits (nunataks), the entire area was covered by the Selwyn Lobe of the Cordilleran ice sheet (Jackson, 1986). The relatively rapid ice flow through areas adjacent to the Tintina Trench resulted in extensive

glacial erosion and later deposition upon deglaciation. Till deposits on the Vangorda Plateau and in the Swim Basin to the southeast range in thickness from less than 1 m to 200 m.

Much of the Vangorda Plateau is underlain by a thin veneer (less than 1 m thick) of colluvium and soil over bedrock; however, portions of the plateau are underlain by discontinuous deposits of glacial till and glacio-fluvial deposits. Important exceptions are a buried valley filled with up to 100 m of overburden over the subcrop of the Grum deposit and a ridge of highly compacted till up to 40 m thick overlying the Vangorda deposit (RGC, 1996). Thick till and fluvial deposits also occur in the Rose Creek, the west fork of Vangorda Creek, and in the Blind Creek valleys.

Upland areas are generally covered by colluvium with exposed rock and felsenmeer (where the top layer of rock outcrop that has been broken up by freeze-thaw action) above approximately 1,770 m above sea level (masl). These areas include Mount Aho, Mount Mye, and Rose Mountain. Rock outcrop and felsenmeers also exist at lower elevations on these mountains on north- and west-facing slopes, where nivation processes are common. In the alpine valleys of Mount Mye, till sediments are derived from local ice sources and the Cordilleran ice sheet.

Local Surficial Geology

Typical native soils at the FMC consist of thin discontinuous deposits of glacial till and glacio-fluvial deposits overlying phyllitic bedrock. Local surficial geology is described below, according to FMC area.

Faro Mine Area

The Faro Mine Area includes the Faro Pit, NFRC, Zone II Pit, S-Wells, the ETA and extensive waste dumps. Before the Faro Pit was developed, the area comprised a veneer of glacial till and glacio-fluvial deposits, intermixed with slope-derived colluviums. The Faro Creek Valley and the former Faro Creek Channel contain thicker colluviums and fluvial deposits. The NFRC (including Zone II Outwash and S-Wells) consists of alluvial/outwash materials over bedrock, ranging in thickness from 5 m to 20 m. In the S-Wells area, till and weathered bedrock underlay the sand and gravel. The Zone II Pit has been backfilled with waste rock produced during mining operations. The ETA overlies the former Faro Creek Channel, which is presently composed of tailings ranging between 6 m and 20 m deep.

Rose Creek Tailings Area

The RCTA includes the Original and Secondary Impoundments and the Intermediate Impoundment, as well as the RCD and the CVD and CVD Pond. Within the RCTA, there is approximately 55 million tonnes of tailings, generally comprised of coarse-grained fractions at the zones of deposition on the northern/central edges of the original and second impoundments, and finer-grained fraction near the impoundment dam faces. Tailings deposits range from 250 m wide to 800 m wide and up to a maximum thickness of 25 m.

Beneath the tailings and along the periphery of the Rose Creek Valley, sands and gravels of fluvial and glacio-fluvial origin are interspersed with till deposits. Within these sands and gravels there are areas of inter-layered fine-grained silts and clays, typical of backwater or glaciolacustrine deposits. The fluvial and glacio-fluvial deposits vary throughout the Rose Creek Valley, and reach depths of 50 m in the centre of the valley. The glacial till extends to a depth of 25 m at the edges of the valley. Surficial deposits in the valley are largely fluvial deposits from Rose Creek and its tributaries. The alluvial unit is composed of a heterogeneous mix of silt, sands, gravels, and cobbles. The alluvial deposits are thickest in the centre of the valley.

Vangorda/Grum Area

Up to 100 m of till overburden overlaid the Grum deposit; the overburden thinned out to less than 40 m in the northeastern and southeastern portions of the pit (RGC, 1996). Similar to the Faro Pit, the area around the Grum Pit had a glacial till unit overlying bedrock. Investigations to the south and west of Grum Pit reported by SRK (2010b) typically identified calcareous phyllite of the Vangorda Formation underlying silty to sandy glacial till in both areas. East of the Grum Waste Dumps, Grum Creek and several tributaries drain towards Vangorda Creek. Generally, alluvium material is found over till material with varying amounts of sand, gravel, and clay. Weathered bedrock, transitioning to competent bedrock, provides the foundation.

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Similar to Grum Pit Area, three primary units appear to be identifiable in the Vangorda Pit Area. However, at the latter there is an overlying overburden unit composed of silty, sandy glacial till (about 30 m thick) that sits atop a sand and gravel unit overlying weathered bedrock that transitions into competent calcareous phyllite. Several fault zones have been identified in the bedrock (RGC, 1996).

Immediately to the west and south of the Grum Pit, there are about 28 million tonnes (14.4 Mm^3) of overburden and waste rock covering 1.48 km^2 of surface area. This includes a sulphide cell covering a surface area of about 0.28 km^2. This waste rock is underlain by thin colluvium and bedrock. Southwest of the Vangorda Pit there are approximately 16 million tonnes (8.2 Mm^3) of waste rock occupying about 0.4 km^2 of area. In addition, there is a 5,900 tonne (11,400 m^3) stockpile of the fines of the oxidized ore or baritic fines (RGC, 1996).

Previous Surficial Geology/Soil Studies

The characterization of soil baseline conditions has been compiled and described based on studies completed in the FMC and the RSA. The results for the FMC have been completed on areas that were either disturbed when the study took place, or if undisturbed, were identified as potential future disturbance areas.Table 6-1 summarizes studies that provide information about near-surface soil conditions by mine area.

6.2.2.3 Seismic and Terrain Hazards

Regional Seismicity

Earth-shaking events can trigger various natural hazards, including landslides, avalanches, liquefaction of saturated soils, and surface ruptures. Findings from a 2013 CH2M HILL seismic hazard assessment summary showed that there is little documented evidence of recent displacements along the Tintina Fault zone in this region of the Yukon. There appears to be a small concentration of epicentres aligned along the Tintina fault; however, these are minor earthquakes (less than Magnitude [M] 5). Furthermore, most of the activity has been at the northern end of the Tintina Fault zone, close to the Alaskan border (Cassidy et al., 2005).

A GPS-based deformation study by Leonard et al. (2008) associated the Tintina fault zone with low-level seismicity (up to M5) and calculated a maximum right-lateral strike-slip rate of only 0.5 millimetres per year (mm/year), suggesting that the fault no longer accommodates significant seismic deformation. In contrast, the zones with the highest deformation rates are those that most directly represent the North America plate boundaries with the Pacific plate and/or Yakutat block: the Fairweather fault zone (27.3 mm/year) and the southern St. Elias zones (3.6 to 18.3 mm/year) (Leonard et al., 2008), located more than 400 km southwest of the FMC.

Through the interior of the Yukon, there are only three focal mechanisms from recent moderate (less than M5) earthquakes near the Tintina fault system (Cassidy et al., 2005; Leonard et al., 2008). They are a mixture of right lateral strike-slip and thrust earthquakes and do not align with the orientation of the Tintina fault system. Furthermore, there has been no evidence found for active faulting along the Canadian segments of the Tintina fault zone or the Denali fault system (Cassidy et al., 2005).

Local Seismicity

Data on recent earthquakes that occurred within about 250 km of the FMC site (62.2°N and 133.2°W) from September 1985 to November 2012 were extracted from the Earthquakes Canada/GSC database. No earthquakes with magnitude greater than 5 have occurred within approximately 220 km of the site. Within a 50-km radius of the FMC, approximately 38 earthquakes have been recorded since 1985. Only one event, an M4.6 event occurring in November 2002 in the Pelly Mountains, exceeded M4. The closest documented event, an M2.2, occurred about 15 km northwest of the FMC on Christmas Day, 1986.

Mass Movement Processes

The most likely terrain hazards identified in a 2002 Indian and Northern Affairs Terrain Hazard Assessment of the Tay River Map Area (105K), which covered the region that includes the FMC, are snow avalanches and rock mass movements (Doherty et al., 2002).

The peaks of Mount Mye, Mount Aho, and Rose Mountain are subject to a high snow-avalanche-mass movement hazard. Avalanches can contain large volumes of boulders and debris and are considered the most hazardous mass movement process to the FMC (Doherty et al., 2002).

Rock mass movements are most often related to thawing permafrost resulting from denuded soils or the erosion of soft glacio-lacustrine and glacio-fluvial sediments on river banks.

Solifluction lobes and slope creep are also common on the slopes of Mount Mye, Mount Aho, and Rose Mountain, but pose a less severe risk to works at the FMC. Solifluction is common above the tree line and is enhanced in moisture-rich soils on north- and west-facing slopes (Lipovsky and Bond, 1999).

Permafrost

The FMC lies within the discontinuous permafrost zone (Duk-Rodkin, 1999). Low to moderate ice content permafrost is likely extensive at higher altitudes within colluvial and morainal deposits. Valley bottom sediments may have a higher ice content, including large ice inclusions such as ice wedges, ice veins, and tabular ice bodies, especially in the fine-grained alluvial and glaciolacustrine sediments. Variations in permafrost distribution are also controlled by surface sediment composition, soil moisture, slope aspect, and snow depth. Within areas mantled by till, permafrost is more common on north-facing slopes and in old growth forests because these sites typically receive reduced solar radiation.

Previous drilling at the Little Creek Dam in the Vangorda/Grum area identified discontinuous permafrost at about 11 m below ground surface; however, the vertical extent of this permafrost is unknown (SRK, 2010b). Discontinuous zones of permafrost have also been noted in drilling records from the NFRC Area and in the shallow subsurface from drilling and test pitting for the Faro Creek Diversion realignment.

Patterned ground, palsas, thermokarst, and frost boils are commonly associated with the glaciolacustrine deposits in the alpine valleys of Mount Mye. Thermokarst is also present on alluvial plains where streams are eroding fine-grained surficial deposits. Similarly, the removal of the organic blanket will often result in the melting of the permafrost and excess water will be allowed to flood the surface, creating poorly drained soil conditions (Doherty et al., 2002). Other evidence of permafrost activity occurs in the alpine and subalpine zones and includes frost shattering, stone stripes, and solifluction (Bond, 2001).

6.2.2.4 Geochemistry

Geochemistry of Potential Borrow Areas – CH2M HILL Studies

Detailed geochemistry for the mine wastes and FMC site are addressed in the Geochemical Characterization Report (Appendix 6A).

CH2M HILL conducted investigations in 2012 and 2013 to characterize soil and rock geochemical information for several potential borrow areas at undisturbed locations in the FMC (outside of the existing footprint areas).

In 2012, samples were collected at 15 shallow (i.e., 0 to 0.15 m below ground surface) locations including areas north of Rose Creek, downstream of the Cross Valley Dam Pond, west of the Faro Pit, several locations along the Haul Road, and east of the Grum Pit. Some samples from the Faro Mine Area had slightly elevated arsenic and nickel concentrations (compared to Canadian Council for Ministers of the Environment [CCME] *Soil Quality Guidelines for the Protection of Environmental and Human Health, Parkland*). These results suggested the shallow samples were within an acceptable range given their intended use for cover, drainage material, and as a growth medium for the FMRP.

Additional sampling was conducted in 2013 in undisturbed areas identified as potential sources of bedrock and soils. This program included advancing 24 boreholes, conducting 47 test pits, and field mapping nine areas. The following samples were submitted for laboratory analysis:

- 123 samples for soil/rock geochemistry
- 66 samples for soil fertility
- 34 samples for soil geotechnical properties
- 16 samples for rock geotechnical properties

The laboratory analytical program is still in progress and results were not available when this report was developed.

Previous Site Till Geochemistry Studies

In 1998 and 1999, a study was conducted by the Yukon Geology Program, a jointly managed program with the Department of Indian Affairs and Northern Development and the Yukon Government Department of Economic Development to conduct detailed surficial geological mapping and till geochemistry over the Anvil District of central Yukon to assess the potential for an undiscovered buried massive sulphide deposit and to better quantify the background geochemical values for the district (Bond, 2001). Regional till sampling was carried out in four areas adjacent to the known massive sulphide deposits in the Faro area, including those of the FMC. Results from these sampling programs highlighted anomalies in lead, zinc, and copper.

The till geochemistry on approximately 140 samples from a 12-km^2 till grid sampled northwest of the Faro Mine indicated a broad dispersion plume for lead, zinc, and copper extending more than 5 km west of the Faro lead/zinc deposit and into a tributary valley of the Rose Creek Valley-oriented transverse to estimated glacial ice flow.

A total of 20 till samples were taken north of Mount Mye on the north side of the Anvil Batholith. An anomalous lead value exceeding 43.2 parts per million (ppm) lead was obtained from a natural exposure (head-scarp exposure of a small landslide). Additional anomalous lead values are present to the east, in upper North Rose Creek Valley. Three samples returned values ranging between 25 and 27 ppm lead. Two anomalous zinc values collected from samples taken in stream cuts were identified along upper Rose Creek.

Twelve samples were taken within the Anvil Creek Valley along a continuation of Anvil stratigraphy west of the Faro deposits that revealed only minor anomalies.

To the southeast of the FMC, elevated lead and zinc values were identified in the Swim Basin and on the Vangorda Plateau from a till sampling program of 123 samples. Elevated zinc values include anomalies west of Swim Lake, Moose Lake (ainc: 208 ppm and 622 ppm), in upper Blind Creek (ainc: 149 ppm), and marginal to the Pelly River.

Analyses of the till geochemistry vertically in an exposure over the Vangorda massive sulphide deposit showed that the lead concentration is a better indicator of the nearby deposit than zinc because of the greater abundance of zinc compared to lead within the regional bedrock. Six of twenty samples exceeded 138 ppm zinc (the 90th percentile). The data showed concentrations of zinc increase rapidly near the bedrock contact. Eighteen of twenty samples exceeded 24 ppm lead (the 90th percentile). Samples taken within 3 m of bedrock returned values exceeding 66 ppm (the 99th percentile of the regional data set).

In 2006, Gartner Lee Limited (GLL, 2006a) completed a soil geochemical investigation as part of a terrestrial effects study. This investigation examined 168 samples (by depth and parent material) for 29 elements, to evaluate whether elevated elemental levels attributed to mine-generated airborne deposition could be due instead or in part to the influence of underlying mineralized soil materials. Sampling focused on the Faro Mine Area, Vangorda/Grum Area, and on Rose Creek downstream of the Faro Mine Area. Out of the 29 elements evaluated, the study found patterns of elevated lead and zinc concentrations in surface organic soil similar to patterns found in surface lichen, but no similar pattern of elemental concentrations in subsurface organic or mineral soils.

This study suggested that the spatial pattern of elevated elemental levels observed in the study area are the result of deposition from the FMC (called the Anvil Range Mine Complex in *Anvil Range Mine 2005 Investigation of Hydrocarbon-contaminated Soils* [GLL, 2006a]) and eliminates the possibility that these levels can be attributed to natural effects or conditions present before mining.

TABLE 6-1
Soil/Surficial Geology Sampling Location and Data Summary at the Faro Mine Complex
Geology and Terrain – Baseline Report, Faro Mine Interim Works

Mine Area	Data Summary	Source
RSA		
RSA	Surface organic material lead concentrations 10 ppm (median) and 18 ppm (maximum) in reference area Mineral soil lead concentrations 15 ppm (median) and 61 ppm (maximum) in reference area	Gartner Lee Limited. 2006b. Anvil Range Mine Complex – Terrestrial effects study: Investigation into metal concentrations in vegetation, wildlife and soils. Draft for discussion. Prepared for the Government of Yukon. March.
RSA	Surface geochemistry mapped for the RSA and classified by depositional environment; soils data collected from soil pits and exposed facies in the RSA and LSA	Bond, Jeffrey D. 2001. *Quaternary geology and till geochemistry of the Anvil district (parts of 105K/2, 3, 5, 6 and 7), central Yukon Territory.* Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 11, 39 p.
LSA		
FMC	Surface Organic Material lead concentration 269 ppm (median) and 5930 ppm (maximum) Mineral soil lead concentrations 16 ppm (median) and 35 ppm (maximum) in reference area	Gartner Lee Limited. 2006b. Anvil Range Mine Complex – Terrestrial effects study: Investigation into metal concentrations in vegetation, wildlife and soils. Draft for discussion. Prepared for the Government of Yukon. March.
FMC	General description of surficial geology	SRK Consulting Engineers and Scientists (SRK). 2009. *Faro Mine Complex Final Closure and Remediation Plan Project Description - Draft 4*. Prepared for Indian and Northern Affairs Canada and Yukon Government. November.
Faro Mine Road Borrow Site South Side of the Tailings Impoundment	Pictures of 60 test pits with qualitative descriptions by depth based on depositional environment from Bond (2001) Summary of Quarry and Borrow Locations and Estimated Material Reserves	Steffen Robertson and Kirsten (Canada) Inc. 2003a. *Phase 2 Borrow Source Survey, Faro Mine, Yukon*. Prepared for Deloitte & Touche Inc. April.
Faro Mine Area		
North Slope above the Cross Valley Dam, between the Faro Valley Waste Dump and the Original Tailings Impoundment East of the Fresh Water Supply Reservoir, east of the North Fork Rose Creek and northwest of the Faro Waste Rock Dumps	Potential borrow pit area investigation with latitude/longitude of 17 boreholes; locations are in relatively undisturbed areas of the LSA	SRK Consulting (Canada) Inc. (SRK). 2006a. *Additional Borrow Studies, Anvil Range Mining Complex, Yukon, 2004/05 Task 11a*. Prepared for Deloitte & Touche Inc., on behalf of Faro Mine Closure Planning Office. March.
Faro Valley Waste Dump/Till Deposits	Faro Valley Waste Dump toe has small areas of intact (biologically active) surface soils Faro Valley Waste Dump was free-dumped till materials with coarse texture and high fragment content	Environmental Dynamics Inc. 2008. Faro Mine Site Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. Prepared for Deloitte & Touche Inc. May.
Lube Shack Tank Farm Mill Diesel Tank Emergency Generator Yard Waste Oil Tank ETA	A total of 4 out of 6 sites exceeded hydrocarbon guidelines; Emergency Generator Yard likely exceeded hydrocarbon guidelines; ETA listed as unknown Borehole data describes colour and texture over 0.5-m depth intervals	Gartner Lee Limited (GLL). 2006a. *Anvil Range Mine 2005 Investigation of Hydrocarbon-contaminated Soils.* Prepared for Deloitte & Touche Inc. June.

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TABLE 6-1
Soil/Surficial Geology Sampling Location and Data Summary at the Faro Mine Complex
Geology and Terrain – Baseline Report, Faro Mine Interim Works

Mine Area	Data Summary	Source
Faro Mine Area Low-grade Ore Stockpile A, Stockpile B, Stockpile C, adjacent to Faro Open Pit	Indicated highly variable physical characteristics near-surface Drilling stopped when natural soils encountered pits visually logged and samples taken; boreholes logged at 1-m intervals or as appropriate	SRK Consulting Engineers and Scientists (SRK). 2006c. *Anvil Range Mining Complex: Assessment of Select Oxide Fines and Ore Stockpiles 2005/06 Task 30*. Prepared for Deloitte & Touche Inc. July.
Haul Road Borrow Rose Creek Borrow Site Rose Creek Haul Road Borrow Site Tailings Borrow Site Organic Soils	Pictures of 60 test pits with qualitative descriptions by depth based on depositional environment from Bond (2001) Summary of Quarry and Borrow Locations and Estimated Material Reserves	Steffen Robertson and Kirsten (Canada) Inc. 2003a. *Phase 2 Borrow Source Survey, Faro Mine, Yukon*. Prepared for Deloitte & Touche Inc. April.
Well PW3 in Zone II Outwash Area	The general soil profile near the PW3 well consists of the following. The PW3 well is representative of the hydrostratigraphy in the Zone II Outwash Area. • 0-2.5 m Gravelly sand with trace silt • 2.5 – 3.5 m silty sand and sandy silt with organics (lowest conductivity) • 3.5 – 6.7 m sand and gravel with cobbles (highest conductivity) • 6.7 – 7.9 m sand and gravel cemented • 7.9 – 9.1 m sand and gravel with cobbles (highest conductivity)	SRK Consulting Engineers and Scientists (SRK). 2007. *Anvil Range Mining Complex continued seepage investigation zone 2 Pit Outwash Area 2005/06 Task 20e.* Prepared for Deloitte & Touche Inc., on behalf of Faro Mine Closure Planning Office. January.
Grum/ Vangorda Area		
Vangorda Overburden Dump Grum Overburden Dump Vangorda and Grum Waste Dumps	Vangorda Overburden Dump material was heterogenous with elevated levels of lead and zinc Grum Overburden Dump: glacial till with sampled textures ranging from sandy loams to loams with coarse fragment contents of approximately 15 to 75% Both waste dumps were freely dumped till materials with coarse texture and high-fragment content	Environmental Dynamics Inc. 2008. Faro Mine Site re-vegetation study: Waste Rock Dumps and Tailings Impoundment. Prepared for Deloitte & Touche Inc. May.
Lube Shack Tank Farm	Both sites exceeded hydrocarbon guidelines Borehole data describes colour and texture over 0.5-m depth intervals	Gartner Lee Limited (GLL). 2006a. *Anvil Range Mine 2005 Investigation of Hydrocarbon-contaminated Soils*. Prepared for Deloitte & Touche Inc. June.
East of Grum Pit Vangorda Creek East of Vangorda Pit	Till depth for three potentially undisturbed areas	SRK Consulting (Canada) Inc. (SRK). 2006a. *Additional Borrow Studies, Anvil Range Mining Complex, Yukon, 2004/05 Task 11a*. Prepared for Deloitte & Touche Inc., on behalf of Faro Mine Closure Planning Office. March.
Vangorda Waste Rock Pile	Specifications on surface materials used and design of trial covers; treatments range from no cover to geotextiles with highly compacted till	SRK Consulting Engineers and Scientists (SRK). 2006b. *Anvil Range Mining Complex Waste Rock Pile Cover Trial – Construction As-built Report, Task 14a – FINAL*. Prepared for Deloitte & Touche Inc., on behalf of Faro Mine Closure Planning Office. February.

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TABLE 6-1
Soil/Surficial Geology Sampling Location and Data Summary at the Faro Mine Complex
Geology and Terrain – Baseline Report, Faro Mine Interim Works

Mine Area	Data Summary	Source
Moose Pond Borrow Site Grum Creek Borrow Site Vangorda/Grum Back Road Vangorda Overburden Dump Grum Overburden Dump Upper Vangorda Creek Organic Deposits East of Vangorda Pit	Pictures of 60 test pits with qualitative descriptions by depth based on depositional environment from Bond (2001) Summary of Quarry and Borrow Locations and Estimated Material Reserves	Steffen Robertson and Kirsten (Canada) Inc. 2003a. *Phase 2 Borrow Source Survey, Faro Mine, Yukon*. Prepared for Deloitte & Touche Inc. April.
Grum Overburden Material Dump	Potential reclamation soil cover source for FMC described average percent particle size and pH for 13 samples over 2 sampling years Sand = 47.8, SD = 7.4 Silt = 38.1, SD = 5.9 Clay = 14.1, SD = 3.9 pH = 7.8, SD = 0.2	Environmental Dynamics Inc. 2009. *Faro Mine Complex Closure and Remediation Plan Revegetation Plan. Draft*. Prepared for Indian and Northern Affairs Canada and Yukon Government. November. (Soil Analysis – Appendix A (EDI, 2009a))
Vangorda Open Pit – exposed till cover material RSA and LSA gridded sampling	Zinc concentrations highest within 2 m of bedrock, while lead concentration more uniformly distributed throughout the profile	Bond, Jeffrey D. 2001. *Quaternary geology and till geochemistry of the Anvil district (parts of 105K/2, 3, 5, 6 and 7), central Yukon Territory.* Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 11, 39 p.
Vangorda Waste Dump	Infiltration rates were highest (3.98 cm/hr) on till with no cover vs waste rock (avg = .32 cm/hr) Data collection issues and design make it difficult to draw conclusions on soil property differences between treatments Subsurface geology comprises silt and clay till. The till unit generally extends to bedrock. In borehole 2001-1, the clay till unit was observed to extend to the depth of the borehole (38.1 m below grade). Clay content increased at depths ranging from 7.6 to 9.1 m, although there was no quantification of the content. Two additional borehole descriptions at the Vangorda Waste Rock Pile in the report describe clay till extending from the surface through the full extent of the borehole.	SRK Consulting Engineers and Scientists (SRK). 2008a. Anvil Range Mining Complex monitor mine waste rock trial covers: 2007 data summary 2007/08 – Task 18a, FINAL. Prepared for Deloitte & Touche Inc. May. Gartner Lee Limited (GLL). 2001. In AECOM Canada Ltd. 2009. Faro Mine Complex Closure and Reclamation - Project Proposal: Current Environmental Conditions Supporting Document. March - Unpublished.
Rose Creek Tailings Area		
Rose Creek West Pit Area Rose Creek Haul Road Tailings Borrow Areas	West Pit Locations ranged from coarse sands and gravels to finer-textured materials, predominantly sand or silt Haul Road textures were loamy sands to loams with approximately 30 to 60% coarse fragments (> 2 mm) Tailings Borrow ranged from sandy loams to silt loams with coarse fragment contents of approximately 5 to 55%	Environmental Dynamics Inc. 2008. Faro Mine Site Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. Prepared for Deloitte & Touche Inc. May.
Haul Road		
Haul Road Borrow	Textures were sandy loams to loams with 40 to 60% coarse fragments	Environmental Dynamics Inc. 2008. Faro Mine Site Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. Prepared for Deloitte & Touche Inc. May.

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TABLE 6-1
Soil/Surficial Geology Sampling Location and Data Summary at the Faro Mine Complex
Geology and Terrain – Baseline Report, Faro Mine Interim Works

Mine Area	Data Summary	Source
Granular Deposits east of the Fresh Water Supply Reservoir Faro Mine Road Granite Outcrop	Pictures of 60 test pits with qualitative descriptions by depth based on depositional environment from Bond (2001) Summary of Quarry and Borrow Locations and Estimated Material Reserves	SRK Consulting Engineers and Scientists (SRK). 2003a. *Phase 2 Borrow Source Survey, Faro Mine, Yukon*. Prepared for Deloitte & Touche Inc. April.

Notes:
% = percent
cm/hr = centimetre per hour
mm = millimetre
ppm = parts per million
SD = standard deviation

6.2.3 Atmospheric Environment

6.2.3.1 Climate

General Climate

The FMC is located in the Yukon Plateau-North ecoregion of the Boreal Cordillera Ecozone, approximately 22 km north of the Town of Faro. The climate around the FMC is typical of sub-arctic continental areas in that it is subject to significant annual temperature ranges and moderate amounts of precipitation. Because of prominent terrain features such as the Vangorda Plateau, Anvil Range Mountains, and the Macmillan Highlands that surround the FMC, the site experiences significant seasonal temperature fluctuations and precipitation levels. Cold winters and warm summers are typical for this region. Temperature inversions are frequent because of the mountainous terrain; valley bottoms experience winter temperatures about 10 degrees Celsius (˚C) cooler than higher elevations. Summer temperatures in the valley bottoms are frequently warmer than upper elevations. This is consistent with the environmental lapse rate (i.e., the rate atmospheric temperature decreases with an increase in altitude) (Janowicz et al., 2005).

Temperature

Regional Temperature Normals and Extremes

Regional daily average temperatures, normals, and extremes were collected from the Environment Canada Faro AUT Weather Station, as well as the Faro Airport Station (Faro A Station). During the winter, the lowest daily average temperature of -24.6˚C typically occurs in January. During the summer, the highest daily average temperature of 21.0˚C typically occurs in July. The daily temperature varies by 12˚C in summer and by 8˚C in winter. Regionally, historical Environment Canada data shows a warming trend, where the extreme minimum temperatures in winter have risen by 0.3˚C and the extreme maximum temperatures in summer have risen 2.4˚C between 1981 and 2010 (AECOM, 2009).

Local Temperatures

Two FMC weather stations are located at the FMC; one at the Faro Waste Dump (Faro Dump Station), and the second formerly at the Grum Waste Dump, but now located at a former gravel pit north of that area (Grum Dump Station) (Figure 6D-2 of Appendix 6D, Climate Baseline Report). Temperature measurements at these stations have been collected at each station every 5 seconds, with averages logged hourly, and monthly mean temperatures calculated using these data. Average temperatures at the Faro Dump Station range from 12.3˚C in summer to -15.6˚C in winter, while the corresponding average temperatures at the Grum Dump Station range from 12.1˚C to -15.5˚C. A comparison of concurrent temperature data from the Faro Airport weather station indicates that summer temperatures experienced at the FMC are generally cooler than those measured at Faro. This difference is expected because of the elevation difference between the airport and the FMC. Inversions in such mountainous terrain likely cause recorded winter temperatures at the Faro Airport weather station to be up to 10˚C lower than temperatures at the Faro Dump Station. While there are no complete, long-term datasets from the FMC weather stations, a strong correlation has been observed between temperatures measured at the Faro Airport and those registered by FMC weather stations (Figure 6D-6 of Appendix 6D; AECOM 2009).

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Precipitation

Precipitation characteristics for the FMC are described based on data collected and summarized by Environment Canada between 1981 and 2010 at the Faro A Station and are referred to as climate normals for that location. During this time period, mean total annual rainfall was 218.4 millimetres (mm) and mean total annual snowfall was 114 cm, corresponding to a mean snow water equivalent of 101.3 mm. The total annual precipitation ranged between 166 mm (1988) and 355 mm (1990), with an average of 320 mm per year (Appendix 6D).

Monthly rainfall was generally highest between May and September, when snowfall was at a minimum. The wettest months were July and August, with monthly average rainfalls totalling 56.1 mm and 47.5 mm, respectively. Snow-free months were restricted to June and July, with all other months experiencing snowfall from as little as 0.636 cm in May to as much as 21.7 cm in November (or 0.6 mm and 19.2 mm snow water equivalent for May and November, respectively).

Wind Speed and Direction

Surface wind speed and direction at the FMC were assessed for a 5-year period between 2006 and 2010 using measurements collected from the Faro A Station and the two FMC stations. This series of years was chosen for the air quality effects assessment and are considered to present a representative summary. Onsite wind speeds averaged 2.13 metres per second (m/s) at the Faro Dump Station and 2.49 m/s at the Grum Dump Station. In comparison, wind speeds at the Faro AUT Station averaged 2.21 m/s. Annually, more frequent periods of calm winds were observed at the Faro AUT station (approximately 5.3 percent of the recorded hourly wind speeds) than the Grum Dump Station (less than 1 percent of recorded hourly wind speeds).

Seasonally, summer wind speeds between May and September averaged 2.35 m/s at the Faro Dump Station and 2.38 m/s at the Grum Dump Station. In comparison, summer winds at the Faro AUT Station averaged 2.21 m/s. Winter wind speeds from October to April averaged 1.96 m/s at the Faro Dump Station and 2.57 m/s at the Grum Dump Station. Comparatively, winter wind speeds at the Faro AUT Station averaged 2.21 m/s.

At the Faro Airport Station, the prevailing summer wind directions are from the southeast and northwest, while winter winds originate predominantly from the southeast. At the Faro Dump Station, the prevailing summer wind directions are from the northeast and southwest, while prevailing winter winds are from the southeast. The Grum Dump Station experiences summer winds predominantly from the northwest and winter winds from both the southeast and the northwest.

Solar Radiation

While solar radiation is not a published component of the Environment Canada stations at Faro, the FMC stations did record solar radiation data from December 2003 to July 2009. Five complete years of data, 2004 to 2008, were used to characterize onsite solar radiation. Average daily solar radiation calculated using this dataset ranges from the lowest detected levels of 0.129 kilowatts in December to a high of 5.599 kilowatts in June. Highest daily solar radiation levels occurred between April and July, with the lowest daily solar radiation experienced between November and January.

Relative Humidity

Relative humidity (RH) data for the site were based on data collected at the Faro A Station between 1981 and 2010. During this time, RH readings were collected twice daily during the summer months (April through October; 06:00 and 15:00), and once daily for the remainder of the year (15:00). The annual average RH at the Faro A Station taken at 15:00 is 62.69 percent with monthly mean values ranging from 41.44 percent (June) to 81.17 percent (November). RH was generally higher in morning readings, ranging from 74.6 percent (May) to 89.99 percent (September), with an annual average of 81.92 percent.

6.2.3.2 Air Quality

Overview

Air quality in the FMC area is considered to be an important consideration and a primary goal for the IW, and therefore is selected as a valued component (VC) for the IW. Air quality is selected as a VC because of its intrinsic

importance to the health and well-being of humans, wildlife, and vegetation. The following subsection provide an overview of existing air quality conditions in relation to the FMC site, as detailed in Appendix 6E.

Existing air quality for the IW is characterized by ambient concentrations of the following key air quality indicators:

- Nitrogen oxides (NO_x)
- Sulphur dioxide (SO_2)
- Carbon monoxide (CO)
- Ozone (O_3)
- Particulate matter (PM)
- Particulate based metals

Greenhouse gases were not characterized as part of the existing environment because the IW is scheduled for completion within 10 years. The IW is therefore not expected to contribute measurably to global climate conditions during this time.

Study Area

The study area chosen to assess air quality for the IW is the aerial extent of potential effects from project related emissions, including the sensitive receptors closest to the FMC. This study area was established as a 100- km-by-100-km square area approximately centred on the FMC.

Factors Affecting Air Quality

The following sources currently influence ambient air quality near the FMC and are expected to remain as contributors during the IW:

- Airborne dust from vehicle traffic on unpaved roads
- Fugitive emissions from material handling
- Wind-blown dust emissions from the tailings storage facilities
- Combustion of diesel and other fuels (heavy equipment, power generation, and heating)

Additionally, criteria air contaminants resulting from regional sources may influence ambient air quality, and are expected to remain as contributors during the IW.

Data Sources

Ambient air quality was evaluated in order to serve as a benchmark to which project related emissions could be compared in order to assess potential effects. Both local and regional ambient air quality data were compiled to characterize baseline conditions. Data from locally established monitoring stations were used to characterize particulate matter and particulate based metals; whereas regional sources provided data for contaminants not explicitly measured during on-site monitoring programs.

In 2008, SENES Consultants Limited (SENES) established on-site monitoring stations at the FMC and conducted an ambient air monitoring program for total suspended particulates (TSP), particulate matter with aerodynamic diameter of less than 10 microns (PM_{10}), and particulate metals. Samples were collected at eight sites within the FMC and one site in the Town of Faro. A one-in-six day sampling schedule was used during the period of July to October 2008 to capture 13 24-hour-average concentrations (Senes, 2009). Sample sites were grouped in the Faro Mine Area and Vangorda/Grum Area to provide data for specific areas as well as the overall FMC (as shown in Figure 6E-3, Appendix 6E).

Regional ambient air quality data were obtained for the nearest Environment Canada National Air Pollution Surveillance (NAPS) stations in Whitehorse, YT, and Norman Wells, Northwest Territories (Figure 6E-2, Appendix 6E). 2010 and 2011 NAPS data for criteria air pollutants were reviewed, which consisted of hourly monitoring data for O_3, SO_2, CO, NO_x, NO_2 and very fine particulate matter ($PM_{2.5}$; particulate matter with aerodynamic diameter of less than 2.5 microns). Mean annual concentrations for O_3, SO_2, CO, NO_x, NO_2, and $PM_{2.5}$ were also reviewed (Environment Canada, 2013a).

Particulate and criteria air pollutant data were compared with government air quality standards from the Yukon, British Columbia, or Ontario, where applicable. Yukon Ambient Air Quality Standards (AAQS) (YG, 2010) were the preferential standard and were used where available, otherwise standards from other jurisdictions were used.

Existing Air Quality Conditions

The following section describes baseline ambient air quality conditions, established through analysis and review of available data, including both local and regional monitoring results.

Criteria Air Contaminants (Other than Particulate Matter)

Background ambient air quality concentrations for non-particulate criteria air contaminants including NOx, CO, SO_2, and O_3 are shown in Table 6-2, while detailed data are provided in Table 6E-3 in Appendix 6E. These data were derived from the Whitehorse NAPS station except for SO_2, which was characterized based on the Norman Wells station, as it is not measured at the Whitehorse station. Background ambient air quality concentrations for all criteria air contaminants were found to be below Yukon AAQS standards (YG, 2010).

It is recognized that air quality values derived from the regional monitoring stations are likely higher than those for the FMC because there is more human activity near the NAPS stations. Because data on certain criteria air pollutants is lacking for the FMC, these values are still considered useful for estimating baseline levels for the FMC.

TABLE 6-2
Proposed Ambient Air Quality Baseline Levels – Criteria Air Contaminants
Faro Mine Interim Works

Contaminant	Averaging Time	Baseline Concentration	Yukon AAQS
NOx	1-hour	31 (ppb)	213 (ppbv)
	24-hour	26 (ppb)	106 (ppbv)
	Annual	12.4 (ppb)	32 (ppbv)
CO	1-hour	1.1 (ppm)	13 (ppm)
	8-hour	0.8 (ppm)	5 (ppm)
$PM_{2.5}$ (TEOM)	24-hour	7 (µg/m^3)	30 (µg/m^3)
PM_{10}	24-hour	7.1 (µg/m3)	50 (µg/m^3)[a]
TSP	24-hour	11.7 (µg/m^3)	120 (µg/m^3)
SO_2	1-hour	1.5 (ppb)	172 (ppbv)
	24-hour	1 (ppb)	57 (ppbv)
	annual	0.00 (ppb)	11 (ppbv)
O_3	8-hour	47 (ppb)	65 (ppbv)

Notes:

[a] BC Ambient Air Quality Objectives
µg/m^3 = micrograms per cubic metre
ppbv = parts per billion, volumetric
TEOM = Tapered Element Oscillating Microbalance

Particulates

Background ambient air quality conditions for particulate matter were generated using both local and regional data. Measurements taken at nine local monitoring stations (eight at the FMC and one in the Town of Faro) were used to characterize baseline concentrations of TSP and PM_{10} (Senes, 2009). $PM_{2.5}$ data were derived from the Whitehorse NAPS station. Based on a 24-hour averaging time, baseline ambient concentrations of 7 µg/m^3 for $PM_{2.5}$, 7.1 µg/m^3 for PM_{10} and 11.7 µg/m^3 for TSP are proposed. Background ambient air quality concentrations for particulates were all found to be below Yukon AAQS standards (YG, 2010). Baseline ambient concentrations

for particulates are presented in Table 6-2, above, while detailed data are presented in Tables 6E-3 and 6E-5 in Appendix 6E.

Particulate-Based Metals

Monitoring data for 22 particulate-based metals based on maximum observed 24-hour concentrations were below Ontario ambient air quality guidelines for metals (Table 6E-6 in Appendix 6E). Ontario standards (Ministry of the Environment, 2005) were used in the case of particulate-based metals, as neither Yukon AAQS nor BC Ambient Air Quality Objectives were available.

Proposed baseline ambient concentrations for particulate-based metals developed based on 24-hour average concentrations are presented in the context of Ontario ambient air quality criteria (AAQC) in Table 6-3.

TABLE 6-3
Proposed Ambient Air Quality Baseline Levels – Metals Contained in Particulate Matter
Faro Mine Interim Works

Element	Baseline Concentration 24-hour Average (µg/m^3)	AAQC[a] 24-hour Average (µg/m^3)	Jurisdiction
Antimony	MDL	25	Ontario Standard
Arsenic	0.0049	5	Ontario Standard
Barium	0.046	10	Ontario Guideline
Beryllium	MDL	0.01	Ontario Standard
Boron	MDL	120	Ontario Standard
Cadmium	0.0025	0.025	Ontario Standard
Chromium	0.26	1.5	Ontario Guideline
Cobalt	MDL	0.1	Ontario Guideline
Copper	0.48	50	Ontario Standard
Iron	1.39	4	Ontario Standard
Lead	0.084	0.5	Ontario Standard
Manganese	0.021	2.5	Ontario Guideline
Molybdenum	0.0011	120	Ontario Guideline
Nickel	0.009	2	Ontario Standard
Selenium	MDL	10	Ontario Guideline
Silver	0.0009	1	Ontario Standard
Strontium	0.0042	120	Ontario Guideline
Tellurium	MDL	10	Ontario Standard
Tin	0.015	10	Ontario Standard
Titanium	0.027	120	Ontario Standard
Vanadium	MDL	2	Ontario Standard
Zinc	0.1	120	Ontario Standard

Sources:

[a] Ontario Summary of Standards and Guidelines to support O. Reg. 419, April 2012

Notes:

MDL = below Method Detection Limit for >98% of samples.

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6.2.4 Water Resources

6.2.4.1 Hydrology

Introduction

The FMC is located within the regional Vangorda Creek and Rose/Anvil Creek watersheds. The watercourses within these basins are all tributaries to the Pelly River: Vangorda Creek flows directly to the Pelly River through the town of Faro, and Rose Creek is a tributary to Anvil Creek, which in turn discharges to the Pelly River approximately 46 km north of Faro. Within the FMC, a number of hydrological modifications or conveyance features were developed to facilitate mining operations. During mining and post-mining operations, considerable effort was exerted to monitor stream flow and meteorological conditions at the FMC. Data continues to be collected at existing monitoring locations, as part of site operations, to maintain an active database of hydrological conditions. In addition, information on the regional hydrology is available through federal and YG data collection programs.

The hydrology information provided in the following subsections is directly related to the requirements for the IW. The hydrology-related information provides a description of the watershed boundaries, drainage areas, connectivity to adjacent watercourses, and drainage patterns. The analysis of flow records for the FMC provides estimates of peak, minimum, seasonal, and annual average flows. Baseflow estimates are provided for the Rose Creek and Vangorda Creek catchment areas that cover the FMC. More detailed information about site hydrology is provided in the Hydrology Baseline Report, attached as Appendix 6F.

Regional Hydrology

Precipitation, annual snowmelt, air temperature, evaporation, and evapotranspiration influence the region's hydrology. Details on regional and local climate parameters are provided in Section 6.2.3.1 and in the Climate Baseline Report (Appendix 6D). Overall, the region is characterized by large snowmelt runoffs that peak between late May and early June. Stream flows then generally taper off through the summer months. Stream and river flows increase during periods of heavy rainfall throughout the summer and fall, until freeze-up in October. The larger watercourses, such as the Pelly River, maintain significant baseflows throughout the year, while small to medium streams tend to have lowest flows from December to March or April when the groundwater table is lowest.

Local Hydrology

Faro Mine Complex Major Hydrological Features

A number of hydrological features within the FMC are important from a surface water hydrological perspective and are monitored as part of ongoing remediation efforts. These include pre-mining sections of local watercourses, stream diversions, and surface water impoundments that were developed to facilitate mining operations. Table 6-4 lists these features.

TABLE 6-4
FMC Hydrology-related Features
Faro Mine Interim Works

FMC Feature	Description	Hydrological Relevance
Faro Pit	Main excavated pit in Faro Mine Area	Receives local surface water and pumped water from the ETA, ID Pond and groundwater from the Zone 2 wells and S-wells No direct contribution to surface water hydrology
Various Waste Dumps	Waste rock from pit excavation	Potential surface water runoff during extreme rainfall events; contributes to surface flow quantity
Intermediate Dam Pond	Containment of contaminated surface water behind intermediate dam	Water pumped to the Faro Pit. Spillway from dam is being upgraded as part of IW
Various seepage collection systems	Collect potentially contaminated seepage	Contained and pumped for treatment

TABLE 6-4
FMC Hydrology-related Features
Faro Mine Interim Works

FMC Feature	Description	Hydrological Relevance
Cross Valley Dam Pond and CVD	Surface water containment area behind CVD	Pond acts as a water treatment polishing pond
RCD	Diversion of Rose Creek around tailings area	Requires minor upgrades to convey 1-in-500 year design rainfall event
NFRC	Tributary of Rose Creek conveying surface water and seepage from waste dumps	Conveyance of regional flows
North Wall Interceptor Ditch	Collects uncontaminated surface water from north side of Rose Valley and Upper Guardhouse Creek	Conveyance of local runoff
NFRD	Haul road crossing of NFRC	Creates a surface water retention area upstream from drain and limits flow
Upper Guardhouse Creek	Collects local uncontaminated surface water and directs to North Wall Interceptor Ditch	Conveyance of local runoff
Lower Guardhouse Creek	Collects potentially contaminated mill area surface water	Conveys flow to the Intermediate Pond where it is pumped for treatment
Faro Zone II Pit	Collects contaminated groundwater	Collected and pumped to Faro Pit
Faro Creek	Undisturbed section of Faro Creek collecting uncontaminated surface water	Conveyance of regional flows
Faro Creek Diversion	Diversion of Faro Creek around Faro Pit	Conveys uncontaminated surface water around Faro Pit
Pumphouse Pond and Dam	Collects surface water from South Fork Rose Creek and part of NFRC	Discharges into Rose Creek
Vangorda Pit	Excavated mine pit in Vangorda/Grum Area	Receives local surface water and seepage Receives pumped water from Little Creek Pond, Grum Pit, Grum V15, and Grum Sulphide Cell Surface Water Collection Ponds
Grum Pit	Excavated mine pit in Vangorda/Grum Area	Collects local surface water
Vangorda Creek	Undisturbed section of Vangorda Creek conveying surface water	Conveyance of regional flows
VCD	Diversion of Vangorda Creek around Vangorda Pit	Conveys uncontaminated surface water around Vangorda Pit
Moose Pond	Small pond collecting local surface water and seepage from Grum Waste Dump.	No surface water discharge. Connected via groundwater to Vangorda Creek system
Sheep Pad Ponds	Collects Grum Interceptor Ditch water for solids settling	Discharges to Vangorda Creek
Grum Interceptor Ditch	Collects uncontaminated surface water and discharges to Vangorda Creek via Sheep Pad Ponds	Collects local surface water and receives discharge from Vangorda water treatment plant
Little Creek Dam and Little Creek Dam Pond	Collects water from Vangorda Waste Dump	Pond water is pumped to Vangorda Pit
Dixon Creek	Conveys local uncontaminated surface water	Tributary of Vangorda Creek

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Faro Mine Complex Sources of Data and Information

A considerable amount of information exists to characterize the hydrological conditions at the FMC. The majority of site-specific data was collected during the post-mining maintenance period. These data are available through a variety of compiled sources, including annual reports generated through FMC care and maintenance activities.

Meteorological and stream flow data for the regional area relevant to the FMC are available from government agency monitoring locations. Climate data are available through the Environment Canada Climate Archive (http://climate.weather.gc.ca/). Flow monitoring data are available through the Environment Canada water survey database (http://www.ec.gc.ca/eau-water).

These data and other available information are detailed in Appendix 6F, which also details the methodology for data review and the results of historical and current FMC hydrological investigations.

Vangorda Creek and Rose Creek Watersheds and Catchment Areas

For analyzing hydrology at the site, the Vangorda Creek and Rose Creek watersheds are subdivided into 13 catchment areas: five catchments in the Vangorda watershed and eight catchments in the Rose Creek watershed. Appendix 6F provides corresponding watershed figures and describes the catchment delineation methodology. The watershed catchments are summarized in Table 6-5, below.

TABLE 6-5
Surface Water Catchments
Faro Mine Interim Works

Catchment ID	Description	Area (hectares)	Mean Elevation (masl)
Rose Creek Regional Catchments (Tributary to FMC X14 monitoring location)			
RC1	NFRC (Upper) – includes the extent of the NFRC to the confluence with the FCD. The flow contributed to the FMC hydrology is monitored by the R7 station.	9,874	1,480
RC2	Faro Creek and FCD –includes both the Faro Creek and FCD to its confluence with the NFRC.	1,589	1,540
RC3	NFRC (Lower) – includes the area tributary to the NFRD at the Haul Road.	992	1,110
RC4	SFRC – includes the extent of the area tributary to the SFRC to the confluence with the NFRC (just south of the NFRD) and is bound by the Vangorda Creek catchment to the east.	7,253	1,450
RC5	RCD – RC5 is tributary to RC6 and represents the NFRC between the NFRD and confluence with the SFRC.	124	1,220
RC6	RC6 represents the RCD around the tailings area.	1,842	1,310
RC7	Upper Guardhouse Creek and North Wall Interceptor Ditch – includes the extent of the area tributary to the Upper Guardhouse Creek and North Wall Interceptor Ditch before the confluence with Rose Creek.	637	1,290
RC8a	Faro Pit –includes the area tributary to the Faro Pit. The pit is considered a water storage location in the context of surface water hydrology.	305	1,140
RC8b	Tailings Area – includes the area between the Faro Pit and tailings area; the flow within this area is monitored by the X23 station. This catchment outlets to the Rose Creek Catchment by the Siphon at the CVD.	539	1,130
RC9	Rose Creek west of the FMC – includes the remaining area tributary to the Rose Creek, upstream from the X14 monitoring location. Water exiting this catchment flows to Anvil Creek and, eventually, the Pelly River.	2,974	1,380
Vangorda Creek Regional Catchments			
VC1	Vangorda Creek and VCD – includes the extent of the area tributary to Vangorda Creek upstream from the VCD; flow through this catchment is represented by the V1 monitoring location.	2,007	1,460

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TABLE 6-5
Surface Water Catchments
Faro Mine Interim Works

Catchment ID	Description	Area (hectares)	Mean Elevation (masl)
VC2	Vangorda Creek and Shrimp Creek – Includes the area tributary to the Vangorda Pit (not captured by VCD) and the area Northwest of Vangorda Creek (GSC/V2/Moose Pond) downstream from the haul road to the V27 monitoring location.	842	1,180
VC3	Grum Pit – represents the area tributary to the Grum Pit.	176	1,310
VC4	Shrimp Creek/Dixon Creek – includes the extent of the area tributary to Shrimp/Dixon Creek upstream from the confluence with Vangorda Creek and the V27 monitoring location.	1,360	1,210
VC5	Vangorda Creek – includes the remaining areas tributary to Vangorda Creek upstream from the V8 monitoring location.	4,430	1,240

Hydrological Conditions

Recurrence Interval Event Stream Flows

A number of studies used the available FMC hydrological, meteorological, and physical site data to determine baseline hydrological conditions. The available data were reviewed and integrated into the baseline analysis through a quality assurance/quality control process that determined the most suitable data for inclusion in the analysis. The data analysis carried out to develop baseline hydrological data, the steps applied during the review and quality assurance/quality control process for each relevant data set are discussed in Appendix 6F.

Previous hydrological studies for the FMC reported in CH2M HILL (2013g) have generally focused on determining instantaneous peak flows for a range of recurrence interval events. The studies have relied on regional analyses to determine discharge yield, based on catchment area for a range of flood events. NHC and BGC (2004) conducted a regional analysis based on data obtained from seven regional gauges. During the study, the period of record represented by the gauges ranged from 14 years to 40 years. The catchment areas for the gauges ranged from 91 km^2 to 7,250 km^2. Instantaneous peak discharges were estimated for the mean annual event and for the 1-in-50-, 1-in-100-, 1-in-200-, 1-in-500-, and 1-in-1,000-year return period floods. Table 6-6 summarizes the peak discharge hydrology estimates at the R7 gauge (NFRC, upstream from the FMC), NFRD, SFRC, X14 gauge (Rose Creek downstream from FMC), and Vangorda Creek Diversion locations and indicates recurrence interval peak discharge.

TABLE 6-6
Summary of Peak Discharge Hydrology (Previous Studies)
Faro Mine Interim Works

				Discharge (m^3/sec)							
Reference	Location	DA (km^2)	Instantaneous, Daily, or Hydrograph	Mean Annual	1-in-2-year	1-in-50-year	1-in-100-year	1-in-200-year	1-in-500-year	1-in-1,000-year	PMF
NHC/BGC (2004)	R7 gauge	95	Instantaneous	9.2	N/A	37	45	54	67	77	N/A
NHC/BGC (2004)	29BC003	91	Instantaneous	4.27	N/A	14.2	18.6	24.0	33.1	43	N/A
SRK (2010)	R7 gauge	99[a]	Instantaneous	N/A	10	N/A	42	50	63[b]	N/A	N/A
SRK (2006)	R7 gauge	99[a]	Daily	N/A	6.7	N/A	28	33	40	47	N/A
Value used in current study	*R7 gauge*	*99[a]*	*Instantaneous*	*9.2*	*10*	*37*	*42*	*50*	*63*	*77*	*N/A*

TABLE 6-6
Summary of Peak Discharge Hydrology (Previous Studies)
Faro Mine Interim Works

				Discharge (m^3/sec)							
Reference	**Location**	**DA (km^2)**	**Instantaneous, Daily, or Hydrograph**	**Mean Annual**	**1-in-2-year**	**1-in-50-year**	**1-in-100-year**	**1-in-200-year**	**1-in-500-year**	**1-in-1,000-year**	**PMF**
NHC/BGC (2004)	SFRC[d]	73[a]	Instantaneous	7.3	N/A	29	35	42	53	61	N/A
SRK (2010)	SFRC	73[a]	Instantaneous	N/A	7	N/A	33	39	49	N/A	N/A
SRK (2006)	SFRC	73[a]	Daily	N/A	4.9	N/A	21	25	30	34	N/A
WMC (2006Y)	SFRC	83.5	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	300
Value used in current study	*SFRC*	*73[a]*	*Instantaneous*	*7.3*	*7*	*29*	*33*	*39*	*49*	*61*	*300*
NHC/BGC (2004)	NFRC at NFRD	118	Instantaneous	11.0	N/A	44	54	65	81	93	N/A
SRK (2010)	NFRC at NFRD	118	Instantaneous	N/A	11	N/A	49	58	72[b]	N/A	N/A
SRK (2006)	NFRC at NFRD	118	Daily	N/A	8	N/A	34	40	48	55	N/A
WMC (2006b)	NFRC at NFRD	122.5	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	384
Value used in current study	*NFRC at NFRD*	*118*	*Instantaneous*	*11*	*11*	*44*	*49*	*58*	*72*	*93*	*384*
NHC/BGC (2004)	Rose Creek upstream from Fuse Plug	203	Instantaneous	18	N/A	71	86	103	130	150	N/A
WMC (2006Y)	Upper End RCD	(217.3)[c]	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	674
NHC/BGC (2004)	X14 gauge	230	Instantaneous	20	N/A	79	96	115	145	167	N/A
SRK (2010)	X14 gauge	229[a]	Instantaneous	N/A	20	N/A	83	98	122[b]	N/A	N/A
SRK (2006)	X14 gauge	229[a]	Daily	N/A	16	N/A	65	77	94	108	N/A
WMC (2006Y)	Lower end RCD	(217.3)[c]	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	692
Value used in current study	*X14 gauge*	*229[a]*	*Instantaneous*	*20*	*20*	*79*	*83*	*98*	*122*	*167*	*692*
SRK (1990)	Vangorda Creek Diversion	18.8	Instantaneous	4.2	4.1	9.0	10.0	N/A	18.0	N/A	N/A
SRK (2003a)	Vangorda Creek Diversion	20.1	Instantaneous	N/A	N/A	N/A	N/A	N/A	31	N/A	180
SRK (2010)	Vangorda Creek Diversion	19.5	Instantaneous	N/A	N/A	N/A	N/A	13	30	N/A	N/A

[a] Drainage area from HEC-HMS model (CH2M HILL, 2013j

[b] Best fit curve used for 1-in-500-year event instead of envelope curve

[c] Unclear in WMC (2006b) where discharge point is for lower sub-basin

[d] Reported value not in NHC (2004), used plots to extrapolate value

Notes:

DA = daily average
N/A = not applicable
WMC = Water Management Consultants Inc.

Probable Maximum Flood Flows

The probable maximum precipitation (PMP) and PMF are events that occur with less frequency than once in every 1,000 years. While the PMF is not specifically relevant to the IW, it is a key design event for the Faro Mine Remediation Project (FMRP). A study performed by WMC and a committee of the Faro Mine Closure Planning Office (2006a) examined the FMC PMF event in detail. The findings of this study are included in Appendix 6F.

The probable maximum precipitation (PMP) was determined to be a 175-mm-in-24-hours, rain-on-snow event, which is most likely to occur in June. Table 6-7 summarizes the PMF findings for Rose Creek. CH2M HILL has reviewed WMC (2006a) and has found the assumptions and peer-reviewed work to be appropriately conservative.

TABLE 6-7
Summary of PMF for Rose Creek
Faro Mine Interim Works

Area [a]	PMF (m^3/s) [a]
NFRC	384
Upper end of Rose Creek Diversion	674
Lower end of Rose Creek Diversion	692

[a] Water Management Consultants, 2006x

Base Flow Conditions

The continuous flow data sets for FMC monitoring stations R7 (NFRC) and V1 (Vangorda Creek) were examined, and base flow values were then derived from these records to represent average base flow conditions in the Rose Creek and Vangorda Creek watersheds. Based on these average monitored baseflow conditions, the average baseflow conditions in each of the Rose Creek and Vangorda Creek catchment areas was estimated. These catchment area base flow estimates are shown in Tables 6-8 and 6-9, below.

TABLE 6-8
Rose Creek Monthly Base Flow Estimates
Faro Mine Interim Works

Rose Creek Model Catchments	Area (hectares)	Monthly Base Flow (m^3/sec)
RC1	9,874	Dec-Apr: 0.3 May-Nov: 1.0
RC2	1,589	Dec-Apr: 0.05 May-Nov: 0.16
RC3	992	Dec-Apr: 0.03 May-Nov: 0.1
RC4	7,253	Dec-Apr: 0.22 May-Nov: 0.73
RC5	124	Dec-Apr: 0.003 May-Nov: 0.0125
RC6	1,842	Dec-Apr: 0.06 May-Nov: 0.18
RC7	637	Dec-Apr: 0.02 May-Nov: 0.06
RC8a and RC8b (Siphon)	852	0.4 (monthly)

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TABLE 6-9
Vangorda Creek Monthly Base Flow Estimates
Faro Mine Interim Works

Vangorda Creek Model Catchments	Area (hectares)	Monthly Base Flow (m^3/sec)
VC1	2,007	Sept-Apr: 0.30 May-Aug: 0.40
VC2	742	Sept-Apr: 0.11 May-Aug: 0.15
VC3	276	Sept-Apr: 0.04 May-Aug: 0.05
VC4	1,360	Sept-Apr: 0.20 May-Aug: 0.27
VC5	4,352	Sept-Apr: 0.65 May-Aug: 0.87

Although knowledge of surface water/groundwater interaction is somewhat limited across the site because of the limited number of data available to support the characterization of the nature of stream-aquifer interaction at the site, baseflow values monitored during periods of drought conditions are indicative of groundwater influence on the low flow conditions in the streams. Further groundwater discussions are provided in Appendix 6G.

6.2.4.2 Groundwater Quantity and Quality

Hydrogeological Setting

The study area for groundwater resources at the FMC is the aquifers underlying the Faro Mine Area and the Vangorda/Grum Mine Area. Groundwater flows within the study area are typical of mountainous environments: upland mountain areas act as groundwater recharge areas, and groundwater flows toward valley-bottom discharge areas. In general, all groundwater within the Faro Mine Area flows to the Rose Creek surface drainage (which feeds into Anvil Creek); groundwater within the Vangorda/Grum Area flows into Vangorda Creek. While pre-mining groundwater drainage patterns are assumed to have mirrored local topographic gradients, several features associated with the mine development now affect localized groundwater flow patterns (e.g., pits, tailings, and other mine-related features).

Data Collection

Existing groundwater data for the FMC was gathered from a large number of information sources, including historical field monitoring data for groundwater level and quality collected during previous consultant investigations, ongoing monitoring programs, and investigations completed in 2012 and 2013 by CH2M HILL. CH2M HILL used the data collected during various site investigations to develop groundwater flow models for the Faro Mine Area that were subsequently used for the assessment of baseline conditions. This section presents the baseline conditions for groundwater within the FMC. Additional details about groundwater baseline conditions are provided in Appendix 6G, attached.

FMC Hydrogeological Features

Two separate aquifer systems underlie the FMC; the Rose Creek aquifer system that underlies the Faro Mine Area and discharges into Rose Creek, and the Vangorda Creek aquifer system that underlies the Vangorda/Grum area and discharges into Vangorda Creek. These two groundwater systems are described in more detail below.

Faro Mine Area

Groundwater conditions in the Faro Mine Area are influenced by numerous mine-related and surface water features including the following:

- Faro Pit and various associated WRDs
- Zone II Pit adjacent to the Faro Pit

- Groundwater/surface water interaction within the NFRC drainage
- ETA and SIS below the mill and stockpile areas
- S-wells SIS adjacent to the NFRC downgradient of the Intermediate WRD
- RCTA, including the CVD, ID, Secondary Dam, Original Dam, and RCD Channel

Overall, the hydrogeology of the Faro Mine Area is characterized by two significant alluvial aquifer systems (the RCAA and the NFRC Alluvial Aquifer) underlain locally by low-permeability till deposits, a moderate to low permeability weathered bedrock unit, and a generally low permeability competent bedrock unit. Due to their significantly higher permeability, a very high percentage of the groundwater flow moving through the Rose Creek aquifer system occurs through the alluvial deposits.

The Faro Pit has a large influence on hydrogeology in the vicinity of the Faro Rock Dumps. Faro Pit generally acts as a groundwater sink, collecting groundwater seepage and subsurface inflow from the surrounding rock dumps. A small amount of outflow is believed to leave the pit in response to groundwater extraction operations within the nearby Zone II Pit. The primary inflows to Faro Pit occur as precipitation, pit wall and surface seepage from surrounding WRDs, and subsurface inflow from the aquifer system underlying the WRDs. The Faro Mine Area includes several large WRDs that act as areas of infiltration for rainfall and snowmelt. Much of this infiltrating water discharges back to the ground surface in the form of seeps contributing to surface water runoff while the remainder becomes deep percolation and recharges the groundwater aquifer system. The previously infilled Zone II Pit is located between the Northeast and Intermediate WRDs. Groundwater levels within the Zone II Pit backfill are controlled by groundwater pumping to limit potential subsurface seepage into the nearby NFRC. Groundwater is pumped from the pit to maintain groundwater elevation in the rock backfill at no greater than 1,096 masl.

The Zone II Outwash and S-Wells areas are located in the alluvial floodplain along the NFRC. The S-Wells area lies south of the Intermediate WRD while the Zone II Outwash area lies east of the Zone II Pit. The generalized stratigraphy of these areas consists of alluvial materials overlying weathered and competent bedrock, with locally limited deposits of glacial till material. In the S-Wells area however, the alluvial aquifer is separated into an upper and lower aquifer by the presence of a low-permeability aquitard, while in the Zone II area, the alluvial aquifer appears to be a single aquifer system with overlying outwash material deposited at the ground surface. Recent studies show that groundwater in both of the areas is hydraulically connected with the NFRC, and mine-impacted groundwater has the potential to discharge to the NFRC, with resulting impacts to surface water quality. Past experience in the S-Wells area has illustrated that these interactions do occur.

The ETA is located along the former Faro Creek Channel, north of the RCTA. The stratigraphy of the area is comprised of limited thicknesses of sand and gravel, underlain by weathered and competent bedrock. Disposal of tailings materials in this area during mine operations has resulted in the deposition of a 6- to 20-m-thick low-permeability tailings unit in the upstream portion of the ETA adjacent to the Mill Area and Main Rock Dump. The ETA receives water from upgradient WRDs and associated seeps, including the discharge from the X23 seep that exhibits some of the highest metals and sulfate concentrations detected across the FMC.

The RCAA is located in the Rose Creek Valley, downstream of the confluence of the NFRC and SFRC. This aquifer system is a classic fluvial depositional system deposited by the NFRC and by Rose Creek itself. The alluvial aquifer is composed of a mixture of silt, sand, and gravel, with thicknesses of up to 50 m near the centre of the valley. Alluvial deposits are now covered by up to 25 m of tailings in the central valley area. The primary hydrogeological units in the Rose Creek valley include the relatively low-permeability tailings deposits underlain by high-permeability alluvial deposits, overlying lower permeability weathered and competent bedrock. Limited discontinuous low permeability glacial till deposits have also been observed overlying the bedrock units, primarily along the valley margins.

Vangorda/Grum Area

This section describes the hydrogeology of the Vangorda/Grum area of the FMC located within the upper portions of the Vangorda Creek Drainage.

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Grum Pit Area

Similar to the Faro Pit, the area around the Grum Pit has a low-permeability overburden (glacial till) unit overlying low-permeability bedrock. A second confined (limited extent) overburden unit, called the Thalweg aquifer, may also be present, which is composed of high-permeability sands and gravels, about 20 to 30 m thick. Above the bedrock contact, a permeable unit of unknown extent may also be present and may be connected to the Thalweg aquifer (RGC, 1996). Groundwater investigations in 2009 (SRK, 2010) in the south and west of Grum Pit identified calcareous phyllite of the Vangorda Formation underlying silty to sandy glacial till in both areas. Three hydrostratigraphic units were identified as consisting of a surficial silt, sand, and gravel unit; weathered bedrock; and competent bedrock (SRK, 2010).

West of the Grum Waste Dumps, Grum Creek and several tributaries drain towards Vangorda Creek. Generally, alluvial material is found deposited over till material with varying mixtures of sand, gravel, and clay. Weathered bedrock, transitioning to competent bedrock, provides the foundation. The thicker overburden and fluvial sediments of the Grum Creek Area have been interpreted to provide the greatest conduit for groundwater movement. At one borehole in the Grum Creek Area, two permeable water-bearing units were observed above the bedrock: a coarse-grained gravel and boulder layer and a sand and silt unit, separated by a low-permeability silt layer (RGC, 1996). Although limited data are available, a confined aquifer was identified at depths below approximately 12 m. Drainage from the Grum Waste Dump is anticipated to predominately flow towards the south/southeast, particularly in thicker overburden materials of Grum Creek and associated smaller tributaries (RGC, 1996).

Vangorda Pit Area

Similar to the Grum Pit Area, three hydrostratigraphic units appear to be identifiable in the Vangorda Pit Area. However, at Vangorda, there is an overlying confining, low-permeability overburden composed of silty, sandy glacial till (about 30 m thick) that sits atop a saturated sand and gravel unit overlying weathered bedrock that transitions into competent and lower-permeability calcareous phyllite. Several fault zones have been identified in the bedrock (RGC, 1996).

Similar to the Grum Creek Area, the greatest conduit for groundwater movement away from the Vangorda Waste Dumps is expected to be via sediments underlying the Vangorda Creek Area. Typically, overburden consisting of compact silty and sandy glacial till overlies a more permeable basal sand and gravel unit. Underlying this unit is the low permeability calcareous phyllite bedrock of the Vangorda Formation (RGC, 1996). In the investigated areas of Vangorda Creek Valley, fluvial sediments up to about 20 m thick show greater permeability. A confining unit of low-permeability till with silty to sandy composition overlies more permeable sand and weathered bedrock. The thickness of each unit varies but, combined, they are not typically greater than 30 m (SRK, 2010).

In general, water levels downgradient of the Grum/Vangorda Pits exhibit about 1 m of seasonal fluctuations. Groundwater in the alluvium appears deeper (about 7 to 10 m below ground surface) and shallower in the overburden (about 2 to 6 m below ground surface). Water levels reported for the bedrock are relatively stable, about 7 m below ground surface (AECOM, 2009).

Groundwater Quantity

To estimate groundwater flows in the Faro Mine Area, two calibrated groundwater flow models were used. Both of these models cover the entire upper Rose Creek drainage, but one is refined to perform detailed analysis in the RCTA, while the other supports refined analysis of the NFRC area.

A groundwater flow model has not been prepared for the Vangorda/Grum Area, and therefore greater uncertainty exists regarding the magnitude of groundwater flows in that area. However, the existing understanding of groundwater in the Vangorda/Grum Area is sufficient to support the assessment of IW activities because the main discharges to receiving waters for the IW period are expected to occur at the Faro Mine Area. Additional modeling for the Vangorda/Grum Area will be conducted to support the FMRP.

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Faro Mine Area

The model refined in the NFRC area was used to estimate steady state groundwater flow conditions in the approximately 4.2- km^2 area that contains the Northeast Rock Dump, NFRC, Zone II Pit and Outwash, and S-Wells areas (CH2M HILL, 2013). Results of this modeling analysis suggest that approximately 20 L/sec of groundwater flow moves through the aquifer system beneath the NFRC in this area. The analysis further indicated that the primary sources of recharge to the groundwater system include infiltration from precipitation, streams, and pits, as well as groundwater inflow from upstream areas, while the major components of groundwater outflow are discharges to streams and pits, pumping from wells (S-Wells SIS and Zone II Pit Well), and underflow to downstream areas.

Rose Creek Tailings Area

The model refined in the RCTA was used to estimate the steady state groundwater flow conditions in the 4.6-km^2 area encompassing the RCTA and the CVD. Results from this modeling analysis estimated groundwater flow through this area to be approximately 117 L/s. The analysis further indicated that the primary sources of recharge to the groundwater system include infiltration from precipitation and streams (RCD, Faro Creek Channel, and Rose Creek downstream of the CVD), as well as groundwater inflow from upstream areas. Major components of groundwater outflow are discharges to streams and drains (drainage channels downstream of the CVD), and underflow to areas further downstream in the Rose Creek Valley.

Vangorda/Grum Area

A calibrated groundwater flow model has not been prepared for the Vangorda/Grum Area, and therefore no quantitative analysis estimating rates of groundwater flow through the area has been performed. Well monitoring at the Vangorda/Grum Mine Site during the care and maintenance period suggested that groundwater flows from the various pits and WRDs into Vangorda Creek (in a predominately southern direction).

Before development of Grum Pit, a small lake existed at this location, representative of a pre-mining water table (RGC, 1996). The Thalweg aquifer along the north-northeast portion of the pit provides recharge to the pit. Groundwater flow is estimated to be in a predominately southerly direction.

The Vangorda Pit water level elevation averages 1,085 masl and had ranged between 1,074.6 and 1,094.1 masl since 2004 (DES, 2012a). Seasonal pumping maintains Vangorda Pit as a groundwater sink. Groundwater flow in the area is expected to be toward the south/southwest, predominately sourced from the sand and gravel units associated with Vangorda Creek and its associated small tributaries. As the water level in the pit is retained below surrounding groundwater elevations (as it will be for the long term), flow may be received from all directions.

Groundwater Quality

Groundwater quality throughout the FMC is changing and evolving because of ongoing geochemical processes within the waste rock dumps, the open pits, and tailings deposits. Ongoing studies have used concentrations of sulphate and zinc to classify water quality impacts at the site according to the concentrations outlined in Table 6-10. Impacts to groundwater quality across the FMC are summarized below. The relative levels of contamination are categorized according to the concentrations listed below for use in illustrating figures and differentiating areas of impact within the text.

TABLE 6-10
Summary of Concentrations used for the Classification of Groundwater Contamination
Faro Mine Interim Works

Groundwater Quality Classification	Mean SO_4 Concentration (mg/L)	Mean Zn Concentration (mg/L)
Not Impacted / Minimally Impacted	< 40	< 0.05
Slightly Impacted	40 – 400	0.05 – 0.5
Moderately Impacted	400 – 4, 000	0.5 – 5
Highly Impacted	> 4, 000	> 5

Faro Mine Area

Faro Pit

Faro Pit water quality is highly impacted with moderate sulphate concentrations (less than 1,000 mg/L) and high zinc concentrations (above 5 mg/L) for data reviewed between 1998 and 2012 (DES, 2012b). Contaminated water from the S-Wells SIS and from the Zone II Pit is currently pumped to Faro Pit. The quality of seep water flowing to Faro Pit (discharging from the Faro waste dumps) ranges from not impacted to highly impacted, as shown in Figure 6G-21. Sulphate levels in Faro Pit water have remained steady while zinc concentrations have steadily increased over the last decade. The most current field sampling results show that similar conditions are occurring in seepage from the Main Waste Dump at X23, as quality continues to deteriorate as sulphate, manganese, and dissolved metals concentrations increased and seepage became more acidic (RGC, 2013).

Northeast Rock Dumps Area

The Northeast Rock Dumps are located to the northeast of the Zone II Pit and southeast of the Faro Pit and cover an area of about 0.51 km^2, with a maximum elevation of 1,290 masl. The near pit dumps are located immediately to the south and southwest of the pit, just north of the Main and Intermediate Dumps, and cover an area of 0.2 km^2, with a maximum elevation of 1,200 masl (RGC, 1996). Groundwater quality at areas in the vicinity of the Northeast Waste Dump can be summarized as follows:

- Areas downgradient from the Northeast Waste Dumps: Three well pairs (BH12A/B, BH13A/B, and BH14A/B) are located at the toe of the Northeast Waste Dumps and are screened mainly in weathered bedrock and deeper bedrock (Figure 6G-26, Appendix 6G). Groundwater conditions in this area have worsened substantially over the last 10 years, and zinc concentrations up to about 10 mg/L have been detected at the well pair closest to Zone II (BH14A/B; highly impacted). The well pairs located farther northeast have moderate groundwater impacts. Mine-related contamination is expected to increase in this area and additional investigation is required to evaluate the extent of contamination (RGC, 2012).
- NFRC upgradient from Northeast Waste Dumps: Three wells are located near NFRC upgradient from Northeast Waste Dumps (P09-UN1 through P09-UN3) and are screened in alluvial sediments or weathered bedrock (Figure 6G-27, Appendix 6G). Here, sulphate concentrations are less than 200 mg/L and zinc concentrations up to 1 mg/L. The moderate contamination impacts shown in this area are a result of mine-impacted groundwater flow from the Northeast Waste Dumps (RGC, 2012).

North Fork of Rose Creek

The two most extensively studied areas within the NFRC Valley are the Zone II Outwash area and the S-Wells Area. Numerous wells have been installed in both locations to characterize the alluvial thickness, depth to bedrock, groundwater flow patterns, and groundwater quality. Groundwater quality has been substantially impacted in both the Zone II Outwash and S-Wells areas because of subsurface migration of mine-affected water from waste dumps in the Zone II Pit area and from the Intermediate Waste Dump, respectively. Field investigations conducted in 2013 suggest that the NFRC is a gaining stream along the majority of its length between its confluence with the FCD and the NFRD. These conditions suggest that groundwater contamination in the vicinity of the stream represents a viable pathway for contaminants of concern to enter the stream system and degrade surface water quality. To address this concern, a seepage interception system has been installed at the S-Wells site that consists of a shallow permeable trench and a series of deeper weathered bedrock extraction wells. Recent groundwater quality data also indicate that sulphate and zinc concentrations are increasing in groundwater at the base of the Northeast Waste Dump, suggesting that this area may also represent a conduit for metals loading to the NFRC.

Zone II Pit and Outwash Area

Groundwater in the waste-rock-filled Zone II Pit is managed (pumped) to mitigate potential seepage from the pit to the Zone II Outwash area. As discussed above, groundwater contamination in the vicinity of the Zone II area may travel along two potential pathways: groundwater contamination could discharge to NFRC, in which case it would likely bypass the RCAA through the RCDC; alternatively, it may travel as subsurface underflow, resulting in continued loading to the RCAA.

Water in the Zone II Pit (well X26) is highly impacted with fairly stable zinc concentrations. Sulphate concentrations have been more variable since 2008, likely because of more aggressive pumping. However, sulphate and zinc concentrations within the pit continue to increase. Zinc and sulphate loads collected from the Zone II Pit were 5.8 tonnes per year (tpy) and 184 tpy, respectively, in 2011. Between July and September 2012, loads collected from the pit were approximately 3 tpy of zinc and 134 tpy of sulphate. Contaminant concentrations at X26 tend to be lower in the spring when meteoric water inputs are greater (RGC, 2012).

In the alluvial aquifer within the Zone II Outwash area, two wells are highly impacted, five wells are moderately impacted, one well is slightly impacted, and one well is not impacted. In the bedrock aquifer, four out of five monitored wells are moderately impacted and one is highly impacted. Most groundwater both in the shallow and bedrock aquifers in the Zone II Outwash is moderately impacted, with some highly impacted groundwater near the toe of the waste dump (locations BH2, BH6, and BH8). Concentrations have generally remained stable or show gradual increasing trends in Zone II Outwash wells over the monitoring period. Monitoring wells to the north of Zone II Outwash have had substantial mine-related contamination increases in recent years. The *2012 Groundwater Quality Review* (RGC, 2013) suggests that the breakthrough of more highly contaminated groundwater might occur in this area from the toe of the Intermediate Waste Dump to the west.

S-Wells Area

Contaminated groundwater daylights both as seeps along the Intermediate Waste Dump face to the north of the S-Wells Area and also flows south toward NFRC within alluvial, weathered bedrock, and bedrock aquifers. Groundwater contamination in this area discharges to NFRC and could contribute loading to the RCAA as leakage from the NFRC or RCD further downstream. The 2008 S-Cluster groundwater investigation (SRK, 2009) concluded "the plume of contaminated groundwater [in S-Wells Area] is likely moving underneath the NFRC in permeable materials and discharging to the NFRC at indeterminate locations."

In general, groundwater in the S-Wells Area is moderately to highly impacted, with some slightly impacted alluvial and overburden locations on the far eastern portion of the site. The shallow groundwater system generally has the highest contamination, with 11 out of 21 wells classified as highly impacted (and 8 wells classified as moderately impacted). Groundwater contamination does extend into the bedrock as well, with highly impacted groundwater detected in one bedrock well (SRK-08-SPW2) and moderately impacted groundwater detected in the remaining bedrock wells (RGC, 2012).

An SIS was constructed in 2009 to intercept contaminated groundwater flowing from the Intermediate Waste Dump before it reached NFRC. It consists of three parts (RGC, 2012):

- A shallow rock-filled interceptor trench located in the shallow aquifer (overburden) with one pumping well (SRK08-PW3).
- Two pumping wells (SRK08-SPW1 and SRK08-SPW2) screened in the deeper bedrock aquifer. However, only one well typically operates because the other well contains high iron concentrations. Addition of this flow stream containing high iron concentrations to the discharge from the other S-Wells extraction facilities has historically resulted in extensive iron fouling of the conveyance pipelines and more intensive associated operations and maintenance requirements.
- Surface water interception via a rock drain at the toe of the Intermediate Waste Dump, which diverts water to the shallow aquifer interceptor trench.

S-Wells SIS water is pumped to the Faro Pit and currently operates year-round (RGC, 2012). Zinc and sulphate loads in 2011 captured by the S-Wells SIS were 21.3 tpy and 300 tpy, respectively. Between May 2012 and December 2012, 17.8 tonnes of zinc and 272.5 tonnes of sulphate were captured at the S-Wells SIS.

Groundwater quality in wells classified as slightly to moderately impacted has relatively stable concentration trends. However, water quality in some wells along the southern toe of the Intermediate WRD continues to deteriorate gradually (SRK05-SP1A/B and SRK05-SP2). Groundwater quality in the till unit, located to the west of the SIS, also continues to degrade (this water is not captured by the SIS). Groundwater quality in the bedrock aquifer is improving

overall as a result of pumping the S-Wells SIS bedrock wells. However, operation of the shallow aquifer interceptor trench of the S-Wells SIS has not made a noticeable impact on shallow groundwater quality (RGC, 2012).

Emergency Tailings Area

The ETA has some of the most highly contaminated groundwater and surface water in the Faro Mine Area and represents a major source of contaminant loading to the RCAA (AECOM, 2009). Flow monitoring and sampling completed in 2005 and 2006 along Faro Creek below the ETA indicated that the total zinc load discharged from the ETA (surface flow and subsurface seepage discharging downstream from the mine access road) ranged from about 35 to 80 tpy (RGC, 2007). The contaminated seepage is a combination of surface flow originating as toe seepage from the Main WRD and groundwater flow from the WRD through highly permeable alluvial sediments from the Old Faro Creek. The ETA tailings also contribute significantly to the groundwater and surface water contaminant loading (SRK, 2006). Seeps discharging to the ETA at the base of the Main Waste Dump, which combine with flowing surface water across the ETA in Old Faro Creek and Mill Canyon Creek, are highly impacted and show increasing contaminant load trends as evidenced by the water quality at X23.

Surface water and groundwater qualities in the ETA show increasing trends for acidity, sulphate, and zinc, and these trend are expected to continue. Seepage from the Main WRD has become noticeably more acidic over the last 3 years, suggesting ongoing breakthrough of acid rock drainage products and a decline in the buffering capacity of the Main WRD waste rock and ETA alluvial soils (RGC, 2012). In 2006, an interim SIS was constructed at the southeast end of the ETA (downgradient from the mine access road) to collect surface water runoff and seepage (from two prominent seeps). The SIS operates during the ice-free seasons, and collected water is pumped to the Faro Water Treatment Plant or the Faro Pit. The ETA SIS intercepted an estimated 31.2 tpy of zinc and 488 tpy of sulphate in 2011 and an estimated 86 tpy of zinc and 940 tpy of sulphate in 2012. Seepage not intercepted by the SIS was observed discharging directly to the Faro Creek Canyon. Overburden and weathered bedrock groundwater quality and surface water quality downstream from the ETA is highly impacted (locations P09-ETA2 and FCS-4), and the seasonal operation of the ETA SIS does not appear to be improving this condition. However, groundwater in deep bedrock downgradient of the ETA does not show indications of mine-related contamination based on data from monitoring well P09-ETA1 (RGC, 2012).

Rose Creek Tailings Area

Generally, clean groundwater from the south and southeast flows to the RCTA, and contaminated groundwater flows from the Faro Mine to the RCTA from the north, with a significant portion of contamination associated with the Faro Creek Canyon. Locally, the tailings contribute to groundwater contamination in the RCTA as well. The extensive leakage of clean water from the RCDC (south of the RCTA) has a major influence on the spatial water quality trends in the RCAA, especially further downgradient near the CVD. In the western half of the RCTA, there is a significant spatial trend from south to north of not impacted groundwater transitioning to moderately impacted groundwater.

Groundwater quality in the Original and Second Impoundment area ranges from not impacted to highly impacted, with the highest sulphate and zinc concentrations occurring in the tailings. Higher concentrations are generally observed in groundwater in the northern portion of the RCAA likely because of contaminant discharges from the Faro Creek Canyon. The upper portions of the underlying alluvial aquifer are highly-impacted. The highest sulphate and zinc concentrations are detected in tailings porewater in the southeastern (multilevel wells P03-01 and P03-03) and northwestern (multilevel well P03-06) areas of the Second Impoundment. Zinc concentrations tend to be highest near the interface of the sand and gravel RCAA and the overlying tailings. Groundwater contamination in the far southeast section of the impoundment areas is thought to be mainly a result of direct tailings-related contamination (RGC, 2012).There are continued increases in contamination in the alluvial aquifer near the mouth of Faro Creek Canyon (multilevel well P03-06), which is a primary flow path for contamination from the Faro Mine Area to the RCTA. Groundwater in the Intermediate Impoundment Area ranges from not impacted to highly impacted as well, with the highest sulphate and zinc concentrations in the tailings. Sulphate and zinc concentrations are very high in shallow tailings porewater and have been relatively stable for the last 10 years. In contrast, alkalinity and pH have decreased substantially in the tailings porewater since 2009, indicating a breakthrough of the acid front in the Intermediate Impoundment area (RGC, 2012).

Groundwater at the toe of the ID is moderately impacted in the alluvium and till. Concentrations of mine-related contaminants have generally increased since 2001 in this area, and seepage from the coarse tailings beaches of the upgradient impoundments and input from the Faro Creek Canyon are likely sources. Conditions are expected to deteriorate in the coming years as the groundwater contamination front in the RCTA progresses. Groundwater in the southern portion of the area is generally less contaminated than in the northern portion because of the inflow of clean groundwater leaking from the RCDC to the south. However, concentrations in this area do show a significant trend of increasing sulphate, iron, magnesium, and manganese. It is believed that the mine-related total dissolved solids (TDS) plume front has reached this area.

Groundwater on the southern edge of the Rose Creek Valley, downgradient from the CVD, remains only slightly impacted by mine-related groundwater contamination. Groundwater contamination in the northern area has higher sulphate and magnesium concentrations, indicative of the leading edge of the TDS plume. Concentrations of sulphate and metals are gradually increasing in shallow groundwater along the north side of the valley downgradient of the CVD, but zinc concentrations remain low (less than 0.05 mg/L).

Groundwater farther downgradient from the CVD (wells X16A/B) is not impacted. However, the well pair upgradient from this location (X17A/B) has had increases in mine-related contamination since 2008, which is likely to continue. This water is now within the slightly impacted range, indicating continued movement of the leading edge of the TDS plume front down the valley (RGC, 2012).

Vangorda / Grum Area

Most groundwater monitoring locations in the Vangorda/Grum Area are between the toes of the waste dumps and Vangorda Creek. In general, the Vangorda/Grum Area is characterized by low-permeability materials with some higher permeability alluvial material associated with current and former stream channels. Therefore, seepage from waste dumps is expected to follow preferential flow paths.

Vangorda Pit and Area

As the Vangorda Pit is considered a groundwater sink, drainage of contaminants into Vangorda Creek is not expected so long as the pit is maintained at current or lower water levels. The pit water quality is highly impacted based on elevated zinc concentrations. Since 2000, sulphate and zinc concentrations at the surface of Vangorda Pit have been steadily increasing. Groundwater within the Vangorda WRD is moderately to highly impacted, with contaminant concentrations increasing downgradient of the WRDs despite the till berms installed to reduce seepage. The highest zinc concentrations are detected in more permeable alluvial sediments (associated with preferential flow paths) and have recently increased near the northwestern toe of the Vangorda Rock Dump (RGC, 2013). Weathered bedrock and bedrock at the toe of the Vangorda Waste Dump have slightly impacted groundwater with less sulphate than detected in the overburden (RGC, 2012).

Grum Pit and Area

Grum Pit is expected to be a groundwater sink and is not considered a source of contamination to the Vangorda Creek drainage as long as the water is kept contained. The pit water quality is considered highly impacted, based on elevated zinc concentrations. Groundwater quality in the overburden of the Grum waste rock areas is highly impacted by elevated zinc concentrations. In the underlying bedrock, sulphate concentrations are elevated, indicating the groundwater is moderately impacted in these areas. Seep and shallow groundwater collecting at the toes of the waste rock dump and within the Grum Creek channel are slightly to moderately impacted. Overall, shallow overburden and bedrock groundwater quality around the waste rock dumps continues to deteriorate, with deeper bedrock groundwater currently remaining unaffected. Sulphate and other TDS plume parameters have migrated into the Vangorda Creek Valley and do extend beyond specific drainage channels, but zinc concentrations are still low in the area (typically less than 0.05 mg/L) (RGC, 2012).

6.2.4.3 Surface Water Quality

Introduction

Physical and chemical parameters of surface water quality are important indicators of natural and mine-related geochemical processes, and affect the distribution and characteristics of vegetation and aquatic biota. Data collected

between 2008 and 2012 from various surface water monitoring stations were compiled to characterize current conditions at the FMC. Water monitoring stations within the LSA included streams within approximately 500 m of the mine disturbance footprint, incorporating parts of Rose Creek (North and South forks), Faro Creek, and Vangorda Creek. The RSA for water quality assessment encompassed the maximum spatial extent of potential, measurable, project-related influence, including the areas of Rose and Vangorda Creeks downstream of the LSA, Anvil Creek, and areas of the Pelly River immediately upstream and downstream from the mouths of Anvil Creek and Vangorda Creek.

The following sections summarize data analysis methods and results. Additional details are available in Appendix 6H, the Aquatic Baseline Characterization Report.

Water Quality Monitoring Stations

Water quality data were collected and reviewed for 7 reference stations, 20 mine-exposed stations, 4 stations on the Pelly River, and 2 First Nations drinking water stations (Figure 6-3). Reference stations were located upstream of any mine influence. Mine-exposed stations were located on the NFRC, SFRC, Rose Creek, Anvil Creek, and Vangorda Creek, where water quality is or has the potential to be influenced by surface water or groundwater draining from various waste rock piles, pits, ponds or tailings. Data from monitoring stations on the Pelly River were used to determine whether any mine-related influences on water quality from the Vangorda and/or the Anvil-Rose Creek drainages could be detected in the Pelly River. The First Nations drinking water stations were used to determine human health risks that may be resulting from mine runoff.

Water Quality Parameters

The characterization of existing water quality conditions focused on analytes that previous studies at the FMC had identified as being indicative of mine-related influence (Minnow, 2007 and 2010), as well as supporting analytes that contribute to water quality interpretation:

- 14 metals: cadmium, calcium, magnesium, nickel, potassium, silver, sodium, strontium, cobalt, iron, lead, manganese, uranium, and zinc.
- 10 non-metal parameters: alkalinity, ammonia, hardness, nitrate, sulphate, total organic carbon, dissolved organic carbon, total dissolved solids (TDS), TSS, and turbidity.
- 2 field-measured water chemistry parameters: pH and conductivity.

Data Analysis Approach

To facilitate comparisons of water quality data between mine-exposed and reference data, reference data were pooled to compute the minimum, maximum, median, mean, standard deviation, and 5th and 95th percentiles for each analyte. The 5th and 95th percentiles were considered to represent the lower and upper range of background concentrations, respectively. Data from mine-exposed monitoring stations were compared to guidelines for the protection of aquatic life. Wherever possible, the CCME *Canadian Water Quality Guidelines for the Protection of Aquatic Life* were used (CCME, 2013). Alternate guidelines were used (e.g., Environment Canada or British Columbia Ministry of the Environment) where a CCME guideline was not available, or where a more recent/applicable guideline was available. Where water quality guidelines required calculation based on water hardness, median hardness at each station was used to derive a station-specific guideline. For the First Nations drinking water stations, analytes were compared with Health Canada's Guidelines for Canadian Drinking Water (Health Canada, 2010).

Background Water Quality

Data collected from the reference stations at the FMC were summarized to characterize the background water quality (Table 6-11). Reference streams tended to be slightly basic, with a median pH of 7.7 (ranging between 5.2 and 9.15). Water hardness was relatively low, with a median concentration of 48 (mg/L expressed as calcium carbonate ($CaCO_3$), but concentrations as high as 251 mg/L were observed among individual samples. Organic carbon was relatively low and mainly in the dissolved form (dissolved organic carbon and total organic carbon concentrations were approximately equivalent), with a median dissolved concentration of 2.4 mg/L. TSS and turbidity also tended to be low (less than 1.0 mg/L and 0.5 Nephelometric Turbidity Units [NTUs], respectively), but ranged up to 400 mg/L and 6.2 NTU, respectively, typically associated with spring snowmelt or large rain events.

TABLE 6-11

Water Quality Summary Statistics for Pooled Reference Station Data (V1, VR, USFR, R7, FC, R6, W10) [a], FMC, Yukon.

Faro Mine Interim Works

	Analyte	Units	n	Minimum	Maximum	Median	Mean [b]	Standard deviation [b]	Lower Background Benchmark (5th percentile)	Upper Background Benchmark (95th percentile)
Non-Metals	Alkalinity, Total	mg/L	209	5.1	160	40.1	55.1	43.3	10.0	150
	Ammonia-N	mg/L	225	<0.005	0.36	0.01	0.018	0.033	-	0.054
	Conductivity, Field	µS/cm	164	4.4	620	110	137	101	-	292
	Hardness, Total ($CaCO_3$)	mg/L	237	8.2	251	48.0	64.2	48.4	-	159
	Nitrate-N	mg/L	166	<0.002	0.24	0.04	0.06	0.06	-	0.20
	Organic carbon, Dissolved	mg/L	149	<0.5	30.3	2.4	4.4	5.8	0.8	19.0
	Organic carbon, Total	mg/L	151	<0.5	27.8	2.3	4.2	5.4	0.7	15.0
	pH, Field	pH units	184	5.23	9.15	7.73	7.65	0.56	6.6	8.4
	Sulfate	mg/L	234	0.3	25	7.4	8.0	6.0	-	21.5
	Total dissolved solids	mg/L	202	16	300	64	82	50	-	180
	Total suspended solids	mg/L	227	<1	400	<1	7	32	-	20
	Turbidity, Lab	NTU	67	<0.1	6.2	0.53	0.77	1.02	-	2.23
Metals	Cadmium, Total	mg/L	212	<0.000005	0.000348	0.0000120	0.0000256	0.0000396	-	0.000107
	Calcium, Total	mg/L	230	2.47	74.6	14.9	19.0	13.8	-	45.7
	Cobalt, Total	mg/L	207	0.000006	0.00127	0.0000300	0.0000756	0.000168	-	0.000248
	Iron, Total	mg/L	227	<0.001	3.15	0.082	0.15	0.31	-	0.46
	Lead, Total	mg/L	228	<0.000005	0.017	0.000215	0.000600	0.00152	-	0.00203
	Magnesium, Total	mg/L	228	0.27	15.8	2.52	3.86	3.37	-	11.0
	Manganese, Total	mg/L	229	<0.00005	0.212	0.00609	0.0126	0.0230	-	0.0378
	Nickel, Total	mg/L	230	0.00015	0.0107	0.00034	0.00052	0.00092	-	0.0011
	Potassium, Total	mg/L	221	<0.05	2.18	0.55	0.67	0.41	-	1.39
	Sodium, Total	mg/L	226	<0.05	4.9	1.84	1.86	0.66	-	3.08
	Strontium, Total	mg/L	222	0.0168	0.251	0.0681	0.0781	0.0466	-	0.175
	Uranium, Total	mg/L	225	<0.000002	0.00619	0.000683	0.000975	0.000907	-	0.00251
	Zinc, Total	mg/L	230	<0.0001	0.0389	0.0021	0.0039	0.0057	-	0.014

Notes:

[a] Data for individual reference stations are summarized in Attachment Tables B.2 - B.8 in Appendix 6H.

[b] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

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Water Quality at Mine-Exposed Areas Relative to Background Levels

Analytes that were identified in previous studies at the FMC as having elevated concentrations (in relation to background) remained elevated in at least 10 percent of monitoring samples collected at one or more of the stations located downstream of mine disturbances in 2008-2012 (Table 6-12). Alkalinity, conductivity, hardness, sulphate, total dissolved solids, calcium, cobalt, magnesium, nickel, sodium, strontium, and zinc were observed at concentrations above the background concentration range in approximately half or more of samples collected downstream of the Vangorda/Grum Area (station V8) and the Faro Mine Area (station X14, Tables 6-12, 6-13). While the FMC is the main source of many of these variables to downstream areas, natural sources (e.g., landslide on West Vangorda Creek; bank erosion) also contribute to elevated downstream water concentrations of some analytes, such TSS, turbidity, iron, and manganese.

Elevated hardness, sulphate, manganese, and potassium concentrations were detected to the mouths of both Vangorda Creek and Anvil Creek.

Water Quality Relative to Guidelines

Non-Metals

Ammonia, sulphate, nitrate, and pH concentrations were always or almost always within guidelines (Table 6-12). Guidelines for TSS and turbidity are based on a shift from mean or median background levels, rather than specific effect thresholds; detailed evaluation of the data indicated limited mine-related influence on downstream concentrations of these substances (Appendix 6H, the Aquatic Environment Baseline Report).

Metals

Cadmium, cobalt, iron, lead, manganese, uranium, and zinc were the metals found at concentrations above guidelines in 10 percent or more of samples collected at one or more stations downstream of mine disturbances (Table 6-13). The pattern of iron concentration data among stations indicated that elevated concentrations were mainly associated with sources outside of the FMC. Zinc was the mine-related metal most frequently exceeding guidelines in water samples collected from stations in the Rose-Anvil system and in Vangorda Creek. A localized source for cadmium, cobalt, iron, lead, manganese, and zinc was indicated near station NF1 on the NFRC, as fewer guideline exceedances were observed at the next station downstream (NF2). Cobalt, manganese, and zinc concentrations were also above guidelines in some samples collected at Station X14 on Rose Creek (Table 6-14).

Pelly River

Water concentrations measured at Pelly River monitoring stations were compared upstream and downstream of both Vangorda and Anvil Creeks for analytes that are reliable indicators of FMC-related disturbance on water quality (i.e., alkalinity, sulphate, manganese, and zinc). Overall, there were no significant differences in mean concentrations of alkalinity, sulphate, and zinc among stations. Mean manganese concentrations downstream from Vangorda Creek were lower than those at the upstream Pelly River reference station P1. These data indicate FMC-related influences on water quality do not currently extend into the Pelly River.

First Nations Drinking Water Stations

2008 to 2012 water quality data were reviewed for two First Nation drinking water stations, one located on SFRC (at the Access Road culvert) and a second located on a tributary to the SFRC (at the Access Road culvert). At these stations, organic carbon, turbidity, iron, and/or manganese concentrations occasionally exceeded Health Canada's Guidelines for Canadian Drinking Water (Health Canada, 2010).

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6.2.5 Aquatic Ecosystems and Resources

6.2.5.1 Introduction and Study Areas

Aquatic environment conditions have been studied at the FMC throughout its operation, receivership, and C&M phases. Reports describing those studies were reviewed and summarized to characterize the existing aquatic ecosystem conditions for the FMC. These conditions are summarized in the following subsections and are described in detail in Appendix 6H, the Aquatic Baseline Characterization Report. Studies that included the following information were reviewed:

- Habitat characteristics and descriptions
- Stream sediment quality
- Periphyton communities
- Benthic invertebrate communities
- Fish distributions and relative abundances

These investigations have focused primarily on watercourses within a defined aquatic environment LSA (as described in Appendix 6H) that includes streams within approximately 500 m of the FMC disturbance footprint. This area includes parts of Rose Creek (North and South forks), Faro Creek, and Vangorda Creek.

Information was also reviewed for streams within the RSA, including Rose and Vangorda Creeks downstream from the LSA, Anvil Creek, and areas of the Pelly River immediately upstream and downstream from the mouths of Anvil Creek and Vangorda Creek. Figure 6-4 shows the location of these watercourses and study areas in relation to the FMC.

6.2.5.2 Stream Habitat Descriptions

Regionally, the Rose-Anvil and Vangorda Creek watersheds affected by the FMC encompass an area of 980 km^2 and 90 km^2 and contribute 2 percent and 0.2 percent of the Pelly River watershed, respectively. The Pelly River watershed has a total drainage area of 49,000 km^2.

North Fork Rose Creek

The NFRC flows through the FMC from north of the Faro Mine Area, approximately 17 km upstream from the Haul Road (Figure 6-5). It originates in a wetland area that also drains towards the Tay River watershed. Several instream ponds are located near the headwaters. The NFRC channel ranges from segments 2 to 3 m deep and less than 5 m wide to those from 0.2 to 0.8 m deep with wider flat glades with braiding (Table 6-15) (WMEC, 2005b). Generally, the upper reaches of the NFRC are dominated by large cobble and boulder habitats that transition to finer substrates closer to the confluence with the FCD. A small lake is located on a branch flowing into the NFRC, which flows out through a steep creek that is impassable to fish (WMEC, 2005b).

Downstream from the FCD, the NFRC ranges from 8 m to 12 m wide and has gradients between 0.2 percent and 2.0 percent (Table 6-15). The stream morphology within this reach is riffle-pool, and the channel is frequently confined (de Graff, 2013). An instream pond is located just upstream from the Haul Road; this pond is approximately 250 m by 115 m in spring, but becomes smaller under lower seasonal flows (WMEC, 2005a). The depths of the pond fluctuate accordingly, declining from 4 m in the spring to approximately 1 m in late summer (WMEC, 2005b). The NFRC flows beneath the Haul Road through a constructed rock drain that is impassable to fish.

Downstream from the Haul Road, the NFRC is predominantly confined, approximately 8.5 m wide, and has gradients ranging from 0.4 percent to 1.6 percent (Table 6-15). This section of NFRC is primarily of riffle-pool morphology, with an area of cascade-pool (de Graff, 2013).

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TABLE 6-12

Analytes with concentrations above the corresponding upper background benchmark (95th percentile of reference data) in more than 10% of samples [a] at mine-exposed stations, 2008 - 2012

Faro Mine Interim Works

Analyte		Percent of Samples > Background Benchmark																		
		Vangorda Creek Stations								Rose-Anvil Creek Stations										
		V27	V4	VGMAIN	VW3	VW1	VW2	V5	V8	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-metals	Alkalinity, Total		95%	35%	ID	50%	ID	80%	51%										23%		
	Ammonia-N		25%		ID	30%	ID	14%						12%		21%	15%		72%		
	Conductivity, Field	79%	97%	ID	ID	ID	ID	91%	91%			14%	17%	21%		24%	18%	23%	83%	73%	35%
	Hardness, Total (CaCO3)	74%	91%	75%	ID	ID	ID	91%	82%				25%		15%		17%	29%	72%	46%	50%
	Nitrate-N	71%		ID	ID		ID	15%	42%		28%	30%	ID	44%	32%		29%	37%		30%	29%
	Organic carbon, Dissolved			ID	ID	ID	ID									ID				ID	
	Organic carbon, Total			ID	ID	ID	ID		11%												18%
	pH, Field				ID	ID	ID	15%	13%												
	Sulfate	100%	96%	100%	ID	100%	ID	100%	100%				12%	11%	41%	38%	46%	57%	99%	100%	86%
	Total dissolved solids	79%	95%	ID	ID	ID	ID	88%	88%				21%		14%	21%		27%	84%	60%	44%
	Total suspended solids				ID	30%	ID	50%	32%							15%					25%
	Turbidity, Lab		11%		ID	ID	ID	67%	41%				ID		11%	ID			40%	ID	ID
Metals	Cadmium, Total	24%		83%	ID	ID	ID	35%	43%				23%					19%	28%		12%
	Calcium, Total	71%	87%	67%	ID	50%	ID	82%	76%				29%		12%	16%	11%	24%	73%	46%	44%
	Cobalt, Total	11%		89%	ID	ID	ID	59%	46%			29%	75%	14%	28%	24%			100%	63%	27%
	Iron, Total		12%		ID	ID	ID	40%	22%				18%			38%		12%	26%		27%
	Lead, Total			16%	ID	ID	ID	26%	20%		10%		44%	16%	22%	14%			12%	13%	12%
	Magnesium, Total	80%	94%	83%	ID	ID	ID	98%	97%				13%		15%		12%	28%	66%	40%	33%
	Manganese, Total		66%	20%	ID	70%	ID	48%	25%				81%	36%	64%	63%	67%	45%	100%	77%	56%
	Nickel, Total	14%	19%	63%	ID	ID	ID	98%	92%				25%	11%	23%	17%	13%	20%	97%	69%	46%
	Potassium, Total			20%	ID	20%	ID	31%	19%						13%	32%	10%		49%	38%	62%
	Sodium, Total	51%	57%	43%	ID	50%	ID	61%	57%	18%	19%	23%	29%	25%	27%	27%	31%	19%	74%	58%	41%
	Strontium, Total	65%	93%	63%	ID	ID	ID	88%	75%	13%	27%	27%	31%	31%	30%	41%	39%	44%	68%	42%	30%
	Uranium, Total	56%	91%	68%	ID	60%	ID	83%	81%	11%	18%	24%	20%	27%	24%	25%	27%	28%	26%	20%	19%
	Zinc, Total	94%		86%	ID	20%	ID	33%	48%			14%	59%	37%	73%	17%	50%	86%	97%	48%	10%

Notes:

ID - insufficient data (n<10 samples)

[a] And station median was above background median.

Blank cells represent variables for which <10% of samples were elevated relative to the upper background benchmark

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TABLE 6-13
Median analyte concentrations at mine-exposed stations compared to the upper background benchmark (2008-2012)
Faro Mine Interim Works

Analyte		Units	Reference		Vangorda Creek							
			Median	95th Percentile	V27	V4	VGMAIN	VW3	VW1	VW2	V5	V8
Non-metals	Alkalinity, Total	mg/L	40	150	83.5	280	134	56a	152	305a	200	152
	Ammonia-N	mg/L	0.010	0.054	0.010	0.031	0.011	0.018a	0.018	0.005a	0.022	0.020
	Conductivity, Field	µS/cm	110	292	513	545	325a		267a	422a	501	552
	Hardness, Total (CaCO3)	mg/L	48	159	270	336	235	72a	197a	391a	274	301
	Nitrate-N	mg/L	0.04	0.20	0.60	0.07	0.23a	0.17a	0.12	0.16a	0.09	0.15
	Organic carbon, Dissolved	mg/L	2.4	19.0	1.6	4.3	12.6a				4.3	2.9
	Organic carbon, Total	mg/L	2.3	15.0	1.7	4.5	8.73a	10.7a	10.6a	6.97a	3.7	2.85
	pH, Field	pH units	7.7	8.4	8.1	8.0	8.1		8.0a	8.2a	8.2	8.0
	Sulfate	mg/L	7.4	21.5	163.0	56.8	130.0	33.5a	46.2a	95.6a	80.5	121.5
	Total dissolved solids	mg/L	64	180	340	372	255a	120a	220	430a	325	360
	Total suspended solids	mg/L	<1	20	1.0	2.0	1.0	11.2a	7.5a	2.0a	22.8	4.1
	Turbidity, Lab	NTU	0.53	2.2	0.3	1.6	0.3	4.0a		0.6a	5.6	1.5
Metals	Cadmium, Total	mg/L	0.000012	0.000107	0.000066	0.000022	0.000200	0.000209a	0.000015	0.000115a	0.000071	0.000078
	Calcium, Total	mg/L	14.9	45.7	65.0	83.0	64.8	19.5a	47.0	96.3a	65.5	69.5
	Cobalt, Total	mg/L	0.000030	0.000248	0.00003	0.00007	0.00100	0.00029a	0.00011	0.00002a	0.00041	0.00020
	Iron, Total	mg/L	0.082	0.46	0.04	0.24	0.07	0.23a	0.13	0.01a	0.24	0.12
	Lead, Total	mg/L	0.00022	0.00203	0.00039	0.00022	0.00100	0.00128a	0.00022	0.00006a	0.00109	0.00100
	Magnesium, Total	mg/L	2.52	11.0	24	30.2	20.2	5.86a	17.3	36.1a	24.85	24.9
	Manganese, Total	mg/L	0.00609	0.0378	0.0037	0.0454	0.0080	0.0132a	0.0689	0.0004a	0.0362	0.0160
	Nickel, Total	mg/L	0.00034	0.0011	0.0008	0.0008	0.0016		0.0006	0.0012a	0.0023	0.0020
	Potassium, Total	mg/L	0.55	1.39	0.86	1.06	1.04	0.56a	0.89	1.04a	1.20	1.09
	Sodium, Total	mg/L	1.84	3.08	3.1	3.2	2.7	1.0a	3.2	2.5a	3.5	3.5
	Strontium, Total	mg/L	0.0681	0.175	0.230	0.337	0.259	0.091a	0.203	0.327a	0.264	0.275
	Uranium, Total	mg/L	0.000683	0.00251	0.0034	0.0099	0.0036	0.0011a	0.0026	0.0072a	0.0038	0.0041
	Zinc, Total	mg/L	0.0021	0.014	0.0309	0.0036	0.0230	0.2383a	0.0034	0.0048a	0.0089	0.0141

TABLE 6-13
Median analyte concentrations at mine-exposed stations compared to the upper background benchmark (2008-2012)
Faro Mine Interim Works

Analyte		Units	Reference		Rose Creek / Anvil Creek											
			Median	95th Percentile	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-metals	Alkalinity, Total	mg/L	40	150	93	97	98	83	96	94	89	97	109	97	113	120
	Ammonia-N	mg/L	0.010	0.054	0.020	0.021	0.020	0.020	0.014	0.015	0.018	0.030	0.020	0.078	0.010	0.005
	Conductivity, Field	µS/cm	110	292	179	202	207	187	221	204	198	222	216	500	411	243
	Hardness, Total (CaCO3)	mg/L	48	159	97	108	104	91	109	108	97	115	130	217	156	161
	Nitrate-N	mg/L	0.04	0.20	0.08	0.13	0.13		0.19	0.14	0.07	0.15	0.16	0.06	0.12	0.10
	Organic carbon, Dissolved	mg/L	2.4	19.0	2.2	2.1	2.3	3.2	2.2	2.3	3.9[a]	2.3	2.2	2.6	1.7[a]	3.6
	Organic carbon, Total	mg/L	2.3	15.0	2.2	2	2.35	3.2	2.1	2.29	2.76	2.24	2.4	2.6	2.7	3.92
	pH, Field	pH units	7.7	8.4	7.8	7.7	7.7	7.5	7.5	7.6	7.8	7.7	7.8	7.9	7.4	7.9
	Sulfate	mg/L	7.4	21.5	8.1	13.3	12.8	12.0	15.8	17.1	20.0	20.0	23.2	130.0	56.0	43.0
	Total dissolved solids	mg/L	64	180	114	130	129	120	137	130	140	132	148	310	247	180
	Total suspended solids	mg/L	<1	20	1.0	1.0	1.0	4.0	1.0	1.4	3.0	1.0	1.0	2.0	1.0	3.5
	Turbidity, Lab	NTU	0.53	2.2	0.8	0.7	0.8		0.8	0.9	2.9[a]	0.8	0.9	1.8	0.5[a]	13.9
Metals	Cadmium, Total	mg/L	0.000012	0.000107	0.000009	0.000011	0.000014	0.000043	0.000024	0.000026	0.000021	0.000018	0.000020	0.000060	0.000032	0.000030
	Calcium, Total	mg/L	14.9	45.7	29.6	33.6	31.8	30.6	30.1	30.8	28.0	33.5	36.3	61.2	45.0	43.2
	Cobalt, Total	mg/L	0.000030	0.000248	0.00004	0.00004	0.00006	0.00040	0.00012	0.00017	0.00010	0.00010	0.00008	0.00171	0.00034	0.00013
	Iron, Total	mg/L	0.082	0.46	0.14	0.14	0.14	0.30	0.16	0.19	0.38	0.17	0.24	0.38	0.15	0.15
	Lead, Total	mg/L	0.00022	0.00203	0.00049	0.00052	0.00039	0.00188	0.00093	0.00100	0.00039	0.00060	0.00048	0.00078	0.00038	0.00030
	Magnesium, Total	mg/L	2.52	11.0	5.73	6.61	6.11	5.22	6.72	6.47	5.69	7.17	8.74	14.45	9.72	10.4
	Manganese, Total	mg/L	0.00609	0.0378	0.0164	0.0176	0.0181	0.0722	0.0286	0.0623	0.0607	0.0505	0.0353	1.2700	0.3135	0.0468
	Nickel, Total	mg/L	0.00034	0.0011	0.0004	0.0004	0.0005	0.0009	0.0006	0.0009	0.0006	0.0006	0.0008	0.0032	0.0015	0.0010
	Potassium, Total	mg/L	0.55	1.39	0.79	0.84	0.81	0.76	0.86	0.90	0.95	1.00	1.00	1.38	1.28	1.42
	Sodium, Total	mg/L	1.84	3.08	2.2	2.2	2.3	2.1	2.5	2.2	2.3	2.4	2.4	4.3	3.4	2.8
	Strontium, Total	mg/L	0.0681	0.175	0.120	0.133	0.133	0.110	0.142	0.124	0.151	0.157	0.164	0.224	0.157	0.154
	Uranium, Total	mg/L	0.000683	0.00251	0.0014	0.0015	0.0015	0.0009	0.0015	0.0013	0.0017	0.0017	0.0017	0.0014	0.0011	0.0018
	Zinc, Total	mg/L	0.0021	0.014	0.0025	0.0038	0.0068	0.0190	0.0106	0.0240	0.0050	0.0143	0.0287	0.0493	0.0140	0.0048

Notes:

[a] limited data (n<10)

Shaded values indicate median concentration was greater

TABLE 6-14

Percentage of samples collected from mine-exposed stations with analyte values above water quality criteria

Faro Mine Interim Works

Analyte		Vangorda stations								Rose-Anvil stations											
		V27	V4	VG MAIN	VW3	VW1	VW2	V5	V8	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-metals	Ammonia-N	0%	5%	0%	0%a	0%	0%a	4%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%b	0%	0%
	Nitrate-N	0%	0%	0%a	0%a	0%	0%a	0%	0%	0%	0%	0%	no data	0%	0%	0%	0%	0%	0%	0%	0%
	Organic carbon, Dissolved	0%	0%	25%a	100%a	no data	100%a	8%	9%	2%	2%	0%	0%	0%	2%	11%a	0%	0%	1%	11%a	9%
	Organic carbon, Total	0%	0%	71%a	33%a	33%a	33%a	5%	7%	2%	3%	0%	0%	0%	0%	10%	0%	0%	0%	8%	9%
	pH, Field	0%	0%	0%	0%a	0%a	0%a	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Sulfate	0%	0%	0%	0%a	0%	0%a	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	0%	0%
	Total suspended solids	2%	9%	16%	25%a	30%	14%a	50%	26%	6%	4%	2%	7%	0%	2%	15%	0%	3%	2%	8%	25%
	Turbidity, Lab	0%	0%	19%	33%a	50%a	33%a	55%	26%	0%	0%	0%	no data	0%	2%	25%a	0%	0%	12%	20%a	67%a
Metals	Cadmium, Total	6%	0%	11%	50%a	0%a	11%a	8%	3%	0%	0%	0%	23%	0%	4%	4%	2%	4%	0%	0%	0%
	Cobalt, Total	2%	0%	5%	0%a	11%a	0%a	10%	5%	0%	0%	0%	13%	0%	0%	0%	0%	0%	31%	4%	0%
	Iron, Total	2%	5%	10%	25%a	22%a	17%a	27%	15%	2%	2%	2%	12%	0%	0%	12%	0%	0%	4%	4%	12%
	Lead, Total	2%	5%	5%	25%a	11%a	0%a	9%	8%	2%	2%	2%	13%	4%	3%	4%	0%	1%	2%	9%	0%
	Manganese, Total	0%	0%	0%	0%a	0%	0%a	0%	0%	0%	0%	0%	13%a	0%	0%	0%	0%	0%	40%	4%	0%
	Nickel, Total	2%	0%	0%	0%a	0%a	0%a	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Potassium, Total	0%	0%	0%	0%a	0%	0%a	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Uranium, Total	0%	13%	0%	0%a	0%	0%a	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Zinc, Total	51%	2%	14%	50%a	20%	13%a	13%	15%	0%	0%	4%	24%	15%	34%	3%	23%	47%	73%	16%	3%

Notes:

[a] sample size of n < 10

[b] See Appendix 6H for further explanation.

Shaded values indicate more than 10% of samples had analyte concentrations above the guideline.

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TABLE 6-15

Habitat Characteristics of Creeks in the Vicinity of the Faro Mine Complex [a]

Faro Mine Interim Works

Reach			Approximate Reach Length (km)	Channel Width (m)	Wetted Width (m)	Gradient (%)	Dominant Substrate	In-stream Cover (%)	Dominant In-stream Cover	Dominant Riparian Vegetation	Source(s)
Rose-Anvil Watershed	North Fork Rose Creek upstream from Haul Road	Reach 1	17	8 - 12	7.6	0.2 - 2	boulder/cobble	15	boulders, undercut banks, deep pools	shrubs	Robertson 1996 de Graff 2013
	North Fork Rose Creek downstream from Haul Road	Reach 2	2	8.3 - 8.4	6.5 - 6.8	0.4 - 1.6	boulder/ cobble/gravel	11	boulders, deep pools	shrubs	de Graff 2013
	South Fork Rose Creek upstream from Haul Road	Reach 3	5	8.6	7.7	4.8 - 20	boulder/cobble	70	boulder	willow	Minnow 2009 GLL 2003
	South Fork Rose Creek (Haul Road to confluence with North Fork)	Reach 4	10	4.9 - 10	4.2 - 6.9	0.2 - 2.5	boulder/cobble	16	boulders, pools	grasses, shrubs	Robertson 1996 AECOM 2009
	Rose Creek Diversion Channel	Reach 5	5	14 - 28	13 - 15	0.1 - 5.5	boulder	15	boulders	shrubs	de Graff 2013
	Rose Creek downstream from Faro Mine Complex	Reach 6	21	15 - 25	12 - 15	0.5 - 1.5	cobble/gravel	12	pools, boulder, undercut banks	shrubs, alder	Robertson 1996 WMEC 2008 Laberge 2011
	Anvil Creek downstream from Rose Creek	Reach 7	43	35 - 80	NA	0.7 - 1.9	boulder/cobble	NA	NA	NA	Robertson 1996
Vangorda Watershed	West Vangorda Creek	Reach 8	11	2 - 5.6	1.6 - 3.4	1.5 - 4.8	boulder/ cobble/gravel	15	boulder, woody debris	alder, willow	Harder 1987 Minnow 2009
	Upper Vangorda Creek (above falls)	Reach 9	15	4 - 7.4	4 - 4.7	3.5 - 6.8	boulder/ cobble/gravel	20	boulder	willow, grass	Harder 1987 Minnow 2009
	Lower Vangorda Creek (below falls)	Reach 10	3	7.8 - 10	5.2	1.5 - 3.9	boulder/ cobble/gravel	20	boulder	shrubs, alder	Harder 1987 Minnow 2009

Notes:

[a] data compiled from relevant tables and figures in reports presented in Attachment A of Appendix 6H.

NA = no data available

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Downstream from the mine Access Road, the NFRC splits into two channels (Figure 6-5). The original channel joins with the SFRC after flowing through five ponds that were constructed to recharge nearby groundwater wells that supplied process water during mine operations. Culverts are present at the upper end of these ponds, which may seasonally restrict fish movement (de Graff, 2013). The second channel, the North Fork Diversion, was constructed to allow for diversion of sediment-laden water away from the Pumphouse Pond during spring freshet (GLL, 2002).

Faro Creek

North of the FMC, where it originates, Faro Creek is relatively undisturbed. Near the FMC, the creek has been diverted from its original channel around the Faro Pit and into the NFRC (upstream from the Haul Road).

South Fork Rose Creek

The SFRC originates upstream from Dixon Lake (north of the Vangorda/Grum Area), flows across the Haul Road and mine Access Road, then flows northwest along the Access Road, eventually joining with the NFRC (Figure 6-5). Habitat has not been well characterized upstream from the Haul Road; however, the stream reach immediately above the Haul Road has a measured bankfull width of 8.6 m, a gradient of approximately 4.8 percent, and morphology that is predominantly riffle (Table 6-15) (Minnow, 2009). Further upstream, a gradient of 20 percent has been reported (GLL, 2003).

Between the Haul Road and the confluence with the NFRC (a distance of approximately 10 km), the SFRC is between 5 m and 10 m wide with gradients ranging from 0.2 percent to 2.5 percent (Table 6-15). The SFRC varies in this reach from a steeper section with boulder and cobble habitat and slightly steeper gradient (2.2 to 2.5 percent) just downstream from the Access Road to a broader valley that includes the former Freshwater Reservoir (Figure 6-5) (Harder, 1991a; AECOM, 2009). Here, the channel meanders through gravels and finer particles and has a gradient of 0.2 percent (AECOM, 2009). Downstream from the former reservoir area, the SRFC has primarily riffle habitat, followed by a wetland complex, then another section of riffle habitat that extends to the confluence with the original NFRC (AECOM, 2009). Boulders and pools provide instream cover for fish throughout most of the SFRC downstream from the access road.

Downstream from its confluence with the NFRC, the SFRC flows through the 250-m-by-40-m Pumphouse Pond, and then receives flow from the North Fork Diversion. From there, the combined NFRC and SFRC become Rose Creek and flow past the RCTA.

Rose Creek Diversion

The RCD is a 5-km constructed channel located downstream from the NFRC-SFRC confluence that diverts Rose Creek around the RCTA and subsequently offsite (Figure 6-5). In the upper two-thirds of the RCD, stream gradient is typically 0.5 percent or less, with channel widths ranging from 13 m to 15 m and relatively homogenous boulder substrate interspersed with cobbles and gravels (de Graff, 2013). The lower third of the RCD has a gradient of 5 percent, with primarily boulder substrate.

Lower Rose Creek and Anvil Creek

Downstream from the FMC, Rose Creek flows 21 km to its confluence with Anvil Creek. In this reach, the channel gradient ranges from 0.5 percent to 1.5 percent, and channel widths range from 15 m to 25 m. Substrate in this reach is predominately cobble and gravel (WMEC, 2008).

After converging with Anvil Creek, the combined watercourse flows an additional 43 km to the confluence with the Pelly River. In this reach, the channel ranges from 35 m to 80 m wide, with gradients ranging from 0.7 percent to 1.9 percent and substrate consisting mainly of boulder and cobble.

Vangorda Creek

Originating near the top of Mount Mye, northeast of the Vangorda/Grum Area, the upper sections of Vangorda Creek have channel widths ranging from 4 m to 7.4 m and gradients ranging between 3.5 percent 6.8 percent

(Table 6-15). Boulder, cobble, and gravel dominate the substrate in this reach. When it reaches the Vangorda/Grum Area, the creek is diverted around the Vangorda pit in a metal half-culvert.

Downstream from the Vangorda/Grum Area, the channel is confined and consists primarily of gravel, cobble, and boulder substrate, with a gradient of approximately 4 percent (RGC, 1996). An 8-m waterfall on the main stem of Vangorda Creek (just upstream from the confluence with West Fork Vangorda Creek) is a barrier to upstream fish movement.

West Fork Vangorda Creek originates approximately 3 km upstream from the Haul Road and has channel widths ranging from 2 m to 5.6 m and gradients between 1.5 percent and 4.8 percent (Table 6-15). The substrate of West Fork Vangorda Creek is predominantly boulder, cobble, and gravel.

Downstream from the confluence with West Fork Vangorda Creek, Vangorda Creek has a channel ranging from 7.8 m to 10 m wide and gradients between 1.5 percent and 3.9 percent, with boulder, cobble, and gravel substrate (Table 6-15).

6.2.5.3 Stream Sediment Quality

Historical Studies

Sediment quality has been monitored relative to the FMC since as early as 1973 (Rose and Anvil Creeks) and 1991 (Vangorda Creek). Historical studies have varied in terms of precise sampling locations and laboratory techniques; however, sampling methods were generally comparable amongst studies. Elevated metal concentrations were reported in samples collected downstream from the FMC based primarily on analysis of the ≤0.15-mm fraction of the sediment samples. In particular, levels of arsenic, lead, and zinc were higher than the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life Probable Effect Level (CCME, 2013; Minnow, 2007). Detailed data and the location of sampling stations are shown in Appendix 6H, the Aquatic Baseline Characterization Report.

Recent Studies

The most recent sediment data collections for the FMC took place in 2007 and 2008 and are considered to represent current site conditions, because water quality has been relatively stable during this time (Appendix 6H). Generally, the sediments from the FMC area are composed of sand, gravel, or larger rocks, consistent with the fast-flowing characteristics of most streams in the area. Of samples collected in the NFRC, Rose Creek, and Vangorda Creek, silt and clay fractions represented less than 5 percent combined, except at NFRC upstream from the Access Road, where the proportion of silt plus clay was 30 percent. All samples had less than 4 percent of total organic carbon.

Sediment metal concentrations collected from reference areas of Rose and Vangorda Creeks did not exceed CSQGs in either whole sediment samples or the fraction containing fine sand and smaller particles. Sediment arsenic, lead, manganese, and zinc concentrations in mine-exposed areas were elevated relative to reference levels and guidelines, and were roughly three times higher in the fine fraction versus whole sediment samples. However, sediment samples from the same areas resulted in no observable toxic effects to the amphipod *Hyallela azteca* in laboratory tests (Minnow, 2009). Appendix H provides detailed sediment metals data according to individual sampling areas.

6.2.5.4 Periphyton and Primary Productivity

Periphyton communities were characterized in 2009 along the NFRC and the RCD (de Graffe, 2013). The group of photosynthetic bacteria known as Cyanophyta dominated the communities in the NFRC just downstream from the confluence with the FCD, but a shift to diatom (Bacillariophyceae) -dominated communities occurred closer to the Haul Road and continued downstream throughout the RCD. Cyanophyte abundance declined at stations farther downstream where water quality is known to reflect increased mine influence. Through the downstream areas of the NFRC and in the RCD, periphyton communities shifted towards greater abundance and diversity of diatoms (Bacillariophyceae).

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The highest periphyton densities were observed in the NFRC, just downstream from the mine Access Road. In this and other areas of the NFRC, the diatom *Achnanthes minutissima* was the most commonly observed species (ranging from 4 to 72 percent). *Achnanthes*, especially *A. minutissima,* is generally considered tolerant of a wide variety of environmental conditions and, in other studies, has been observed in streams affected by mining or metals (Yoshiaki et al., 2004; Ponader and Potapova, 2007).

6.2.5.5 Benthic Invertebrate Communities

More than 23 studies of the benthic invertebrate community associated with the FMC took place between 1973 and 2010.

Historical Studies

Historical surveys took place at standardized locations biannually from 1991 until 2008 (alternating between Rose and Vangorda Creeks), to meet the requirements of FMC Water Licences. The majority of these studies used artificial substrate placements, though the studies varied in terms of numbers of replicate samples and levels of taxonomic identification. Generally, these studies suggested some differences between communities in reference areas and receiving environments in both Rose and Vangorda Creeks. However, differences did not appear to be mine-related, as data did not show patterns consistent with a deleterious effect. Appendix 6H provides more details about these studies.

Recent Studies

Benthic invertebrate surveys took place annually from 2007 to 2010 using various sampling methods and analyses. The following section summarizes the methods and results of these surveys, while full details regarding the results of sampling and community analyses are provided in Appendix 6H. Several retrospective analyses were performed as part of the current baseline summary (Appendix 6H) to investigate potential trends or patterns.

Minnow (2009) compared 2007 and 2008 benthic invertebrate community data that were collected using artificial substrates, Hess sampling, and kick net sampling. Data collected by Hess and kick net sampling were found to be more sensitive than artificial substrate studies in detecting differences between reference and mine-exposed communities. The data suggested subtle effects on benthic invertebrate community characteristics in areas downstream from mine disturbances.

In 2009, de Graff (2013) assessed benthic invertebrate communities in the NFRC and RCD using kick net sampling and subsequent data analysis through Environment Canada's Canadian Aquatic Biomonitoring Network web-portal (Environment Canada, 2013b). This approach allows investigators to compare collected community data with a regional reference community data set using existing models (in this case, the January 2010 Yukon Reference Model [Bailey and Reynoldson, 2010]). The results of this analysis suggested most FMC sampling stations were within the reference condition (i.e., minimal site-related influence), except for three stations along the NFRC; only the one of these three stations, located just downstream from the mine Access Road, was considered to be conclusively different from reference (i.e., two were inconclusive).

In 2010, Laberge (2011) used kick net sampling at the FMC and compared reference and mine-exposed communities based on various endpoints such as species richness, sample abundance, percent Ephemeroptera-Plecoptera-Trichoptera, and percent chironomids. Although no statistical comparisons were conducted, the study concluded some impairment was evident at mine-exposed areas on Rose Creek (NFRC near the mine Access Road and Rose Creek downstream from the RCD). However, it also concluded that a full community recovery was evident in lower Rose Creek, just upstream from the Anvil Creek confluence.

The results from Minnow (2009) were recently reanalyzed with data from Laberge (2011) as part of the current baseline characterization (Appendix 6H). Similar to other studies, this analysis showed community samples from (1) the NFRC upstream from the mine Access Road, (2) Rose Creek downstream from the FMC, and (3) Lower Vangorda Creek were within or only slightly different from reference conditions.

In summary, recent surveys have indicated that most benthic invertebrate communities in streams adjacent to and downstream from the FMC area are similar to those in reference areas uninfluenced by mining. Exceptions were the lower NFRC, and in Rose Creek immediately downstream from the FMC.

6.2.5.6 Fish Communities and Habitat Utilization

The following section describes existing information on the fish communities and important habitat features in streams near the FMC. These data are based on various site investigations that date back to the mid-1970s, with emphasis on more recent studies describing fish species distribution and abundance. Table 6-16 summarizes fish communities according to watercourse reaches and Figure 6-5 shows habitat features described below on Rose and Vangorda Creeks, respectively.

North Fork Rose Creek

Fish migration between the upper and lower portions of NFRC is prevented by the rock drain at the Haul Road. Upstream from the Haul Road, Arctic grayling, slimy sculpin, burbot (*Lota lota*), round whitefish (*Prosopium cylindraceum*) and longnose sucker (*Catostomus catostomus*) have all been reported. Of these, slimy sculpin are most abundant. Very few burbot and whitefish have been observed in the upper reaches of NFRC. Although few Arctic grayling have been captured upstream from the Haul Road in recent studies (de Graff, 2013; EDI, 2013a), higher numbers have been observed (WMEC, 2005b). The pond created by the rock drain appears to provide important over-wintering habitat for grayling because the pond does not freeze to the bottom (EDI, 2013b). Potential spawning habitat for grayling has been identified just upstream from this pond, as well as near the ponds at the headwaters of the NFRC.

In the NFRC downstream from the Haul Road, Arctic grayling, slimy sculpin, burbot, and round whitefish have been reported. Slimy sculpin were the most abundant, though numerous arctic grayling were also present (WMEC, 2005b; de Graff, 2013; EDI, 2013b). Arctic grayling spawning and spawning habitats have been reported both in the NFRC downstream from the Haul Road and in the vicinity of the constructed ponds just upstream from the confluence with the SFRC (WMEC, 2005b; EDI, 2013a). Fish access between the constructed ponds and the lower NFRC is restricted seasonally by culverts, but the NFRC diversion provides an alternate route for fish passage from the RCD and SFRC to the NFRC.

South Fork Rose Creek

Fish populations in the SFRC upstream from the Haul Road are separated from those in the rest of the system by culverts at the Haul Road and mine Access Road and by stream gradients of more than 20 percent upstream from the Haul Road. Both of these prevent upstream migration. Arctic grayling and slimy sculpin are the only fish species that have been captured upstream from the Haul Road (Minnow and WMEC, 2009; EDI, 2013a).

Between the mine Access Road and the confluence with the NFRC, Arctic grayling, juvenile Chinook salmon, slimy sculpin, burbot, and round whitefish have either been captured or observed, although only Arctic grayling and slimy sculpin have been found in most studies (AECOM, 2009; WMEC, 2005c). In addition to the NFRC (see above), grayling spawning has been reported at the Pumphouse Pond, located at the confluence of the NFRC and SFRC (WMEC, 2005b).

Rose Creek Diversion

Generally, habitat and fish cover in the RCD is constrained by a lack of natural stream processes, homogeneous substrates, and sparse riparian vegetation. Arctic grayling, Chinook salmon, slimy sculpin, burbot and round whitefish have been found within the RCD, but only Arctic grayling and sculpin are common. Arctic grayling reside in the upper portions of the RCD throughout the year, although some Arctic grayling from this and other areas of the FMC area migrate to the Pelly River to overwinter (EDI, 2013b). Upstream migration of Arctic grayling in the steep lower portion of the RCD was recorded by EDI (2013b). Spawning Chinook salmon were observed once in the RCD (Minnow, 2010).

Lower Rose Creek and Anvil Creek

Downstream from the FMC, Arctic grayling, juvenile Chinook salmon, slimy sculpin, burbot, round whitefish, and longnose sucker have been observed or captured. Lake chub (*Couesius plubeus*) have also been captured near the Pelly River. Slimy sculpin were the most frequently captured species in previous studies.

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TABLE 6-16

Summary of fish species presence in the vicinity of the Faro Mine Complex (details in Attachment Table G.1 of Appendix 6H)

Faro Mine Interim Works

Reach			Fish Species						
			Arctic Grayling (*Thymallus arcticus*)	**Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*)**	**Slimy Sculpin (*Cottus cognatus*)**	**Burbot (*Lota lota*)**	**Round Whitefish (*Prosopium cylindraceum*)**	**Longnose Sucker (*Catostomus catostomus*)**	**Lake Chub (*Couesius plumbeus*)**
Anvil-Rose Watershed	NFRC upstream from Haul Road	Reach 1	✓	NA	✓	✓	✓	✓	–
	NFRCdownstream from Haul Road	Reach 2	✓	–	✓	✓	✓	–	–
	SFRC upstream from Haul Road	Reach 3	✓	–	✓	–	–	–	–
	SFRC (Haul Road to confluence with North Fork)	Reach 4	✓	✓	✓	✓	✓	–	–
	RCD Channel	Reach 5	✓	✓	✓	✓	✓	–	–
	Rose Creek downstream from Faro Mine Complex	Reach 6	✓	✓	✓	✓	✓	✓	–
	Anvil Creek downstream from Rose Creek	Reach 7	✓	✓	✓	✓	✓	✓	✓
Vangorda Watershed	Upper Vangorda Creek	Reaches 8 and 9	Not Accessible						
	Vangorda Creek at mouth	Reach 10	✓	✓	✓	✓	✓	✓	✓

Note:

[a] AECOM 2009. No data records provided.

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The Rose-Anvil Creek system is identified as having low to moderate suitability for Chinook salmon spawning, with suitable but limited habitat for juvenile Chinook salmon (Yukon Placer Secretariat, 2010). WMEC (2010a) also concluded that Anvil Creek would be expected to support only low numbers of spawning Chinook salmon.

Vangorda Creek

There are two significant barriers to fish passage on Vangorda Creek: (1) an 8-m waterfall located 3 km upstream from the mouth of Vangorda Creek and (2) a culvert under the mine Access Road on the West Fork of Vangorda Creek (Figure 6-5). No fish have been reported in the upstream reaches of Vangorda Creek above these barriers (RCG, 1996; Minnow, 2009). Arctic grayling, juvenile Chinook salmon, slimy sculpin, burbot, round whitefish, longnose sucker, and lake chub have all been identified in the lower reaches of Vangorda Creek. Although numbers vary from year to year, juvenile Chinook salmon have been the most abundant species captured in this reach (WMEC, 2005c; WMEC, 2008). The lower portion of Vangorda Creek has moderately suitable habitat for Chinook salmon rearing (Yukon Placer Secretariat, 2010). High densities of juvenile Chinook salmon have been reported in Lower Vangorda Creek during the spring and summer months, likely moving in from Blind Creek and the Pelly River.

6.2.6 Terrestrial Resources

6.2.6.1 Vegetation

Introduction

The following subsection describe existing information on vegetation resources in the area of the FMC. This summary is based on a review of studies that focused on the FMC and local area, as well as general information describing the region that includes the FMC. The following terrestrial assessments conducted between 1996 and 2003 provided the basis for the baseline characterization:

- Several engineering reports for which soil information was collected
- A metals contamination study of vegetation and soils within the FMC (C.E. Jones and Associates Ltd., 2003)
- A terrestrial effects study related to support closure and remediation planning (GLL, 2006a)
- A mapping of vegetation zones as part of a larger abandonment plan (RGC, 1996)
- A vegetation survey and development of a 1:20,000 scale map of vegetation associations in the LSA (GLL, 2008)
- A rare plant survey (AECOM, 2008)
- A vegetation survey around the periphery of WRDs (EDI, 2008)

In addition, localized revegetation and remediation efforts have taken place at specific sites within the FMC, which undergo regular monitoring (EDI, 2009, 2010, 2013a, and 2013b).

Information about the ecology of the region surrounding the FMC was summarized based on field verification studies and territorial references, including the following:

- Ecoregions of Yukon Territory (Smith et al., 2004)
- Soils of Yukon (YG, 2013a)
- Vegetation inventory completed in 1976 by the Montreal Engineering Company Ltd (cited in RGC, 1996).
- Vegetation classification for Sheep Mountain (Staniforth, 1998)
- The 2006 GLL terrestrial effects study

Study Areas

For the IW, the geographic region around the FMC was delineated into an LSA and an RSA (Figure 6I-2 in Appendix 6I). The LSA encompasses a 1-km buffer around all FMC facilities, infrastructure, and road corridors, resulting in a total area of 8,122.8 hectares. It comprises the area in which there is reasonable potential for effects (direct and indirect) on vegetation and soils from IW activities. The RSA was defined in order to assess effects at a broader geographical scale and to gain a better regional understanding of vegetation and soils (Figure 6I-2). The RSA includes the area where contaminants have been recorded at greater than background levels (GLL, 2006a), but is limited by the Pelly River to the west. The RSA is 58,803 hectares in area.

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Regional Study Area Vegetation

The FMC is located within the Yukon Plateau-North Ecoregion, in the Boreal Cordillera Ecozone (Smith et al., 2004). Vegetation in the RSA is typical of boreal, sub-alpine, and alpine ecosystems of this ecozone. In the boreal ecosystems of the Yukon Plateau, forests are dominated by open black spruce stands with moist moss or drier lichen understories. White spruce, occasionally with trembling aspen or lodgepole pine, grows on warmer and better-drained soils (Smith et al., 2004). The sub-alpine ecosystems, various shrubs and an abundance of lichens dominate the tundra. Low-growing ericaceous shrubs, prostrate willows, and lichens dominate the alpine. Talus slopes are also common at these high elevations, and are typically covered by crustose lichens. Where forest fires have occurred, *P. tremuloides* and balsam poplar (*Populus balsamifera*) are common.

Local Study Area Vegetation

Vegetation Associations

A 2007 vegetation study by GLL provides the most detailed ecological information for the LSA to date (GLL, 2008). This study identified 13 vegetation associations within the LSA, based on 17 ground plots and 59 visual plots (GLL, 2008; Table 6-17). The following paragraphs briefly discuss this study, including the total area of each association relative to the LSA (Table 6-17), and describe the characteristics of the associations. Attachment 6I-2 in Appendix 6I provides a complete discussion of the associations.

TABLE 6-17
Faro Mine Closure Project Local Study Area Vegetation Associations Baseline Area [a]
Vegetation and Soils Baseline – Faro Mine Interim Works

Vegetation Association	LSA Baseline Area	
	Area (hectares)	Percent of the LSA
Sedge/Willow	54.6	0.7
Willow/Sedge	254.7	3.1
Willow/White Spruce	326.0	4.0
Willow/Dwarf Birch	182.2	2.2
Dwarf Birch/Willow	232.2	2.9
Dwarf Birch/Lichen/Subalpine Fir	357.8	4.4
Dwarf Birch/Subalpine Fir	279.9	3.4
White Spruce/Willow	3,657.4	45.0
White Spruce/Feathermoss	105.1	1.3
Pine	52.4	0.6
Mixed Coniferous-Deciduous	682.0	8.4
Deciduous	276.6	3.4
Graminoid	49.3	0.6
Project Footprint [b]	1,621.7	19.9
LSA Total Area	8,122.8	100.0

[a] Adapted from GLL (2008)

[b] Project Footprint represents the disturbed areas an infrastructure of the FMC. This is not a vegetation association, but provides detail on the relative occurrence of these features within the LSA.

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Sedge / Willow (S/W)

This wetland association is common in both boreal and subalpine zones, occurring in depressions and drainages where water collects. It covers approximately 0.7 percent of the LSA. A mixture of sedge and graminoid species dominates these areas, with water sedge (*Carex aquatilis*) being the most common. Willows, dwarf birch, and some white spruce occur around the edges of wetlands, and sphagnum mosses (*Sphagnum* spp.) are abundant throughout.

Willow / Sedge (W/S)

Approximately 3.1 percent of the LSA consists of willow / sedge associations, which are linked with standing or flowing water, along lakes, pond, and creek drainages. It is a common riparian association found at a variety of elevations throughout the LSA. The shrub layer is dominated by various willow species that include tea-leaved willow (*Salix planifolia*) and Athabasca willow (*Salix athabascensis*). Water sedge are common below the shrub layer, along with various wetland mosses.

Willow / White Spruce (W/Sw)

This vegetation association is most frequently found in riparian drainages along creeks and rivers in the boreal zone, and makes up approximately 4.0 percent of the LSA. An open canopy of mature white spruce is scattered amongst a well-developed shrub layer that includes a variety of willows and dwarf birch. The groundcover is most often a combination of shrubs, sedges, lichens, and mosses.

Willow / Dwarf Birch (W/B)

This riparian association comprises approximately 2.2 percent of the LSA. It is widespread in the lower elevations, typically occurring on gentle to steep slopes near drainages or open water in the boreal zone. Willows and dwarf birch are co-dominant, with the occasional white spruce and Labrador tea (*Ledum groenlandicum*), with sparse grasses, and forbs.

Dwarf Birch / Willow (B/W)

The birch / willow association makes up approximately 2.9 percent of the LSA. It is characteristic of slopes at higher elevations in the subalpine zone and. While dwarf birch is the dominant shrub, willow species, Labrador tea, shrubby cinquefoil (*Dasiphora fruticosa*), and bog billberry (*Vaccinium uliginosum*) are also common. A variety of ground shrubs are found in the understory, though lichens dominate the groundcover.

Dwarf Birch / Lichen / Subalpine Fir (B/L/Fa)

This vegetation association is largely a subalpine and alpine community, typical of areas with rock outcrops and windswept ridges. This association makes up approximately 4.4 percent of the LSA and is dominated by dwarf birch (0.5 m tall) and lichen species. Krumholtz subalpine fir is scattered throughout the association with bearberry (*Arctostaphylos uva-ursi*), crowberry (*Empetrum nigrum*), bog bilberry and mountain avens *(Drayas* spp.) also present.

Dwarf Birch / Subalpine Fir (B/Fa)

This association is a subalpine community that occurs on well-drained soils and slopes at the upper elevations, and comprises approximately 3.4 percent of the LSA. Dwarf birch is the dominant cover species, with subalpine firs scattered throughout the area. Willow species, Labrador tea, common juniper (*Juniperus communis*), and white spruce are present but infrequent. Low-growing shrubs include bog bilberry, bearberry, crowberry and mountain cranberry (*Vaccinium vitis-idaea*). Graminoid and lichen species are present in the groundcover.

White Spruce / Willow (Sw/W)

The White Spruce/Willow association is the most frequent vegetation association within the LSA. It occurs in both the boreal and subalpine zones on various upland and lowland slopes, and totals approximately 45 percent of the LSA. White spruce dominates the canopy, with the occasional subalpine fir. The shrub layer is dominated by willow species (1 m tall) with a low percentage of dwarf birch, Labrador tea, and shrubby cinquefoil. Dwarf shrubs include bog bilberry, bearberry, net-veined willow (*Salix reticulata*), and crowberry. Common horsetail (*Equisetum*

arvense) and various bluegrass species are also frequent. The forest floor is frequently carpeted by stair-step moss (*Hylocomium splendens*), reindeer lichens (*Cladina rangifera*), and pelt lichens (*Peltigera* spp.).

White Spruce / Feathermoss (Sw/Fm)

This association occurs most frequently on well-drained alluvial flats and on mesic sites in lowland areas throughout the boreal zone. It totals approximately 1.3 percent of the LSA. The tree canopy comprises dense white spruce, with a sparse shrub understory including various willow species, dwarf birch, shrubby cinquefoil, and low shrubs. A thick carpet of feathermoss (*Pleurozium shreberi*) is prevalent throughout.

Pine (Pl)

The pine association is dominated by a tree canopy of lodgepole pine, predominantly occurring in upland areas around the Grum and Vangorda Pits in the boreal zone. It makes up approximately 0.6 percent of the total LSA. In these areas, there are a few scattered white spruce, and the shrub layer is dominated by Sitka alder (*Alnus viridis* ssp. *sinuata*) and Scouler's willow (*Salix scouleriana*). The low shrub layer is composed of Labrador tea, prickly rose (*Rosa acicularis*), and buffaloberry (*Sheperdia canadensis*). The ground cover is minimal consisting of bog bilberry, crowberry, bunchberry (*Cornus canadensis),* bearberry, and twinflower (*Linnaea borealis*).

Mixed Coniferous-Deciduous (Mx)

The mixed coniferous-deciduous forest association is typically established on well-drained sites over a broad elevation range, and makes up approximately 8.4 percent of the LSA. These areas consist of a mix of coniferous and deciduous trees, including white spruce, trembling aspen, balsam poplar, and lodgepole pine. Soil moisture and nutrient richness determine the persistence of subalpine fir and or black spruce. In these areas, forest fires have resulted in a mixed-seral stand, where trees of various species make up both the canopy and the understory. Low-growing shrubs such as bog bilberry, crowberry, and Labrador tea are also present.

Deciduous Forests (Dd)

Approximately 3.4 percent of the LSA is a deciduous vegetation association occurring on sites regenerating from a disturbance (e.g., fire or human development). These sites tend to be located on well-drained slopes and are rich in species diversity. Most often occurring in the boreal zone, trembling aspen dominates, followed by balsam poplar on moister sites. Tall shrubs include willow species, Sitka alder, shrubby cinquefoil, Labrador tea, dwarf birch, buffaloberry and prickly rose. The ground layer is often a diverse mix of bearberry, mountain cranberry, blueberry willow (*Salix myrtilifolia*), bunchberry, bastard toad-flax *(Geocaulon lividum*), fireweed (*Epilobium angustifolium*), northern grass-of-parnassus (*Parnassia palustris*), and twin flower.

Graminoid (Gr)

The graminoid association is found in lowland areas in the boreal zone, and makes up about 0.6 percent of the total LSA. This association generally occurs in areas re-established from seed mixtures through revegetation programs at the FMC. Grasses include a variety of brome (*Bromus* spp.), reedgrass (*Calamagrostis* spp.), and fescue species (*Festuca* spp.). Sedge species, fireweed, and wormwood (*Artemesia* spp.) are also present.

Species at Risk and Rare Plants

Species at risk (SAR) are plant species considered to be extirpated, endangered, threatened, or of special concern by the federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The federal *Species at Risk Act* (SARA) regulates SAR and legislates activities within the critical habitats of those species (Environment Canada, 2013c).

The SAR in YT are listed based on their COSEWIC standing (YG, 2013a). There are currently three plant species at risk and one under review in Yukon (Table 6-18).

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TABLE 6-18
Plant Species at Risk Potentially Occurring in the Regional Study Area
Vegetation and Soils Baseline – Faro Mine Interim Works

Species	Common Name	COSEWIC (date listed)	SARA	NatureServe Ranking of Status in YT
Draba yukonensis	Yukon draba	Endangered (November 2011)	Not listed	S1
Micranthes spicata	spiked saxifrage	Threatened (May 2013)	Not listed	S2
Carex sabulosa	Baikal sedge	Threatened (May 2005)	Threatened	S2
Podistera yukonensis	Yukon podistera	Under Review (November 2014)	Not listed	S2

Rare plants are plant species that are uncommon or infrequently encountered, and includes both species whose status is not known and species that are of conservation concern. A registry of rare plants is maintained in Yukon by the Yukon Conservation Data Centre, including those that are termed as reportable (i.e., for which the Conservation Data Centre is actively seeking records of observations. Rare plants include, but are not limited to, SAR.

Three surveys that directly or indirectly targeted rare plants have been completed within the LSA: (1) A rare plant survey by GLL in 2008 focused on areas that are to be disturbed by rock resloping in the overall FMRP, (2) A 2007 vegetation study of the LSA that focused on vegetation associations, and (3) a vegetation study by EDI (2008) that described vegetation types at the FMC. No rare plant species listed by COSEWIC or SARA were found in these three plant surveys.

Overall, there is limited potential for rare species to be present in the LSA or the RSA. The existing footprint of the FMC (approximately 20 percent of the total LSA) has been disturbed considerably through mining activities, roads, historical trails, and waste rock storage areas. As a result, there is minimal soil accumulation, which has a limited capacity to establish vegetation. Furthermore, the classified non-footprint vegetation associations in the LSA are typical of much of the central Yukon and do not generally host rare species.

Introduced Plant Species

Because of the amount of disturbance in the FMC footprint, there is a potential for introduced plant species to be present and to further establish themselves in the future. Previous FMC vegetation surveys identified seven introduced species (YG, 2013c; Attachment 6I-1-4 in Appendix 6I). These introduced species were then further classified based on their "invasiveness" according to the Yukon Invasive Plant List (YG, 2013c; Attachment 6I-1-3 in Appendix 6I). Invasiveness rankings are detailed in Appendix 6I.

The following introduced species are known to currently occur within the LSA:

- Narrowleaf Hawk's beard (*Crepis tectorum*) – present (AECOM, 2008; EDI, 2008) and highly invasive
- Kentucky bluegrass (*Poa pratensis*) – present (EDI, 2008), but may not replace native species or change ecosystem function
- Giant bentgrass (*Agrostis alba*) – present (EDI, 2008), but currently not invasive in the Yukon
- Red fescue (*Festuca rubra*) – present (AECOM, 2008), but currently not invasive in the Yukon
- Field pennycress (*Thlaspi arvense*) – present (AECOM, 2008), but currently not invasive in the Yukon
- Herb sophia (*Descurainia sophia*) – present (EDI 2008, AECOM 2008), but has not shown to persist in Yukon
- Biennial cinquefoil (*Potentilla biennis*) – present (EDI, 2008), but not likely to persist in the Yukon

Contaminant Concentrations in Vegetation

Background

Past operations at the FMC have resulted in elevated metal concentrations in vegetation in the LSA and RSA, compared with territorial background and reference site concentrations (C.E. Jones and Associates Ltd., 2003; GLL, 2006). Studies in 2002 (C.E. Jones and Associates Ltd., 2003) indicated that elemental deposition was a result of mining operations; however, no information was provided about its timing. The terrestrial effects assessment completed by GLL (2006) measured elemental concentrations in vegetation and lichen to identify sites with the highest metals concentrations and sites where these concentrations were likely to continue to increase. Unfortunately, no pre-mining information is available; therefore, information collected from 2004 to 2005 was compared with reference sites around the Swim Lakes, approximately 9 km east of the Vangorda/Grum Area.

To consider airborne deposition of metals, natural soil mineralization, and large landscape processes, lichens were targeted as the indicator species by GLL (2006). Lichens depend entirely on airborne materials and precipitation for nutrients and are largely unaffected by mineralization of the underlying soils. A brief discussion of the trends in metal concentrations in lichens is provided herein, with a more detailed account provided in Appendix 6I.

Metals Concentrations in Lichen

Significantly Elevated Concentrations

Compared with the Swim Lake reference sites and YT reference levels, there are significantly elevated concentrations of lead and arsenic in the lichen samples from the LSA. In mine-affected areas, concentrations of lead and arsenic were up to 450 times and 250 times higher than reference sites, respectively. In total, approximately 76,900 hectares of the RSA showed lichen lead concentrations at least 3 times greater than reference sites in the Swim Lake area.

Moderately Elevated Concentrations

Concentrations of zinc, copper, iron, silver, and thallium were moderately elevated in the LSA, compared with reference sites. In mine-affected areas, maximum lichen concentrations for these metals ranged from 15 to 75 times greater than Swim Lake maxima. Equivalent-to-reference concentrations were generally reached at distances of 0 to 2 km from the Vangorda/Grum Area, northeast along the exposed (mine-side) slopes of Mount Mye, and southwest along the exposed slopes of Rose Mountain. Elevated elemental levels generally extend northeast along North Fork Rose Creek, north up and past Mount Aho, and northwest down the Rose Creek Valley.

Minimally Elevated Concentrations

Concentrations of barium, chromium, mercury and nickel were three to nine times greater in mine-affected areas than in reference sites. The zones of contamination for these elements were also generally smaller than those of lead or other elements considered highly or moderately elevated, relative to reference levels. Although selenium concentrations near the mine were 25 times the Swim Lake maximum, this element is considered to be minimally elevated because the area affected by elevated concentrations is very small.

Marginally Elevated Concentrations

There is some evidence of elevated concentrations of antimony, cadmium and cobalt in lichens within mine-affected areas when compared to reference sites. These recorded concentrations were either within reported YT reference ranges (antimony and cobalt) (Gamberg, unpublished) or were similar to levels detected in the study area that to not appear to be related to the FMC (cadmium) (GLL, 2006a).

Metals Concentrations in Vegetation

The results of studies of metals concentrations in vegetation by GLL (2006a) and AECOM (2009) provide the following trends in vegetation metals content:

High Elevation Relative to Reference Levels – Lead

Lead concentrations for all plant species groups studied were greatly elevated in the area immediately adjacent to the tailings impoundment/mill complex, which indicates the mine has affected lead concentrations in vascular plants and mushrooms, as well as in lichens and soils. Lead levels near the mine ranged from 2.5 (horsetails) to 410 (tree sap) times Swim Lake reference means. Willows, grasses, forbs, horsetails, mushrooms, and bear root all had lead levels greater than Swim Lake ranges.

Moderate Elevation Relative to Reference Levels – Zinc

Zinc levels were significantly elevated in berries, willows, and forbs collected next to the tailings impoundment/mill complex. The magnitude of elevation ranged from three times the Swim Lake reference mean (berries) to 20 times (forbs). In most zones affected by the mine, zinc levels in forbs, willow, mushroom, and bear roots exceeded documented YT background ranges (Gamberg, unpublished).

Low Elevation Relative to Reference Levels – Copper, Nickel, Silver, Mercury, and Thallium

Copper, nickel, silver, mercury, and thallium had isolated occurrences of significantly elevated concentrations compared to Swim Lake reference levels. Concentrations ranged from approximately two (copper in willows) to nine times (silver in willows and thallium in Labrador tea) those of Swim Lake reference means. There is no conclusive evidence that the elevated nickel concentration in lichens can be attributed to the presence of the FMC. The maximum nickel concentrations are within published YT background ranges.

6.2.6.2 Wildlife

Introduction

The collection of wildlife baseline data for the FMC area dates back to the 1970s, and includes a variety of local and regional studies. The description of wildlife and wildlife habitat in the following section was compiled based on field studies and previous reports, including recent local studies conducted on behalf of AAM as well as regional studies conducted by EY:

- A winter tracking survey (Ecological Logistics & Research Ltd. [ELR], 2012)
- A waterfowl study (ELR, 2013)
- A log of FMC incidental wildlife observations that has been maintained by site C&M contractors (AAM, 2013; unpublished data)
- An early winter moose survey (Clarke et al., 2012)
- A thinhorn sheep lambing survey (EY, 2013; unpublished data)

The following wildlife reports and studies were completed before AAM assumed responsibility for the site in 2009, and were also reviewed to develop the current description:

- A wildlife baseline study report (Gartner Lee Limited, 2008a)
- A thinhorn sheep summary report (Gartner Lee Limited, 2008b)

Several wildlife information datasets were also reviewed to contribute to baseline information, including breeding bird survey data, EY Wildlife Key Areas (WKA) (EY, 2009), and EY harvest records. SAR resources, including the Yukon Conservation Data Centre, the *SARA* Registry, COSEWIC, and NatureServe Canada, were also examined to identify and characterize potential or known SAR within and around the LSA and RSA. These study areas were established to characterize wildlife and wildlife habitat for the FMC and its surrounding area.

Further details about wildlife baseline conditions are provided in Appendix 6J.

Wildlife Local and Regional Study Areas

The wildlife LSA encompasses the area defined by the existing disturbance footprint, with the addition of a 1-km buffer, which represents an immediate zone of potential project effects. The LSA has a total area of 81.2 km^2 (Figure 6J-2 in Appendix 6J). The FMC footprint area is characterized by roads, mine infrastructure, engineered

waterbodies (i.e., pits and ponds), and patches of regenerating vegetation communities. Regenerating areas transition to boreal woodlands, as well as to subalpine and alpine ecosystems that are adjacent to the footprint area.

The wildlife RSA was delineated to better describe wildlife populations and assess potential effects at a broader geographical scale. The RSA was defined as an area extending 15 km beyond the FMC footprint, resulting in a total area of 1,530 km^2 (Figure 6J-2 in Appendix 6J).

Species at Risk

Several SAR have been identified as occurring or having the potential to occur within the LSA or RSA. These species are listed under *SARA* (Government of Canada, 2013) or the Territorial *Wildlife Act* (YG, 2013), or are designated by COSEWIC (2010). Table 6-19 summarizes SAR that are either confirmed or potentially occurring in the LSA and RSA.

TABLE 6-19
Species at Risk That Are Confirmed or Potentially Occurring in the LSA and RSA
Faro Mine Interim Works

Species	Confirmed or Potentially Occurring in LSA	Confirmed or Potentially Occurring in RSA	Yukon *Wildlife Act* Status	*SARA* Status	COSEWIC Status
Mammals					
Woodland caribou	Confirmed	Confirmed		Special Concern	Special Concern
Grizzly bear	Confirmed	Confirmed			Special Concern
Wolverine *Gulo gulo*	Confirmed	Confirmed			Special Concern
Avifauna					
Bank swallow *Riparia riparia*	Confirmed	Confirmed			Threatened
Harlequin duck *Histrionicus histrionicus*	Confirmed	Confirmed		Special Concern	Special Concern
Horned grebe	Confirmed	Confirmed			Special Concern
Trumpeter swan *Cygnus buccinator*	Confirmed	Confirmed	Specially Protected		
Olive-sided flycatcher *Contopus cooperi*	Potential	Confirmed		Threatened	Threatened
Canada Warbler *Wilsonia canadensis*	Potential	Potential		Threatened	Threatened
Common Nighthawk *Chordeiles minor*	Potential	Potential		Threatened	Threatened
Rusty Blackbird *Euphagus carolinus*	Potential	Potential		Special Concern	Special Concern

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Abundance and Distribution of Major Wildlife Species

Moose

Moose are an important species in the Yukon. First Nation and Yukon residents value moose as a big game species, which they rely on for subsistence. Moose are ranked as secure in the Yukon (Canadian Endangered Species Conservation Council, 2011).

Important habitats for moose include riparian areas adjacent to rivers, marshes, ponds, and meandering streams; burned or logged areas; and treeline and subalpine areas with abundant shrub forage species. Moose use a range of habitats, from valley bottoms to the subalpine zone within both the LSA and RSA. There are no moose WKAs in the LSA or RSA, and the nearest WKA (moose late-winter range) lies in the Ross River Valley, 45 km east of the Vangorda/Grum Area.

The most recent population data available for moose in the FMC area was collected during a 2011 early winter moose aerial survey by EY that covered an area of 6,470 km^2 (Clarke et al., 2012) and overlaps the RSA. The study results indicated high-quality moose habitats are located throughout the study area, with a high average moose density of 364 moose per 1,000 km^2 compared to the territory-wide average of 157 moose per 1,000 km^2 (Clarke et al., 2012). Despite this, a trend analysis indicated the average moose density in the region had declined from the 2004 estimate of 397 moose per 1,000 km^2. The total moose population within the survey area was estimated to be 2,352 individuals ±23 percent, which was lower than the 2004 estimate of 2,450 ±27 percent.

Survey results suggested that Game Management Subzone (GMS) 4-45 (which overlaps the western portion of the LSA) had the highest average moose harvest rate of all the Yukon (Clarke et al., 2012; EY, 2013a). They also suggested the population within GMS 4-45 has declined at an annual rate of two percent from 2004 and a total of 28 percent since 1997 (Clarke et al., 2012). There are moderate to high hunting pressures on moose within the RSA in areas adjacent to the FMC (some of which can be accessed from the FMC Access Road).

Moose were the second most frequently observed species recorded in the FMC Incidental Wildlife Log. They were observed throughout the LSA in every month except November, with the most observations during the summer months (AAM, 2013; unpublished data). Most observations were recorded in the Faro Mine Area, including in the vicinity of the parking lot and guardhouse, the ETA, CVD Pond, ID Pond, Rose Creek, RCD, Faro Diversion, and generally in the Down Valley area. Moose were also observed along the Haul Road and periodically in the Vangorda/Grum Area. Detections of moose within the LSA during the 2012 winter tracking survey revealed that moose use nearly all habitats types found in the LSA, but that their habitat use is focused around riparian areas of Rose Creek and other riparian draws (ELR, 2012).

Thinhorn Sheep

There are two subspecies of thinhorn sheep in the Yukon: Dall's (*Ovis dalli dalli*) and Stone's (*Ovis dalli stonei*); the southern Yukon is the northern extent for the latter. Sheep in the FMC area are referred to as 'fannin' and have an intermediate pelage colour between the darker Stone's sheep and the lighter Dall's sheep, which may be the result of crossbreeding (Worley et al., 2004). Fannin sheep are reported to range only in the Pelly and Ogilvie mountains. Neither Stone's nor Dall's sheep have been listed by COSEWIC.

Fannin sheep have been observed in the FMC from May to November, and most regularly in the Vangorda/Grum Area (AAM, 2013; unpublished data). Several sheep were also observed incidentally in this area during September 2013 waterfowl surveys (ELR, 2013), and included a large group of rams, ewes, yearlings, and lambs. Beyond the FMC, most individual sheep have been observed on Mount Mye, Sheep Mountain, and Rose Mountain, with some observed on Mount Kulan and the Yukon Plateau, and in the Blind Creek and Swim Lakes areas (Gartner Lee Limited, 2008b). Thirty-one thinhorn sheep WKAs occur within the RSA and include mineral licks, seasonal ranges, and migration corridors; four of these occur within the LSA (Figure 6J-4 in Appendix 6J.

Although 2011 aerial survey results for the regional thinhorn sheep population suggest it is stable, the study noted that hunting pressures have increased in the area (particularly in GMS 4-45) because of increased access (EY, 2011). Furthermore, EY (2011; unpublished data) reported the primary management concern for the surveyed population at that time was an increase in mineral exploration activities in the area.

Caribou

All woodland caribou of the Northern Mountain population are ranked by COSEWIC and are listed under Schedule 1 of *SARA* as a species of special concern (Table 6-19).

The annual ranges of four woodland caribou (Northern Mountain population; *Rangifer tarandus caribou*) herds occur in the Faro region, including the ranges of the Tay River, Finlayson, Moose Lake, and Pelly herds (EY, 2012). Only the annual range of the Tay River caribou herd overlaps the RSA and for this reason caribou observed within the LSA most likely belong to the Tay River herd (Alain Fontaine, personal communication, 2013). The Tay River herd was last surveyed in 1996 by EY, at which time the population was estimated to be 3,750 individuals. The population is currently considered to be stable (EY, 2012).

Woodland caribou feed primarily on ground lichens and tend to use habitats in alpine and subalpine elevations that provide these forage species and vantage points to watch for predators. Winter ranges, migration corridors, and rutting areas used by woodland caribou can be habitats identified by EY as WKAs; however, there are no caribou WKAs within the LSA or RSA.

Caribou have infrequently been observed at the FMC according to the FMC Incidental Wildlife Log records (AAM, 2013; unpublished data). Over the 5 years of wildlife reporting to date, there have been 13 recorded caribou observations onsite during the months of May, June, or July. Most observations have been recorded near the Haul Road, the Rose Creek, Faro Creek Diversion and ETA, as well as near the Grum Dump meteorological station.

Grizzly Bear

Grizzly bear (*Ursus arctos*) are often considered to be a keystone species. They are referred to as ecological indicators, as they are critical to ecosystem diversity and integrity. The western population of grizzly bears is listed by COSEWIC as a species of special concern, but currently has no protection status under *SARA*.

The existing project footprint has limited habitat that is suitable for grizzly bear life requisites because of the disturbed nature of many areas. Reclaimed areas that support the growth of grasses and shrubby subalpine hillsides, however, likely provide some vegetation species for foraging (e.g., berry-producing shrubs and *Hedysarum sp.*), as well as potential prey items (e.g., ungulates and Arctic ground squirrels).

FMC Incidental Wildlife Log records include 60 grizzly bear sightings and an additional 37 bear (i.e., either black or grizzly bear) sightings from May 2009 to July 2013 (AAM, 2013; unpublished data). Pooled for all years, grizzly bears were sighted between April and October—most frequently in May (n = 21), followed by June (n = 17). Grizzly bears were consistently observed during May in all 5 years of observation records, while the timing of sightings was not consistent across observation years. Of the 60 grizzly bear records, 4 observations were of sows with either one, two, or three cubs, accounting for a total of 12 of the individual observation records. Over half of the grizzly bear observations occurred in the Faro Mine Area, including areas in proximity to the CVD Pond, RCTA and the Faro Pit and Diversion. The remaining observations occurred in the Vangorda/Grum Area (e.g., Grum Pit, Vangorda Flume, and SPP areas) and along or near the Haul Road.

Furbearers

Trapping furbearers is an important economic activity in much of the Yukon. The FMC falls within a large group trapping concession that is approximately 35,400 km^2 in area. Several furbearing species have been observed at the FMC (ELR, 2012; AAM, 2013; unpublished data):

- American marten (*Martes americana*)
- Ermine (short-tailed weasel; *Mustela erminea*)
- Mink (*Mustela vison*)
- Least weasel (Mustela nivalis)
- Fisher (*Pekania pennanti*)
- Wolverine (*Gulo gulo*)
- Canada lynx (*Lynx canadensis*)
- Red squirrel (*Tamiasciurus hudsonicus*)

Among these species, the wolverine is listed as special concern by COSEWIC but is not currently listed under *SARA*. The wolverine is believed to be stable within the Yukon (Yukon Conservation Data Centre, 2011). COSEWIC has indicated the Canada lynx is not at risk and the remaining furbearer species listed above have not been listed by COSEWIC. Appendix 6J provides more detailed information summarizing furbearer occurrences in the LSA.

Canids

Grey wolf (*Canis lupus*), coyote (*Canis latrans*), and red fox (*Vulpes vulpes*) occur throughout the Yukon in a variety of habitats. They are currently not listed by either COSEWIC or *SARA*. These canid species were all detected during the 2012 winter tracking survey at low densities (ELR, 2012). Wolf and fox sightings were the most common records among furbearing species in the FMC Incidental Wildlife Log records (AAM, 2013; unpublished data). Canids are known to use roads and linear corridors to move through the landscape. This behaviour was observed at the FMC (e.g., tracks observed along the Haul Road); however, wolf tracks were also observed in forested stands with pine and mature white spruce (ELR, 2012).

Avifauna

The areas surrounding the Town of Faro and the FMC offer suitable habitats for a wide range of avian species, including waterfowl, shorebirds, passerines, upland game birds, and raptors. Many species have been observed in the FMC area (EY, 2003); the species most commonly observed while conducting avian surveys included white-winged crossbill (*Loxia leucoptera*), dark-eyed junco (*Junco hyemalis*), common raven (*Corvus corax*), Swainson's thrush (*Catharus ustulatus*), hermit thrush (*Catharus guttatus*), gray jay (*Perisoreus canadensis*), and American robin (*Turdus migratorius*) (USGS, 2013; CWS, 2007; Tables 6J-7 and 6J-8 in Appendix 6J.

Migratory bird species are protected under the *Migratory Birds Convention Act,* and the Yukon *Wildlife Act* has provisions for non-migratory species. Specifically Section 17 of the latter refers to the protection of non-migratory species' eggs and nests. The following avian SAR have been observed at the FMC:

- Bank swallow - Threatened (COSEWIC)
- Harlequin duck - Special Concern (COSEWIC and *SARA* Schedule 1)
- Horned grebe - Special Concern (COSEWIC)
- Trumpeter swan - Specially Protected (Yukon *Wildlife Act*)

A colony of bank swallows has been observed using a small sandy cliff in a roadside cut bank north of the ID Pond (GLL, 2008a). The olive-sided flycatcher (*Contopus cooperi*) has not been observed onsite but has been recorded as occurring in the area and is associated with open areas containing, or adjacent to, mixed or coniferous mature forest with snags or tall live trees (COSEWIC, 2007). It is listed by COSEWIC and under Schedule 1 of *SARA* as a threatened species.

Waterfowl and shorebird habitats in the LSA are limited to man-made pits and ponds onsite and the altered habitats of the NFRC and the RCD. FMC Incidental Wildlife Log records (AAM, 2013; unpublished data) and a recent waterfowl survey (ELR, 2013) indicate that waterfowl and shorebirds visit the FMC during the ice-free season and have been observed to be diving, foraging, dabbling, drinking, and resting in the aquatic habitats onsite (see Appendix J). Forage availability (e.g., benthic invertebrates, and riparian and aquatic vegetation) varies among the pits and ponds, as do the concentrations of heavy metals in water, sediment, and in the tissues of potential food sources (see Appendix J). Results from total metal content analyses of sediments and aquatic and riparian vegetation indicate some sample sites (e.g., ID Pond, Little Creek Pond and CVD Pond) provide more potential for contaminant availability and uptake than other sites (e.g., SPP, Slot Cut in Grum Pit).

Small Mammals

Small mammals are ecologically important, as some species are considered furbearers (i.e., red squirrels) but most are prey species for land-based carnivores and raptors and support an ecosystem food web. Small mammal species are defined here to include snowshoe hare and porcupine, in addition to species (e.g., small rodents and squirrels) typically included within this group.

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Several small mammal species have been observed within the LSA (GLL, 2006; AAM, 2013; unpublished data):

- Northern red-backed vole (*Clethrionomys rutilus*)
- Common shrew (*Sorex cinereus*)
- Heather vole (*Phenacomys intermedius*)
- Deer mouse (*Peromyscus maniculatus*)
- Siberian lemming (*Lemmus sibiricus*)
- Snowshoe hare (*Lepus americanus*)
- Porcupine (*Erethizon dorsatum*)
- Red squirrel

Amphibians

Five species of amphibians are known to occur in YT; however, based on their distribution, the wood frog (*Rana sylvatica*) is the only one likely to occur in the FMC area (EY, 2005). One wood frog was observed by a field crew in the Vangorda/Grum Area during a vegetation classification survey in July 2007 (Gartner Lee Limited, 2008a). Wood frogs are not at risk at the territorial or federal level and are not anticipated to be abundant at the FMC. There are no reptile species found within the Yukon (Canadian Amphibian and Reptile Conservation Network, 2012).

Invertebrates

The Canada darner (*Aeshna canadensis*), a dragonfly species, is ranked as critically imperiled in the Yukon by NatureServe (2013) and is not listed by COSEWIC. A WKA polygon for this species is located in the Swim Lakes area, approximately 8.5 km east of the LSA boundary. Specimens of this species have not been observed in other habitats appropriate for the species elsewhere in southern Yukon (Randi Mulder, personal communication, 2013).

FMC Wildlife Habitat Summary

The FMC occurs primarily within mid- to high-elevation boreal forest, which is dominated by white spruce with isolated stands of lodgepole pine and with shrub species in the understory. Subalpine vegetation communities are dominated by scrub birch, subalpine fir, white spruce, some lodgepole pine, and lichen. Above the treeline, alpine areas are characterized by rock and bluffs, low ericaceous and willow shrubs, and an abundance of terrestrial lichen (YEWG, 2004). These ecosystems surround the FMC and are in contrast to the footprint area, which is characterized by roads, mine infrastructure, engineered or altered waterbodies, and patches of regenerating vegetation communities.

Despite the altered state of the FMC, many wildlife species have been observed using LSA habitats to breed (e.g., passerine species that nest in shrubs or adjacent forest stands), migrate (e.g., waterfowl rest on pits and ponds; Fannin sheep traverse and rest in the Vangorda/Grum Area), and forage (e.g., moose feed on shrubs in riparian areas). Waterfowl and shorebird habitats within the LSA are dominated by man-made pits and ponds at the FMC; waterfowl use these habitats during migration periods and, to a lesser extent, through the summer.

Moose use a variety of habitats from valley bottoms to the subalpine zone within the LSA and RSA. Within the LSA, moose have been observed predominantly in the western portion of the FMC and in riparian draws of the Rose and Vangorda Creek systems.

Woodland caribou feed primarily on ground lichens in alpine and subalpine habitat and infrequently pass through the site. Along with other wide-ranging species such as wolverine and grizzly bear, caribou may travel through the FMC as part of larger range that includes neighbouring mountains and valleys traveled to fulfill a range of life requisites. The FMC woodlands provide year-round habitat for some mustelid species, including American marten, ermine, and mink, as well as small mammals and upland game birds. Canids have been observed at the FMC and make use of both disturbed and undisturbed areas.

The disturbed nature of the FMC footprint limits the presence of key avian and wildlife habitats within the LSA to the sand cliffs such as those north of the ID Pond (that could be used by bank swallows), the thinhorn sheep WKA movement corridors that traverse the Vangorda/Grum Area, and the portion of a thinhorn sheep WKA winter

range that extends into the LSA from the slopes of Mount Mye. Within the RSA, WKAs have only been identified for thinhorn sheep and include winter range, spring lambing, and early winter rut areas and movement corridors.

6.3 Socio-economic Conditions

This section provides an overview of the baseline conditions related to the socio-economic values and their indicators for the FMC. For the full report on the results and data pertaining to the socio-economic conditions, including methodology and references, refer to Appendix 6L, the Socio-economic Conditions Report, and Appendix 6K, Historical Resource Impact Assessment. The baseline was determined from 2009 onwards, as 2009 was the year that the co-proponents took over the responsibility of the FMC from the receivers. The baseline conditions serve as a benchmark for measurement of potential changes in VCs predicted to occur as a result of the IW. The following Affected First Nations impacted by the FMC were identified in the Devolution Transfer Agreement:

1. RRDC (based in the community of Ross River; Traditional Territory to be all of Kaska Traditional Territory, encompassing FMC)
2. LFN (based in the community of Watson Lake; Traditional Territory to be all of Kaska Traditional Territory, encompassing FMC)
3. KDC (umbrella organization representing interests of Kaska people in Yukon and BC; Traditional Territory encompassing FMC)
4. SFN (based in the community of Pelly Crossing; the FMC is upstream of its Traditional Territory)

The Town of Faro was established because of the FMC in 1969, and it is the closest community to the FMC.

Consequently, the socio-economic baseline conditions are described for the Town of Faro, RRDC (primarily in Ross River), LFN (primarily in Watson Lake), KDC, and SFN (primarily in Pelly Crossing). These were chosen as representative of both those Affected First Nations identified in the Devolution Transfer Agreement (Government of Canada, 2001) and the community (Town of Faro).

Secondary data related to all VCs were collected for each of these First Nations and communities, wherever possible. Secondary data as it relates to the KDC is represented through their members, who are citizens of the RRDC or the LFN. Data collection centered on understanding the conditions of individuals, communities, and businesses as they relate to the following VCs:

- Economy and employment
- Community stability and well-being
- Infrastructure and services
- Land use and access
- Culture and heritage

For each First Nation/community, the conditions of the listed VCs were determined through secondary data, including statistics from YG and Statistics Canada, and from information gathered from community and First Nations websites and documents. Socio-economic data are generally less frequently available compared to environmental data. Best efforts have been made to gather relevant data from 2009 on, for purposes of describing community conditions; however, not all Census data from 2011 have been released. Available data from the 2011 Census were used, but data from the 2006 Census comprise most of the description of the VCs for each community.

6.3.1 Economy and Employment

The local economy (labour force by industry) in the region has historically been heavily reliant on resource development, with mining and oil and gas extraction representing the second largest source of employment in half of the communities (the largest labour force across all four communities is in public administration). More recently, communities are focussing efforts on further developing tourism as a primary economic industry. Labour-force participation is relatively high, averaging above 70 percent, with individual pre-tax incomes ranging

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from a low of $26,061 in Ross River to a high of $34,232 in Faro and household pre-tax incomes ranging from a low of $44,069 in Ross River to a high of $59,628 in Faro (Statistics Canada, 2008).

In terms of education, for the Census 2006 survey respondents aged 15 years and older (a total of 1,420 individuals for the four communities), 50 percent (715 individuals) reported a certificate or diploma as the highest level of schooling reported. Nine percent (125 individuals) reported high school as their highest level of schooling. Approximately 6 percent (90 individuals) reported having a Bachelor's degree and only 3 percent (45 individuals) reported having a Master's degree (Statistics Canada, 2008).

The Consumer Price Index measures the cost of living experienced by communities in Canada. In terms of consumer purchasing power, the cost of living in these communities is slightly higher in comparison to Whitehorse. Individuals from these communities often travel to Whitehorse to purchase groceries and household goods or shop online or by phone. In addition, groceries are commonly supplemented by country foods such as game, berries, and fish.

6.3.2 Community Stability and Well-being

The local area supports a relatively small population, with recent estimates from 2013 showing average populations in the Town of Faro, Ross River, and Pelly Crossing to be approximately 360 people; the largest community is Watson Lake, which is home to 1,474 people (YG, 2013a). Together, these communities are comprised of a mainly non-Aboriginal population, with 35 percent identifying as Aboriginal (Statistics Canada, 2008). Communities such as the Town of Faro and Pelly Crossing have indicated trends of a growing population in recent years, contrasted with the general population change in the region, which is declining. In terms of mobility, all communities are relatively stable, with few people moving into or away from the region.

Additional demographics indicate an aging trend across all four communities, with approximately 39 percent of the total local population (Town of Faro, Pelly Crossing, Ross River, and Watson Lake) aged 50 and above. Those individuals under the age of 24 represent 28 percent of the total local population.

AANDC generates the community well-being score, which ranges from 0 to 100 and provides data on income, education, housing conditions, and labour force activity. In 2006, community well-being scores for the four communities ranged from 68 to 79, with the Town of Faro and Watson Lake both receiving scores in the high 70s.

Community crime rates between 2009 and 2012 have generally undergone little change, with the exception of Watson Lake, where crime saw a 20 percent decrease from 2009 to 2011 (YG, 2012). Following that decrease, however, crime rose again in the community from 2011 to 2012, and Watson Lake continues to have the second highest crime rate in YT (YG, 2012).

6.3.3 Infrastructure and Services

In all communities, schools provide education to students from kindergarten to grade 12, except Ross River, where schooling is to grade 10. In addition, Yukon College has local community campuses and offers post-secondary education programs to all four communities.

Access to medical and emergency services in the region is provided at nursing stations and is available 24 hours a day. Firefighting and ambulance services are provided by volunteers. People requiring complex medical and dental treatment must travel to Whitehorse or outside of the Yukon, although Watson Lake provides limited emergency services. Typically, patients requiring emergency medical attention are flown from their communities to the nearest appropriate facilities, depending on the severity of their medical condition.

Communities are accessible by both road and air, and both the Town of Faro and Watson Lake have airports. Ross River and Pelly Crossing have gravel airstrips maintained by YG. Watson Lake and the Town of Faro are municipalities responsible for delivering police, firefighting, medical, and other municipal services to residents and properties, including road maintenance. YG is responsible for providing these services in Ross River and Pelly Crossing.

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6.3.4 Land Use and Access

Land use in the region includes resource and wildlife harvesting, particularly timber, fish, caribou, moose, and other wildlife. Before development of the FMC, the area was traditionally used by First Nations primarily for hunting and gathering (further detail provided in Section 3.2.1). Trapping within the area remains active today.

Much of the land in the region is used for recreational purposes, including the multi-use 65-km Deno Cho Trail, which connects Ross River and the Town of Faro and is now used to promote tourism and recreation in the area. A number of wildlife viewing platforms are also provided in Faro and are renowned for their vantages for sheep and sandhill cranes.

Local First Nations living in the region include citizens of RRDC, LFN, and SFN. The FMC lies within the traditional territory of the KDC, of which the RRDC and LFN are members. Citizens of these First Nations used the area for harvesting and recreation before the development of the mine. The SFN people are members of the Northern Tutchone Tribal Council, and are part of the Northern Tutchone language and cultural grouping. The FMC is not within the traditional territory of the SFN; however, SFN traditional territory extends upstream on the Pelly River to a few km downstream of the confluence of Anvil Creek. The creeks and rivers that flow through the FMC feed into the Pelly River watershed and SFN traditional territory.

There is no information indicating there is any significant freshwater fishing in the area surrounding the FMC. There are important fisheries downstream of the FMC, particularly the salmon fishery in the Pelly River (Morrell, 1991). There is one main trapping concession surrounding the FMC. Trapline concession 405 is a group trapline held by the RRDC. Trapline harvesters may use the FMC from time to time to access the concession area.

Both the Yukon-based First Nations of the KDC (RRDC and LFN) do not have a land claim agreement, and both assert unextinguished aboriginal rights in the area. The SFN has land claim and self-government agreements with Canada and Yukon.

6.3.5 Culture and Heritage

The community of Faro was established to service the FMC in the late 1960s, as such, the history and heritage of the Town of Faro is closely tied to the mining industry. While further mineral exploration in the area is important to economic stimulus, tourism has become a major focus of the community and is identified as a priority in the town's Integrated Community Sustainability Plan (Town of Faro, 2007). Each May, the Town of Faro hosts a Crane and Sheep viewing festival during the annual migration of the Sandhill cranes up the Tintina Trench. This has become a major event for the community and draws visitors from around the territory.

Aboriginal people comprise most of the population of Pelly Crossing and Ross River, with non-Aboriginal residents accounting for less than 15 percent of the total population. In comparison, Faro and Watson Lake are home to a relatively smaller population of Aboriginal people, who account for 15 percent and 35 percent of each community, respectively (Statistics Canada, 2008). Both Kaska and Northern Tutchone are spoken throughout the region; however, English is the predominant language in all communities in the FMC vicinity.

To support this IWPP, YG engaged a heritage specialist to conduct a heritage resource overview assessment followed by a more detailed heritage resource impact assessment in specific areas. The results of the more detailed assessment are described in the Heritage Resource Impact Assessment (Appendix 6K). The assessment entailed a reconnaissance survey and selected shovel testing across potential borrow areas where disturbance of previously undisturbed areas may occur. Field work was carried out in eight areas of the FMC between September 24 and September 26, 2013. These areas had been previously identified in the overview assessment. Of the eight sites three were found to contain prehistoric lithic scatters in the first 10 cm of soil. These three sites were flagged with a 30-m buffer of yellow No Work Zone flagging tape.

The field crew also recorded a modern horse corral and cabin, a single log privy, and two game hanging racks (used in the late 1900s or early 2000s) that are located within potential borrow pit areas. Due to the relatively modern age of these resources, they were not recorded with the Yukon Historic Sites Inventory.

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SECTION 7

Potential Environmental and Socio-economic Effects and Proposed Mitigation Measures

This section describes the environmental and socio-economic assessment conducted for the Faro Mine IW. Section 7.1 provides an overview of the assessment approach, while Section 7.2 provides details about the assessment methods. The assessment of the IW's potential environmental and socio-economic effects relies on a combination of quantitative and qualitative analysis methods. Sections 7.3.1 through Section 7.3.7 detail the results of the environmental and socio-economic effects assessments as well the human health effects assessment. To address YESAA requirements, Section 7.3.8 describes the effects extreme events, including the effects of malfunctions and accidents. Section 7.3.9 provides a summary and conclusions about the significance of effects.

The following appendices provide further details about quantitative analyses that support the assessment:

- Appendix 7A – Air Quality Effects Report
- Appendix 7B – Description of Water Modelling and Results
- Appendix 7C – Assessment of Effects on Surface Water Quality and the Resulting Effects on Fish and Fish Habitat

7.1 Assessment Scope

The co-proponents' assessment team initiated the environmental and socio-economic assessment by defining an initial assessment scope to guide the team's work, and to support a comprehensive assessment that focused on key issues. As the proposal progressed, the team refined the assessment scope based on input received and changes in our understanding of conditions. This section defines the issues the assessment considered, based on YESAA guidance. It then outlines which values the assessment addresses, and the rationale for their inclusion in the proposal.

7.1.1 Matters Considered in the Environmental and Socio-economic Assessment

In accordance with the requirements of YESAA subsection 50(2), this Project Proposal addresses the following matters that must be considered in a Project Proposal submitted to a Designated Office:

- 42(1)(b) – All stages of the project: The assessment considers all stages of the IW through its 10-year period, as described in Section 5.1 – Project Scope. Additional activities will take place at the FMC after the IW. These activities will be the subject of a future YESAA assessment for the FMRP.
- 42(1)(c) – The significance of any environmental or socio-economic effects of the project that have occurred or might occur in or outside Yukon, including the effects of malfunctions or accidents: Sections 7.3.1 through Section 7.3.6 describe the results of the environmental and socio-economic assessment, and evaluate the significance of effects. Section 7.3.8 addresses effects that may arise from accidents and malfunctions.
- 42(1)(e) – Alternatives to the project, or alternative ways of undertaking or operating it, that would avoid or minimize any significant adverse environmental or socio-economic effects: Section 4 describes alternatives to the IW and alternative ways of executing it.
- 42(1)(f) - Mitigative measures and measures to compensate for any significant adverse environmental or socio-economic effects: The project team has iteratively developed mitigative measures to address potential adverse environmental and socio-economic effects. Some measures have been incorporated into the project design; these are addressed in the project description, which Section 5 provides. Subsequent parts of Section 7 address further mitigative measures.

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In addition to considering the matters required under YESAA subsection 50(2),this Project Proposal also provides information to support the Designated Office in conducting its evaluation by providing information and considering the following additional YESAA subsection 42(1) matters:

- 42(1)(a) – The purpose of the project: Section 4.1 of this Project Proposal addresses the purpose of the IW.
- 42(1)(d) – The significance of any adverse cumulative environmental or socio-economic effects of the project or existing project that have occurred or might occur in connection with the project: While this Project Proposal does not include a cumulative effects assessment, it provides information to support evaluation of the effects of the IW in combination with the most notable other projects and activities – the past mining activities and operations at the FMC. For key environmental components, the assessment considers the absolute effects of the project – a combination of historical activities and those that will take place during the IW.
- 42(1)(g) – The need to protect the rights of Yukon Indian persons under final agreements, the special relationship between Yukon Indian persons and the wilderness environment of Yukon, and the cultures, traditions, health and lifestyles of Yukon Indian persons and other residents of Yukon: The socio-economic assessment considers effects on Valued Components (VCs) and key characteristics that are related to treaty rights (e.g. traditional land use, hunting and fishing) and the protection of cultures, traditions, health and lifestyles.
- 42(1)(h) – The interests of residents of Yukon and of Canadian residents outside Yukon: Canada and Yukon are the proponents of the IW and have considered the interests of Yukon Residents and Canadians in proposing the project. These interests are addressed in Sections 3.2 and 4.1 (Project Background and Project Purpose, respectively).

7.1.2 Valued Components

The IW effects assessment employs a VC, or VC-based, approach that is consistent with guidance provided in YESAB's *Proponent's Guide to Project Proposal Submission to a Designated Office* (YESAB, 2010). This approach focuses the assessment on key interactions between the project and the environment or people. The VCs are relevant environmental, social, or economic elements that have scientific, social, cultural, economic, historical, archaeological, health, or aesthetic importance. When combined, the selected VCs are intended to be comprehensive, providing a framework for the assessment to efficiently identify and consider the effects of the IW.

VCs were selected by considering the environmental and socio-economic context and the type and scale of activities proposed for the IW. Compared with past mining activities or the future FMRP, the IW activities are relatively minor interim measures that are unlikely to change existing conditions for some environmental, social, and economic components. Table 7-1 lists the VCs for the IW assessment and provides the rationale for their inclusion.

TABLE 7-1
Valued Components Considered in the Assessment
Faro Mine Interim Works

Valued Component	Rationale for Inclusion
Air Quality	Air quality has a direct effect on the health of humans, wildlife, and vegetation. Dust mobilization from the FMC has affected air quality in the past, and this will continue through the IW period (e.g., dust from tailings). IW construction and maintenance activities may mobilize dust. The IW includes mitigation measures to reduce dust mobilization and transport.
Surface Water Quality	Surface water quality has a direct effect on the health of humans and the aquatic and terrestrial ecosystems. Aqueous transmission is the primary pathway for contaminants to be released from the FMC. This process began during mining and will continue through the IW. Many IW activities focus on controlling contaminant transmission into the aquatic environment (e.g., contaminated water collection and treatment).

TABLE 7-1
Valued Components Considered in the Assessment
Faro Mine Interim Works

Fish and Fish Habitat	Anvil and Rose Creeks are both fish-bearing streams that provide fish habitat for various species. The lower portion of Vangorda Creek is also fish habitat for Chinook salmon rearing, among other species. The IW could result in changes to water quality and quantity, which could affect fish and fish habitat.
Wildlife and Wildlife Habitat	The FMC is a large area that provides habitat for a range of wildlife species. Some species are important because of their cultural and resource values (e.g., as a food source), while others provide valuable measures of ecological health. The IW may affect wildlife and wildlife habitat directly (e.g., traffic-related mortality) and indirectly (e.g., vegetation disturbance).
Economy and Employment	The IW may stimulate local economies, and could increase employment, skill development, training opportunities, and education in local communities. This VC evaluates the community's ability to adapt to economic growth, the effects of increased disposable income, the distribution of costs/benefits among affected people (adverse effect/income equity), and the effects on local and regional cost of living.
Community Stability and Wellbeing	The IW will use an external work force during each IW component. The presence of this workforce in the community may affect individual, family, and community health, as well as First Nations and non-First Nations cultural wellbeing. The influx of a temporary workforce during each project component may influence (1) community makeup, including changes in demographics, mobility (such as effects of migration [in and out]), and (2) changes in social and cultural conditions.
Infrastructure and Services	The influx of the workforce associated with some of the IW components may strain community infrastructure, housing, and emergency and health services. Increased traffic caused by IW activities may affect local road safety and cause wear to road infrastructure.
Land Use and Access	There are a variety of community land uses (including trails) on and around the FMC. The assessment considers potential effects of the IW on First Nations' traditional land use (for hunting, trapping, and gathering), as well as effects on access for commercial and recreational land users.
Cultural and Heritage	Before mining activities began, local First Nations used the area around the FMC. As a result, the area has cultural value and contains heritage resources. The assessment will consider potential effects of the IW on cultural, heritage, and archaeological values.
Human Health and Safety	The IW and current best management practices aim to protect human health and safety. However, Human Health and Safety is a VC for two purposes: • To continue to protect the community and worker health and safety • To identify the potential effects on both community and worker health and safety

While developing the list of VCs, the assessment team considered several additional components, but concluded these did not warrant direct incorporation as VCs because (1) they are unlikely to be measurably affected by the IW or (2) they are considered vectors for effects on identified VCs. Table 7-2 describes the rationale for excluding components from direct incorporation as VCs.

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TABLE 7-2
Components Excluded from Direct Incorporation as VCs
Faro Mine Interim Works

Component	Rationale for Exclusion
Groundwater	The assessment does not consider groundwater as a direct VC for the IW because it accounts for groundwater's importance as a pathway for effects on the Surface Water Quality and Fish and Fish Habitat VCs. This approach is based on the existing and expected future conditions of groundwater, as well as the foundation for the proposed long-term remediation and closure methods at the FMC. Within the FMC footprint, groundwater quality and flows have already been substantially altered by mining-related site disturbance and contaminant loading. Groundwater conditions within the FMC's footprint will continue to change throughout the life of the IW and beyond. For example, groundwater quality within the FMC's footprint will deteriorate further as contaminant loads increase from mine waste sources. One of the fundamental goals of the IW and the FMRP is to prevent onsite groundwater from significantly impacting local ecosystems. As a result, the interim and long-term (contained in the FMRP) responses to changing groundwater conditions will rely on groundwater collection systems, cover installation, and pit water management, which also affect groundwater. In these circumstances, groundwater is and will be a pathway for effects on the Surface Water Quality and Fish and Fish Habitat VCs. Changes in the quantity and quality of groundwater could affect these VCs, and this assessment has addressed those effects. As a critical pathway of effects, groundwater may also be an important early indicator of conditions for these VCs, and will be a critical component of monitoring programs. The decision to exclude groundwater as a direct VC carefully considered potential direct uses of groundwater near the FMC. The nearest downgradient groundwater use is for the Town of Faro's water supply, with wells located near the mouth of Vangorda Creek. Hydrogeological investigations in this area have concluded that these wells are influenced by surface flows in Vangorda Creek and the Pelly River, depending on relative water levels. There is not a direct groundwater linkage to the FMC. In this case, surface water acts as a vector for the potential effects. As a result, the assessment of effects on surface water addresses potential concerns about these wells.
Soil and Sediment Quality	Soil and sediment quality have been affected by past mining activities via dust transported from the FMC. While the IW will continue to affect these components, changes arising from the IW activities are expected to be minimal, and are not likely to be measurable during the IW. The evaluation of effects on the Fish and Fish Habitat and Wildlife and Wildlife Habitat VCs addresses adverse effects associated with existing conditions.
Climatic Conditions	The assessment did not consider potential effects of the project on climatic conditions because of the short-term nature of the proposed IW. During the IW, its effects on climatic conditions are not likely to be measurable. However, effects on climatic conditions will be more relevant during the assessment of the FMRP.
Aesthetics	Aesthetic conditions were not identified as a VC for the IW because the activities proposed as part of the IW are unlikely to have notable effects on aesthetic conditions. The FMRP will include substantial measures that will affect aesthetic values, but these remediation activities are not part of the IW.
Noise	While the activities proposed for the IW will generate noise at the FMC, the levels of activity and noise are not substantially different from those generated during similar activities at the site since the mine closed in 1998. The FMC is located in a remote location and is home to wildlife with limited exposure to anthropogenic noise. Excessive noise from project activities could affect wildlife use patterns, but for the IW, these have been addressed through the assessment of effects on wildlife, which is a VC.
Vegetation	The activities proposed as part of the IW will have little effect on vegetation near the FMC. Much of the site has already experienced extensive vegetation disturbances, and the IW will be focused in areas of existing disturbance. While revegetation and reclamation activities will be a major component of the FMRP, the IW does not include these activities, except when they are required to mitigate direct effects of IW activities. Vegetation disturbances can affect wildlife and wildlife habitat, and these effects have been addressed through the assessment of effects on those VCs.

7.1.3 Geographic Assessment Scopes

The geographic assessment scope defines the area where IW activities may overlap environmentally, socially, or economically with each of the VCs. The area of influence varies for VCs; therefore, the IW assessment defines geographic assessment scopes separately for each VC and for some specific indicators or key characteristics. Relevant portions of Sections 7.3 describe the specific geographic scopes.

To promote consistent approaches for establishing the spatial boundaries to assess effects on different VCs, the assessment team considered the criteria described in Table 7-3.

TABLE 7-3
Criteria for Defining Study Areas (Spatial Scopes)
Faro Mine Interim Works

Study Area	Definition
Site	Existing disturbed area and immediate zone of direct project effects
Local	Area with reasonable potential for effect interactions (direct or indirect) between the IW and the relevant VC
Regional	Wider area with potential for socio-economic or cumulative effects.

7.1.4 Assessment Temporal Boundaries

The assessment temporal boundary defines the timeframe associated with the effects predictions. For the IW, the assessment considers effects within its 10-year project scope. The co-proponents recognize that effects from the FMC will extend well beyond the duration of the IW. However, there is little benefit in assessing or predicting effects of the IW beyond the proposed 10-year scope of the proposed project. The FMRP activities will be initiated to address long-term effects. The FRMP activities will be of longer duration, have different effects, and are intended to mitigate many of the ongoing effects at the site. The IW activities will be upgraded or expanded, changing their effects on VCs. The details of the FMRP activities are not yet sufficiently defined to predict their long-term effects.

The FMRP will undergo a YESAA assessment before it proceeds. According to the current schedule, the FMRP Project Proposal will be submitted to YESAA during the third year of the IW. The assessment for the FMRP will consider the potential effects of the FMRP, combined with continuing effects of the IW after its proposed 10-year scope. Therefore, the IW assessment only considers effects within its 10-year time period.

7.1.5 Baseline Condition Definition

The IW assessment compared project-related effects with current conditions at the FMC. This approach is appropriate for a project that involves interim measures to control and mitigate existing effects from a legacy project. The co-proponents' overarching objectives focus on protecting and restoring the environment and land uses, as practicable. These objectives guide overall remediation planning towards long-term outcomes which are improvements over existing conditions. During the 10-year scope of the proposed project, the IW activities will also result in some positive outcomes; for example, decreased risks to human health and safety, and to the reduction of risks to water quality.

The specific timeframes used to characterize baseline conditions vary for different environmental, social, and economic elements, depending on data availability, quality, and applicability. Please refer to Section 6 for specific timelines used to define baseline conditions.

7.1.6 External Factors That May Affect the Project

The ability of the FMC and the proposed IW to withstand external factors is an important consideration in the assessment. External factors present risks to the project, which could result in adverse environmental or socio-economic outcomes. Using a risk assessment approach, the IW assessment considers effects that may result from forest fires, floods, and earthquakes.

Global climate change could affect the long-term performance of various FMC components (e.g., diversion capacity). However, the IW assessment has not considered those effects, because of the short (10-year) duration of the proposed project. Within that timeframe, the effects of global climate change are not likely to be measurable. Using current conditions to define baseline conditions assures past effects of global climate change are incorporated into the assessment and project planning.

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The IW assessment also excludes the effects of external socio-economic factors (e.g., limitations on access to goods and services; institutional failure), because of its short duration.

7.1.7 Effects of Accidents and Malfunctions

As Section 7.1.1 described, YESAA requires the assessment to consider the potential effects of accidents and malfunctions associated with the IW. Using a risk assessment approach, the assessment considers the effects that could arise from a variety of potential failure modes and events:

- Engineering failures (e.g., structural failure of building)
- Human error (e.g., operator error, inspector error, mischief, or vandalism)
- Prediction errors (e.g., uncertainty in geochemical predictions, or underestimates of flood events)

7.2 Assessment Methods

The co-proponents' assessment team applied a VC-based approach to the assessment, evaluating project effects on a range of VCs to identify and then characterize potentially significant effects. Section 7.1.2 describes the VCs and the rationale for their consideration in the assessment.

For the selected VCs, the environmental and socio-economic assessment teams used consistent methods comprising two main steps to identify and characterize effects. The first step broadly identified potential interactions between IW activities and the VCs, then classified potential interactions to highlight those warranting detailed evaluation. The second step characterized the important interactions to define and describe the potential effects, and evaluate their significance.

This section describes the methods used in the proposal to assess the potential environmental and socio-economic effects of the IW, and to determine their significance.

7.2.1 Step 1: Initial Identification and Classification of Project/VC Interactions

The first step in conducting the effects assessment involved a comprehensive identification of interactions between IW activities and VCs. It also classified the interactions to highlight those warranting detailed consideration in the effects assessment. This step took place during two workshops, to promote consistency in decision-making: one for environmental VCs, and one for socio-economic VCs.

During these workshops, the potential for specific pathways of effects between each activity in the IW and each VC was considered. This systematic approach created a matrix of project activities and VCs, promoting thorough consideration and identification of all potential interactions, regardless of scale, magnitude, or direction. Within the matrix, each project-activity/VC intersection was classified according to the following numerical criteria:

- "0" = No Interaction: no measurable interaction that could cause an effect
- "1" = Minor Interaction: minimal interaction where measureable effects are possible, but the effects will be avoided or suitably mitigated through compliance with regulatory requirements and application of standard best management practices
- "2" = Major Interaction: potential interaction where measurable effects are likely even with application of best management practices, or where understanding the scale or magnitude of effects requires detailed analysis

The assessment addressed interactions classified as "1" by identifying specific regulatory requirements and best management practices to eliminate or suitably mitigate potential effects. Sections 7.3.1 through 7.3.6 describe the results of the assessment for these interactions.

The assessment addressed interactions classified as "2" by conducting more detailed analyses of potential effects (which is Step 2 the assessment methodology). Where multiple activities could have similar effects on the same VC (e.g., effects of multiple construction-related activities on air quality), some of the interactions classified as "1" were considered in aggregate as a "2" and were subject to more detailed analyses during Step 2. Section 7.2.2 describes the methods used to conduct these assessments for environmental and socio-economic VCs.

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7.2.2 Step 2: Evaluate Effects of Relevant Project/VC Interactions

Each interaction classified as "2" was carried forward for a more detailed assessment. Analytical processes were followed to understand the interaction pathways, predict the effects, identify appropriate mitigation measures, evaluate the significance, and design monitoring plans to confirm the validity of the assessment.

7.2.2.1 Environmental VCs

For environmental VCs, the co-proponents' assessment team applied the following general steps to evaluate project activity/VC interactions. In many cases, the assessment evaluated combined effects of multiple activities to achieve a thorough understanding of the effects of the entire project.

- Identify and describe specific pathways that may lead to effects on VCs.
- Identify indicators and metrics to characterize the interactions between the project and a specific VC.
- Develop and describe ecological objectives that define acceptable conditions and levels of changes for VCs from the baseline conditions
- Analyze project effects on VCs. Analytical methods varied for each VC and for each type of interaction, with appropriate methods selected to achieve the overall assessment goals: to predict the potential environmental conditions arising from the project, and compare the predicted conditions with the baseline and the ecological objectives. In some cases, rigorous scientific modelling approaches were applied to predict effects (e.g., water balance models, contaminant loading models, landscape models). In other cases, more holistic approaches were applied to predict project outcomes based on experience with other projects, case studies, experiments, and professional judgement.
- Develop mitigation measures. Where necessary, the assessment team identified the need for mitigation to address adverse environmental effects. This was an iterative process, resulting in refinements of the design to improve its environmental performance. For the IW, adaptive management is an important component of the project and proposed mitigation plans. Where the effects analysis identified uncertainty about potential effects from changing site conditions, AMPs were developed. AMPs are systematic plans that identify (1) events that may lead to adverse effects, (2) appropriate performance indicators, (3) detailed monitoring programs to understand status and trends of indicators, (4) triggers for actions, and (5) specific actions that will be undertaken.
- Evaluate the significance of residual effects (i.e., effects after mitigation measures are applied). Section 7.2.3 describes this methodology.
- Develop monitoring programs. The intent is to confirm assessment predictions and the performance of the project and mitigation measures.

7.2.2.2 Socio-economic VCs

The assessment team followed similar general steps to evaluate project-activity interactions for socio-economic VCs:

- Identify and describe specific pathways that may lead to effects on VCs.
- Identify key characteristics and metrics to characterize the interactions between the project and a specific VC.
- Describe baseline conditions and acceptable levels of change for VCs.
- Analyze potential project effects on VCs. Analytical methods varied for each VC and for each type of interaction, with appropriate methods selected to achieve the overall assessment goals: to predict the potential socio-economic conditions arising from the project, and compare the predicted conditions with baseline conditions. Secondary data, at best available scales, were analyzed using largely qualitative tools to predict potential socio-economic effects (e.g., comparative approach, experience with other projects, case studies, experiments, and professional judgement).

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- Develop mitigation measures. Where necessary, the assessment team identified the need for mitigation or enhancements to existing best management practices and communication protocols, to address adverse socio-economic effects.
- Evaluate the significance of residual effects. Section 7.2.3 describes this methodology.

7.2.2.3 Extreme Events

The environmental and socio-economic assessment considered two types of risk events, external factors (i.e., floods, earthquakes and forest fires) and malfunctions and accidents. The assessment followed a series of steps to evaluate these effects:

- Identify and describe specific pathways that may lead to increased risk.
- Analyze project risks using risk assessment tools.
- Develop mitigation measures to reduce the risks and their environmental and socio-economic effects. Some risk events can be managed by reducing the likelihood of the events, while others can be addressed by mitigating the magnitude of consequences.
- Evaluate the significance of residual risks (i.e., effects after mitigation measures are applied). Section 7.2.3 describes this methodology.

7.2.3 Methodology for Evaluating Significance

As Section 7.1.1 stated, YESAA requires the consideration of the significance of identified adverse residual effects. The co-proponents' assessment team considered the following list of criteria when evaluating the significance of project activities' residual effects on VCs:

- Direction
- Magnitude
- Likelihood
- Duration
- Geographic extent
- Frequency
- Reversibility
- Socio-economic Context

The following criteria were used to determine the significance of environmental VCs:

- Direction – For all environmental VCs, direction was considered to be negative and addressed as part of the magnitude criteria.
- Magnitude/Likelihood/Duration - These criteria are related, and considered together when determining the significance of environmental VC. Magnitude is the amount of change in an indicator, relative to the existing or baseline condition, or change above an established objective. Likelihood refers to the probability that an effect will occur, and in this case, also considers how often an effect will occur (i.e. frequency of an effect). Duration addresses how long an effect may continue once it has occurred. For example, the period of time required until the VC or indicator returns to its baseline condition, or until the effect can no longer be measured or otherwise perceived. The overall duration of the IW is 10 years, so the significance of effects is assessed within this 10-year period. Effects that extend beyond this period will be considered in the assessment for the FMRP.
- Geographic Extent - This refers to the extent or proportion of a VC affected by a project activity. The geographical extent can vary from site-specific or to larger geographical areas, depending on the VC. Residual effects over larger geographical extents are more significant.
- Reversibility – Reversibility addresses the ability of an adverse effect to return to pre-project or pre-activity conditions. It considers the timeframe within which, and probability that, an effect could be reversed.

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For each criterion, significance is measured as High, Moderate, or Low, with the understanding that criteria and significance are defined according to the specific VC and indicator being considered. In some cases, rigorous scientific modelling approaches were applied to predict effects (e.g., water balance models, contaminant loading models, landscape models) and quantify significance. In others, significance was determined based on experience with other projects and professional judgement. The rating of overall significance for each VC is based on the balance of ratings for the criteria. Before significance was evaluated, the assessment team established that if an activity had a high rating for overall significance, the activity was deemed to have significant effects and was not acceptable to proceed in accordance with YESAA requirements.

Socio-economic VCs

The criteria for socio-economic VCs are similar to the criteria for environmental VCs. However, they are defined more specifically to reflect the socio-economic conditions and indicators. The following criteria were established to evaluate the significance of socio-economic VCs:

- Direction – Socio-economic effects may differ in direction, and are therefore considered when evaluating significance. Direction is defined as the ultimate long-term trend of the socio-economic effect (neutral, positive, or negative), relative to the baseline conditions.
- Magnitude/Duration - The amount or degree of change relative to baseline conditions. The period of time required until the VC or indicator returns to its baseline condition, or until the effect can no longer be measured or otherwise perceived. In this case, duration provides a measure of reversibility as well.
- Geographic extent - The geographic area within which a socio-economic effect occurs.
- Probability/Frequency – This is considered separately from magnitude/duration to reflect the probability that an effect will occur, and how often it could occur (once, daily, weekly, monthly, continuous).
- Social-economic context –The existing socio-economic context or situation, and the additional effects the project may have on a socio-economic VC. It is a measure of socio-economic resiliency and the ability to cope/adapt.

For each criterion except direction, significance is measured as High, Moderate/Medium, or Low. Specific criteria and significance definitions reflect the specific VC and indicator under consideration. A combination of socio-economic modelling approaches, experience with other projects, and professional judgement was used to identify significance. Again, before significance was evaluated, the assessment team determined that if an activity had a rating of high for overall significance, the activity was deemed to have significant effects and was not acceptable to proceed in accordance with YESAA requirements.

Extreme Effects

Risk assessment tools are applied to evaluate the likelihood and consequences of potential extreme events. Risks are estimated using quantitative modelling or qualitative methods (e.g., comparative approach, experience with other projects, case studies, experiments, and professional judgment). If the likelihood and consequence of an extreme event was High, the project activity was deemed to have significant effects and was not acceptable.

7.3 Effects Assessment Results

7.3.1 Initial Identification and Classification of Project/VC Interactions

Table 7-4 provides the results of Step 1 of the effects assessment – the initial identification and classification of potential interactions between project activities and VCs, according to the interaction criteria described in Section 7.2.1.

Subsequent subsections address the effects of all interactions classified as Major interactions (“2”) in Table 7-4 in detail.

7.3.2 Mitigation for Minor Interactions

Table 7-4 identifies numerous potential Minor interactions ("1") where measureable effects are possible, but the effects will be avoided or suitably mitigated by complying with regulatory requirements and applying standard best management practices. For these potential effects, the project's performance relies on the development and effective application of appropriate mitigation - a series of best management practices. Appendix 5A, the Environmental Management Plan, provides mitigation and management plans. These plans describe the best management practices that will be applied during the IW. Table 7-5 identifies specific mitigation and management plans that will apply to each of the activities that make up the IW.

By effectively applying the listed mitigation and management plans, the assessment team concluded that the minor interactions, when considered individually, will not cause significant adverse environmental or socio-economic effects. Where effects of more than one minor interaction could combine to have greater effects on specific VCs, or where they combine with major interactions, the combined effects have been addressed in aggregate; subsequent sections provide more detailed assessments of these.

7.3.3 Air Quality Effects Assessment

This section describes the results of the detailed analysis of potential effects of the IW on air quality. As identified in Table 7-4, this effects assessment has only identified one Major interaction between project activities and air quality (i.e., ranked as "2" in the interaction matrix). That interaction considers the effects of storing tailings in the RCTA. Site operations include dust control measures to minimize dust release from the tailings. However, the assessment recognizes that continued dust mobilization will remain an issue until the FMRP is complete.

Several other proposed activities may also cause dust to be released at the FMC, but these are identified as Minor interactions. The assessment recognizes that although these interactions are minor, their effects may combine with that of tailings storage (the Major interaction). The air quality effects assessment considers the combined effects of all IW activities that may adversely affect air quality. Appendix 7A provides additional details about effects on air quality.

USEPA CALPUFF quantitative dispersion modelling was used in this effects assessment. This modelling estimates the dispersion of estimated project emissions throughout the IW. The dispersion modelling covers an area of 50 km from the centre of the FMC, and incorporates meteorological data. To determine project-related effects, the modelled dispersion patterns are then compared to applicable ambient air standards for particulate matter, as well as metal concentrations within particulate matter. The modelling approach and results are provided in Appendix 7A.

7.3.3.1 Air Quality – Pathways of Effects

The pathways of effects are the mechanisms through which project activities can effect air quality in the region.

Table 7-4 identifies several potential air quality interactions that fall into the following four categories:

1. Dust re-suspension from tailings stored in the RCTA
2. Dust re-suspension from vehicle traffic on roadways within the FMC
3. Dust emissions from general construction activities and earthworks being performed as part of the IW
4. Dust emissions from lime handling at water treatment facilities

Dust emissions from lime handling have not been considered further in the modelling and assessment because these will be addressed by lime handling protocols. The remaining interactions can adversely affect air quality in the study area and are the focus of the modelling and assessment.

Table 7-4 provides further detail.

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TABLE 7-4
Project/Valued Component Interactions
Faro Mine Interim Works

Valued Component										
Project Activity or Physical Work	**Air Quality**	**Surface Water Quality**	**Fish and Fish Habitat**	**Wildlife and Wildlife Habitat**	**Economy and Employment**	**Community Stability and Wellbeing**	**Infrastructure and Services**	**Land Use**	**Culture and Heritage**	**Human Health and Safety**
Site Operations										
Site Operations workforce management; employment; contracts; and taxes	N/A	N/A	N/A	N/A	2	1	0	0	0	0
Tailings storage in the RCTA	2	2	2	2	0	1	0	0	0	1
Waste rock storage	0	2	2	0	0	0	0	0	0	1
Clean water diversion	0	0	0	2	0	0	0	0	0	0
Contaminated water storage in pit lakes and backfilled pits (i.e., Faro, Vangorda, Grum, and Zone II Pits)	0	2	0	1	0	0	0	0	0	1
Contaminated water storage in ponds (e.g., Little Creek Pond, ID Pond, CVD Pond, SPP, Moose Pond, Grum Settling Pond, Vangorda Water Treatment Clarification Pond)	0	2	2	2	0	0	0	0	0	1
Contaminated water transfer from Zone II Pit to Faro Pit	0	1	0	0	0	0	0	0	0	0
Contaminated water interception, collection, and transfer from ETA to Faro Pit	0	2	0	0	0	0	0	0	0	0
Contaminated water interception, collection, and transfer from S-Wells to Faro Pit	0	2	2	0	0	0	0	0	0	0
Seasonal contaminated water transfer from Grum Pit, Grum Dump and Little Creek Pond to Vangorda Pit and V15	0	1	1	0	0	0	0	0	0	0
Seasonal contaminated water discharge into Moose Pond	0	2	2	0	0	0	0	0	0	0
Seasonal water treatment and discharge at Vangorda WTP	1	2	2	0	0	0	0	0	0	1
Seasonal water treatment and discharge at Faro Interim WTP	1	2	2	0	0	0	0	0	0	1
Diversion and site drainage containment system maintenance (dams, spillways, dikes, berms, collection ponds)	0	0	0	1	0	0	0	0	0	1
Sludge disposal from water treatment systems	0	1	0	0	0	0	0	0	0	1
Site Investigations										
Site Investigation workforce management employment; contracts; and taxes	N/A	N/A	N/A	N/A	2	1	1	0	0	0
Boreholes/test pits	0	1	1	1	0	0	0	0	0	1
Soil/rock sampling	0	0	0	0	0	0	0	0	0	1
Monitoring equipment installation including wells, thermistors, and flow measurement facilities	0	0	1	1	0	0	0	0	0	1
Aquifer and pump testing	0	1	1	0	0	0	0	0	0	1
Field trials of remedial measures	0	0	0	0	0	0	0	0	0	1
Access route development (may include stream crossings)	0	1	1	2	0	0	0	2	1	1
Surface geophysics	0	0	0	1	0	0	0	2	1	1
Helicopter / aircraft use	0	0	0	1	0	0	0	0	0	1
DVIHU										
Construction workforce management; employment; contracts; and taxes	N/A	N/A	N/A	N/A	2	1	0	0	0	1

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TABLE 7-4
Project/Valued Component Interactions
Faro Mine Interim Works

Valued Component										
Project Activity or Physical Work	**Air Quality**	**Surface Water Quality**	**Fish and Fish Habitat**	**Wildlife and Wildlife Habitat**	**Economy and Employment**	**Community Stability and Wellbeing**	**Infrastructure and Services**	**Land Use**	**Culture and Heritage**	**Human Health and Safety**
Intermediate Dam Spillway Excavation	1	1	0	1	0	1	0	0	0	1
Borrow material sourcing and transport	1	1	0	0	0	0	0	0	0	1
Erosion protection construction in spillway	1	1	0	0	0	0	0	0	0	1
Equipment relocation within Intermediate Dam Spillway including Intermediate Dam Pond pumping system, water treatment effluent system, and siphon lime mixing system	0	0	0	0	0	0	0	0	0	0
Geomembrane and dam raise (gabions) construction	1	1	0	0	0	0	0	0	0	1
Vegetation removal in RCD	0	1	1	1	0	0	0	0	0	1
Bank slough removal in RCD	0	1	1	1	0	0	0	0	0	1
RCD Dike repair	0	1	1	1	0	0	0	0	0	1
Accessory Activities										
Fuel and material transportation	1	1	1	1	0	0	0	0	0	1
Personnel and supply transportation	1	1	1	1	0	0	0	0	0	1
Hazardous materials storage and use (reagents, fuel, and hydrocarbons)	1	1	1	0	0	0	0	0	0	1
Waste management (disposal to landfills), including domestic waste	0	0	0	1	0	0	2	0	0	0
Backup power generation and site power distribution	0	0	0	0	0	0	0	0	0	0
Waste oil heating system	0	0	0	0	0	0	0	0	0	0
Snow clearing and stockpiling	0	0	0	1	0	0	0	0	0	0
Vehicle and equipment maintenance	0	0	0	0	0	0	0	0	0	0
Infrastructure maintenance (buildings, e.g. Guardhouse, Mill Building)	0	0	0	0	0	0	0	0	0	1
Site access control	0	0	0	0	0	0	0	2	1	1
Housing in Town of Faro	0	0	0	0	0	0	1	0	0	0
Temporary camp	0	1	0	1	0	2	2	0	0	0
Borrow material sourcing and transportation	1	1	1	1	0	0	0	0	0	0
Site road and trail maintenance	0	0	0	0	0	0	0	0	0	1
General project-related traffic management	1	0	0	1	0	0	0	0	0	1
Potable water supply	0	0	0	0	0	0	2	0	0	0
Sewage treatment and discharge	0	0	0	0	0	0	2	0	0	0
Advance operations workforce training	N/A	N/A	N/A	N/A	0	0	0	0	0	0

Note:
NA = Not applicable

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TABLE 7-5
Management and Mitigation Plans Applicable to IW Activities
Faro Mine Interim Works

Project Activity or Physical Work	Sediment and Erosion Control Plan	Emergency Response Plan	Spill Contingency Plan	Tailings and Water Mgmt ERPP	Tailings and Water Mgmt OMS Plan	Waste Mgmt Plan	Wildlife and Habitat Mgmt Plan	Heritage Resource Mgmt Plan	OH&S Plan	Dust Mgmt Plan	Adaptive Mgmt Plan	Sludge Mgmt Plan	Vegetation Protection Plan	Traffic Mgmt Plan
Site Operations														
Site Operations workforce management; employment; contracts; and taxes									✓					✓
Tailings storage in the RCTA		✓		✓	✓		✓		✓	✓	✓			
Waste rock storage	✓			✓	✓					✓	✓			
Clean water diversion	✓	✓		✓	✓		✓		✓					
Contaminated water storage in pit lakes and backfilled pits (i.e., Faro, Vangorda, Grum, and Zone II Pits)		✓		✓	✓		✓		✓		✓			
Contaminated water storage in ponds (e.g., Little Creek Pond, Intermediate Dam Pond, Cross Valley Pond, Sheep Pads Pond, Moose Pond, Grum Settling Pond, Vangorda Water Treatment Clarification Pond)				✓	✓		✓		✓					
Contaminated water transfer from Zone II Pit to Faro Pit					✓				✓					
Contaminated water interception, collection, and transfer from ETA to Faro Pit			✓	✓	✓				✓		✓			
Contaminated water interception, collection, and transfer from S-Wells to Faro Pit			✓	✓	✓				✓		✓			
Seasonal contaminated water transfer from Grum Pit, Grum Dump, and Little Creek Pond to Vangorda Pit and peak flow transfer of contaminated water from V15 and Grum Creek Pumping System to Vangorda Pit			✓	✓	✓				✓					
Year-round discharge of contaminated water to Moose Pond				✓	✓						✓			
Seasonal water treatment and discharge at Vangorda WTP		✓	✓	✓	✓				✓		✓			
Seasonal water treatment and discharge at Faro Interim WTP		✓	✓	✓	✓				✓		✓			
Diversion and site drainage containment system maintenance (dams, spillways, dikes, berms, collection ponds)	✓	✓		✓	✓		✓		✓				✓	
Sludge disposal from water treatment systems			✓		✓				✓			✓		
Site Investigations														
Site Investigation workforce management; employment; contracts; and taxes									✓					✓
Boreholes/test pits	✓		✓			✓	✓	✓	✓				✓	

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TABLE 7-5
Management and Mitigation Plans Applicable to IW Activities
Faro Mine Interim Works

Project Activity or Physical Work	Sediment and Erosion Control Plan	Emergency Response Plan	Spill Contingency Plan	Tailings and Water Mgmt ERPP	Tailings and Water Mgmt OMS Plan	Waste Mgmt Plan	Wildlife and Habitat Mgmt Plan	Heritage Resource Mgmt Plan	OH&S Plan	Dust Mgmt Plan	Adaptive Mgmt Plan	Sludge Mgmt Plan	Vegetation Protection Plan	Traffic Mgmt Plan
Soil/rock sampling	✓		✓			✓	✓	✓	✓				✓	
Monitoring equipment installation including wells, thermistors, and flow measurement facilities	✓						✓	✓	✓				✓	
Aquifer and pump testing	✓					✓	✓	✓	✓				✓	
Field trials of remedial measures	✓						✓	✓	✓				✓	
Access route development (may include stream crossings)	✓						✓	✓	✓				✓	✓
Surface geophysics	✓						✓	✓	✓				✓	
Helicopter / aircraft use		✓					✓		✓					
DVIHU							✓							
Construction workforce management; employment; contracts; and taxes									✓					✓
Intermediate Dam Spillway Excavation	✓						✓		✓	✓			✓	
Borrow material sourcing and transport	✓						✓	✓	✓	✓			✓	✓
Erosion protection construction in Intermediate Dam spillway	✓						✓		✓	✓			✓	
Equipment removal or relocation within Intermediate Dam Spillway including Intermediate Dam Pond pumping system, water treatment effluent system, and siphon lime mixing system	✓								✓					
Geomembrane and Intermediate Dam raise (gabions) construction	✓						✓		✓	✓			✓	
Vegetation removal in RCD	✓						✓		✓				✓	
Bank slough removal in RCD	✓						✓		✓				✓	
RCD Dike repair	✓						✓		✓				✓	
Accessory Activities														
Fuel and material transportation		✓	✓				✓		✓					✓
Personnel and supply transportation		✓	✓				✓		✓					✓
Hazardous materials storage and use (reagents, fuel, and hydrocarbons)		✓	✓			✓			✓					
Waste management (disposal to landfills), including domestic waste						✓	✓		✓					
Backup power generation and site power distribution		✓	✓						✓					
Waste oil heating system			✓						✓					

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TABLE 7-5
Management and Mitigation Plans Applicable to IW Activities
Faro Mine Interim Works

Project Activity or Physical Work	Sediment and Erosion Control Plan	Emergency Response Plan	Spill Contingency Plan	Tailings and Water Mgmt ERPP	Tailings and Water Mgmt OMS Plan	Waste Mgmt Plan	Wildlife and Habitat Mgmt Plan	Heritage Resource Mgmt Plan	OH&S Plan	Dust Mgmt Plan	Adaptive Mgmt Plan	Sludge Mgmt Plan	Vegetation Protection Plan	Traffic Mgmt Plan
Snow clearing and stockpiling	✓						✓		✓					
Vehicle and equipment maintenance			✓						✓					
Infrastructure maintenance (buildings, e.g. Guardhouse, Mill Building)		✓							✓					
Site access control														
Housing in Town of Faro														✓
Temporary camp	✓					✓	✓	✓	✓					✓
Borrow material sourcing and transportation	✓						✓	✓	✓	✓			✓	✓
Site road and trail maintenance	✓						✓		✓	✓			✓	✓
General project-related traffic management							✓		✓					✓
Potable water supply									✓					
Sewage treatment and discharge			✓			✓								
Advance operations workforce training									✓					

Notes:
N/A = not applicable
ERPP – Emergency Response and Preparedness Plan
OMS – Operations, Maintenance and Surveillance
Mgmt - Management

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7.3.3.2 Air Quality – Indicators

Four indicators are selected on which to adequately describe potential effects of the IW on ambient air quality. Changes in air quality are indicated through total suspended particulates (TSP), two size classes of particulate matter, and metals contained within the particulate matter. The two sizes of particulate matter chosen were PM_{10} and $PM_{2.5}$. Several different metal contaminants are used to characterize the metal indicator (Appendix 7A), specifically metals known to occur within the FMC and known to affect both human and environmental health. Changes in air quality are assessed by modelling the concentrations of these indicators at the identified model receptor sites, using IW emission estimates, and air dispersion modelling for all of the identified effects pathways. While metals are modelled for all pathways in order to consider the combined effects, the tailings are an overwhelming source for this indicator.

These indicators were selected based on the effects pathways identified, where particulate matter and metals released into the air as a result of IW activities are most likely to show the greatest change when compared to background ambient air quality. The indicators described formed part of the air quality model, and are shown in Table 7-6 and provided in Appendix 7A.

TABLE 7-6
Source Identification, Pathway, and Indicators Used in Air Quality Effects Assessment
Faro Mine Interim Works

Source Type	Effects Pathway	Indicators
RCTA	The re-suspension of dust from the RCTA through wind erosion.	TSP, PM_{10}, $PM_{2.5}$, metals
Site and access roads	The release of dust from project-related traffic on the various site and access roads.	TSP, PM_{10}, $PM_{2.5}$, metals
Construction activity sites	The release of dusts associated with construction activities onsite, including: • ID spillway - upgrades – Excavation of ID Spillway – Sourcing and transport of borrow material – Construction of erosion protection in spillway • ID raise (geomembrane and concrete barrier - installation) • Excavation and handling of borrow materials	TSP, PM_{10}, $PM_{2.5}$, metals

7.3.3.3 Air Quality – Ecological Objectives

The assessment compares model results to a series of AAQC developed by YT, British Columbia, and Ontario (Table 7-7). An AAQC is a desirable concentration of a contaminant in air, based on protection against adverse effects on health or the environment. AAQC are set with different averaging times (e.g., annual, 24 hour, 1 hour and 10 minutes) appropriate for the effect that they are intended to protect against. The effects considered may be health, odour, vegetation, soiling, visibility, corrosion or other effects.

The assessment preferentially relies on Yukon standards when available, in this case TSP for 24-hour and annual averages, and 24-hour average $PM_{2.5}$ concentrations. If Yukon standards were not available and more than one provincial standard exists for a particular contaminant or averaging period, the most stringent was used for comparison. For 24-hour PM_{10}, the objective from British Columbia was used, while for the metals, Ontario 24-hour average standards and guidelines were used.

Standards and guideline concentration units are in $\mu g/m^3$ unless otherwise noted.

TABLE 7-7
Summary of Ambient Air Quality Standards for All Modelled Contaminants µg/m³
Faro Mine Interim Works

	Average Period		
Contaminant	**24-hour**	**Annual**	
TSP	120	60	Yukon AAQS
PM_{10}	50		British Columbia AAQS
$PM_{2.5}$	30		Yukon AAQS
Antimony	25		Ontario Standard
Arsenic	5		Ontario Standard
Barium	10		Ontario Guideline
Beryllium	0.01		Ontario Standard
Boron	120		Ontario Standard
Cadmium	0.025		Ontario Standard
Chromium	1.5		Ontario Guideline
Cobalt	0.1		Ontario Guideline
Copper	50		Ontario Standard
Iron	4		Ontario Standard
Lead	0.5		Ontario Standard
Manganese	2.5		Ontario Guideline
Molybdenum	120		Ontario Guideline
Nickel	2		Ontario Standard
Selenium	10		Ontario Guideline
Silver	1		Ontario Standard
Strontium	120		Ontario Guideline
Tellurium	10		Ontario Standard
Tin	10		Ontario Standard
Titanium	120		Ontario Standard
Vanadium	2		Ontario Standard
Zinc	120		Ontario Standard

7.3.3.4 Air Quality – Analysis of Potential Effects

Method of Analysis

IW activities could generate dust (including metal particulates), which may affect ambient air quality parameters at receptor sites in the study area, thereby potentially affecting the surrounding environment. Comprehensive air quality dispersion modelling considered emission sources and estimated emissions from each source area (Appendix 7A). Modelling used local meteorological data to characterize and evaluate short-term atmospheric

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dispersion and transport of emissions released by the identified sources in the FMC. Data included wind velocities, wind direction, annual temperatures, atmospheric stability, and mixing-layer depth.

The model uses a series of receptor sites to characterize effects within the study area. Ground level contaminant concentrations for the modelling domains were calculated over the following receptor grid:

- Uniform spacing of 500 m in an area extending out to 12 km from the approximate centre of the project site
- Discrete receptors spaced at 100 m along the boundary of the O.I.C. area where the highest off-property ambient air concentrations are expected
- Uniform spacing of 1,000 m from 12 km out to 50 km from approximate centre of the FMC site

A total of 3,409 receptors were used to calculate concentrations within the entire modelling domain.

The model output predicted ambient air quality 24-hour maximum concentrations for the selected indicators, and annual averages for TSP. The model incorporates the following assumptions.

- Background ambient air quality represents effects from existing contaminant sources in the areas surrounding the FMC.
- The FMC is isolated; therefore, background levels of each contaminant are expected to be small.
- The Town of Faro and the access road from the Robert Campbell Highway likely contribute nitrogen oxide, particulate matter, and carbon monoxide from mobile combustion products, residential heating, and wood-burning.
- Deposition loss from suspended particulates is unknown because of a lack of information about dust particle size. As a result, the model is likely to predict higher ambient concentrations of particulates and metals.
- Timing, numbers and locations for vehicle use are estimated based on the types of activities proposed.
- The property line for IW activities is the boundary of the O.I.C. area (refer to Figure 3-4), which is larger than the FMC footprint. IW activities are also expected to produce emissions indistinguishable from natural variability. Based on both of these facts, concentrations at the edges of the O.I.C. are expected to be small and localized.
- Tailings will cause emissions year-round, which is unlikely due to the likely presence of snow cover during winter months, reducing the generation of fugitive dust.

Identified Potential Effects

Overall, the model predicts that IW activities will likely have a moderate effect on ambient air quality within the ID construction area and around unpaved roads and RCTA. It further predicts IW activities will result in little-to-no effect outside of the O.I.C. boundaries (Appendix 7A).

In the RCTA, wind will erode the dry tailings. This will result in a moderate effect, after the implementation of mitigation measures. Construction around the ID, specifically related to emissions from vehicles and material handling is also likely to have a moderate effect. Traffic on the FMC access and haul roads is also likely to affect local ambient air quality through vehicle emissions and dust re-suspension.

For receptors outside the O.I.C., the model predicts that maximum 24-hour and annual averages of ground level concentrations for TSP, PM, and metals will be less than applicable air quality standards (Tables 7A-9 and 7A-10 in Appendix 7A). Specifically, background concentrations of TSP are approximately 11.7 $\mu g/m^3$, and modelled 24-hour average TSP concentrations are 48 $\mu g/m^3$. The Yukon standard for TSP is 120 $\mu g/m^{3;}$ therefore, TSP is not expected to exceed standards at receptors outside the O.I.C. PM_{10} background concentrations are 7.1 $\mu g/m^3$, and maximum 24-hour average concentrations are 33 $\mu g/m^3$. These concentrations are less than the British Columbia standard of 40 $\mu g/m^3$. $PM_{2.5}$ background concentrations are 7 $\mu g/m^3$, and modelled 24-hour maximums are 3 $\mu g/m^3$. Both background and modelled concentrations are less than the Yukon guidelines of 30 $\mu g/m^3$ for $PM_{2.5}$.

For metals, the model predicts localized exceedances only for chromium and iron at locations in and near active construction areas (Appendix A, Table 7A-11). All other predicted metal concentrations meet the standards. Overall, modelled metal concentrations in particulates at receptors outside of the O.I.C. area range from less than 0.1 percent of the air quality standard for titanium, strontium, and molybdenum, to 41.5 percent for chromium and 53.7 percent for iron. Metals concentrations were estimated by using a ratio of metal to PM_{10} concentrations as described in Appendix 7A.

These exceedances consider a ratio of metal to PM_{10}, where particulate matter decreases until it is less than applicable standards beyond the O.I.C. boundary.

7.3.3.5 Air Quality – Mitigation

General mitigative strategies for dust control include the application of tackifiers, water, and other dust mitigation best management practices (BMPs) as described in the EMP. Based on model results, proposed mitigation measures will result in a 60 percent reduction of dust production. To control dust emissions from the tailings, the IW includes application of chemical tackifiers on a yearly basis to areas that are susceptible to wind erosion.

For planned IW construction activities, water spray will be used to reduce fugitive dust during dry periods. Controlling vehicle access and speeds on unpaved roads will reduce vehicle-generated dust. Work should cease during periods of high winds. Minimizing the drop distance of materials during construction activities will further reduce the likelihood and extent of materials travelling out of the construction area. Lastly, all vehicles and machinery will be washed as needed to reduce dust loads.

Environmental awareness will be a key component of the staff orientation program, particularly as it relates to IW activities that will result in increased traffic on unpaved roads). The use of fuel-efficient vehicles will reduce emissions in the local air shed. No-idling strategies and strict enforcement of speed limits will further maintain air quality parameters within applicable guidelines. Appropriate road maintenance, including water application during dry periods, will reduce dust emissions from these areas.

7.3.3.6 Air Quality – Significance of Effects

A series of significance evaluation criteria were established to assess the significance of the IW effects on ambient air quality. The development of these criteria considered magnitude and likelihood/duration, geographic extent, and reversibility (Table 7-8).

Based on these criteria, the significance of changes in air quality indicators were ranked as Low, Medium, or High. Magnitude ratings ranged from Low, indicating a minimal effect, to High, indicating a substantial effect. The ratings assume the application of appropriate mitigation measures.

7.3.3.7 Residual Effects

The results of the significance evaluation for air quality are described in Table 7-9. Particulate matter emissions from the FMC are not expected to result in offsite exceedances of applicable TSP, PM_{10}, $PM_{2.5,}$ or metal standards. The model predictions are conservative in that all emission sources were modelled simultaneously and it is unlikely that this will occur in practice. Dust suppression best management practices will be utilized wherever feasible to reduce on-property and off-property effects.

It is expected that after the appropriate dust control techniques are employed at the tailings area, construction area, and unpaved roadways, the residual effects of particulate matter emissions (including metals) at off-property locations will be negligible and concentrations will be indistinguishable from those measured during the previous monitoring campaigns. The geographic extent reversibility of air quality effects is low, and although the magnitude and likelihood of effect can be high within and close to the emission sources, a negligible effect is expected at the property line and in the neighbouring Town of Faro.

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TABLE 7-8
Definitions for Evaluating Significance
Faro Mine Interim Works

VC	Indicator	Rationale for Selection	Measurements	Effects Attributes	Significance Ranking	Ranking Criteria
Air Quality	Contaminant Air Concentrations affected by Tailings Area, Construction, and Unpaved road traffic	Elevated pollutant concentrations can be harmful to humans, wildlife and vegetation. Ambient air quality standards will be used to assess significance of effects and these standards and guidelines are measured in terms of contaminant concentrations in air.	Modelled changes in Air concentrations for TSP, PM10, PM2.5, and metals	**Magnitude and Likelihood**	Low	Air concentrations less than applicable standards on-property, throughout the modelled year
					Medium	Air concentrations less than applicable standards off-property, throughout the year, but above on-property <25% of modelled days at any receptor
					High	Air concentrations more than standards on-property, more than 25% of days in modelled year at any receptor
				Geographic Extent	Low	Air concentrations greater than standards only on-property
					Medium	Air concentrations greater than standards off-property
					High	Air concentrations greater than standards on a regional basis (greater than 1 km from site boundary)
				Reversibility	Low	Effects are completely reversible
					Medium	Effects are reversible but with mitigation and it may takes months or years for reversal to occur
					High	Effect is non-reversible despite mitigation.

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TABLE 7-9
Projected Air Quality Effects From IW Activities After Mitigation
Faro Mine Interim Works

IW Activity	Potential Interaction	Reversibility	Magnitude	Frequency/ Probability	Extent	Overall Level of Significance	Mitigation Plan Summary
Tailing area	Wind erosion from dried tailings material	Medium	Low	Medium	Low	Medium	Application of a chemical dust suppression compound on an annual basis or more frequently as required.
Intermediate Dam Construction	Emissions from various activities associated with vehicles, material handling, blasting etc.	Low	Medium	High	Low	Medium	Apply water spray during dry periods to disturbed areas, control of vehicle access and speeds, work stoppage under high wind events, minimize material drop distance, periodic washing of vehicles to reduce load out of dust.
FMC Access and Hauls Roads	Emissions from road dust re-suspension caused by traffic	Low	Low	Low	Low	Low	Fuel efficient vehicles, environmental awareness, proactive identification of emission sources, maintenance programs, reduced idling times, water application to roads during dry periods, snow grading on top of roads, posting and enforcement of speed limits.

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7.3.3.8 Air Quality – Monitoring

Dispersion modelling analysis has shown the effects in the O.I.C. to be moderate when using conservative emission estimates and dust mitigation methods for the three emission source areas. Overall, significance is None to Low, outside the O.I.C. By implementing dust management according to the (Appendix 5A) effects outside the O.I.C. will be insignificant. Therefore, this document does not propose air quality monitoring.

7.3.4 Aquatic Effects Assessment

This section describes the detailed analysis results for the IW's potential effects on the aquatic VCs of surface water quality, and fish and fish habitat.

Table 7-10 identifies various minor interactions between IW activities and aquatic VCs. These minor interactions are not generally associated with the mobilization and transportation of chemical contaminants from the FMC. Rather, they are related to particulate releases (soils or sediments), which occur episodically as a result of weather (i.e., precipitation or snowmelt events) or specific work activities. Sediment effects on aquatic VCs are different than those associated with chemical contaminants. Potential effects of these interactions are addressed by mitigation and management plans identified in Section 7.3.2, rather than by predictive modelling. Additional discussion is provided in Section 7.3.4.7.

Table 7-10 also identifies a series of major interactions for aquatic VCs that are associated with existing mine waste material storage, contaminated water storage, and treated water releases. Many of the site operations of the IW are intended to minimize release of contaminants from the FMC through activities such as diverting clean water and collecting and treating contaminated water. Also, the comprehensive AMP (Appendix 5C) serves as a mechanism for the co-proponents to respond to changing conditions. Regardless, contaminant release into receiving environments is inevitable at the FMC and will continue through the IW period.

The aquatic VCs effects assessment evaluates the combined effects of chemical loadings to surface water at the FMC. The assessment considers two scenarios and applies different approaches to predict water quality changes and interpret effects. First, the assessment considers a "Normal" scenario that uses a water and load balance model to predict water quality in the streams affected by the FMC. Second, the assessment considers an "Adverse" scenario that assumes a new source or transport pathway causes a rapid increase in aquatic zinc concentrations. The adverse scenario is assumed to exist for a limited time until mitigation measures (set forth in Appendix 5C) can be implemented to return conditions to Normal. Predictions for the Adverse scenario are based on 2013 monitoring data that indicate a new zinc load to the NFRC. In addition to the summary presented below, Appendices 7B (Water Quality Modelling and Results) and 7C (Analysis of Aquatic Effects) provide additional details about the analysis of IW effects on water quality and aquatic biota.

7.3.4.1 Context

The effects of the IW on aquatic VCs must be considered in the context of the FMC as a legacy mining project that was not operated by the current co-proponents. Deterioration of water quality at the FMC is a primary driver for developing and implementing a final remediation solution (the FMRP). The proposed IW involve temporary measures to minimize effects of the FMC while the co-proponents plan, permit, procure, and implement the FMRP. Consequently, The IW do not offer a water quality outcome that would be considered acceptable for a long-term remediation plan; rather, the IW are intended to minimize effects while the FMRP is finalized.

Many of the existing site management and maintenance activities at the FMC were established to minimize contaminant releases (e.g., clean water diversion, collection and treatment of contaminated water). The continuation of these activities is a key component of the IW and a cornerstone of proposed efforts to control and minimize the effects of the FMC on human health and safety, and the environment. Despite these efforts, however, mine-related contaminant sources such as waste rock, tailings, and open pits, will continue to release contaminants into receiving environments around and downstream from the FMC during the IW. Furthermore, acid-rock drainage conditions at the FMC are progressing and contaminant mobilization from waste materials will likely increase during the IW. Contaminants will be conveyed to surface water receiving environments via surface and groundwater pathways.

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TABLE 7-10
Project interactions with aquatic value components and associated mitigation and residual effects
Faro Mine Interim Works Project

Project Activities/Physical Works		Interaction Ranking		
Category	**Specific**	**Surface Water Quality**	**Fish and Fish Habitat**	**Description of Interaction**
Site Operations	Storage of tailings material in the RCTA	2	2	Contaminants will continue to be released into surface waters via treated effluent and groundwater, with potential to affect aquatic biota in downstream areas.
	Seasonal treatment and discharge of water at Interim Faro Water Treatment System	2	2	Contaminants will continue to be released into surface waters via treated effluent with potential to affect aquatic biota in downstream areas.
	Storage of waste rock	2	2	Contaminants will continue to be released into surface waters via surface runoff, groundwater, and treated effluent with potential to affect aquatic biota in downstream areas.
	Storage of contaminated water in pit lakes and backfilled pits (Faro, Vangorda, Grum and Zone II)	2	0	Contaminants will continue to be released via treated effluent and potentially through groundwater.
	Storage of contaminated water in ponds (e.g., Little Creek Pond, Intermediate Pond, Cross-Valley Pond, Sheep Pad Pond, Moose Pond, Grum Settling Pond, Vangorda Water Treatment Pond)	2	2	Contaminants will continue to be released via treated effluent and potentially through groundwater. Also potential for TSS release from some ponds, which could affect fish habitat.
	Interception, collection and transfer of contaminated water from S-Wells to Faro Pit	2	2	Contaminants will continue to be released as a result of incomplete interception. Pipeline break would result in discharge of pit water to the environment.
	Seasonal discharge of contaminated water into Moose Pond	2	2	Potential contaminant release via groundwater to Vangorda Creek
	Seasonal treatment and discharge of water at Vangorda Water Treatment System	2	2	Contaminants will continue to be released into surface waters via treated effluent and have potential to affect aquatic biota in downstream areas.
	Transfer of contaminated water from Zone II Pit to Faro Pit	1	0	Pipeline break could occur, resulting in discharge of pit water to the environment
	Interception, collection and transfer of contaminated water from ETA to Faro Pit	1	0	Contaminants released through incomplete interception. Pipeline break would result in contaminants reporting to tailings or Rose Creek aquifer.
	Seasonal transfer of contaminated water from Grum Pit, Grum Dump and Little Creek Pond to Vangorda Pit and V15	1	1	Pipeline break could occur, resulting in discharge of pit water to the environment
	Disposal of sludge from water treatment systems. Original Impoundment at Faro, and Vangorda Pit	1	0	Potential remobilization of contaminants from disposed treatment sludges.

TABLE 7-10
Project interactions with aquatic value components and associated mitigation and residual effects
Faro Mine Interim Works Project

Project Activities/Physical Works		Interaction Ranking		
Category	**Specific**	**Surface Water Quality**	**Fish and Fish Habitat**	**Description of Interaction**
Site Investigations	Boreholes/test pits	1	1	Potential TSS release and/or contaminants from water use and release during drilling
	Monitoring equipment installation including wells, thermistors, flow measurement facility	0	1	Potential TSS release and/or contaminants from water use and release during drilling
	Aquifer and pump testing	1	1	Potential TSS release and/or contaminants from water use and release during drilling
	Access route development (may include stream crossings)	1	1	Potential channel disturbances
DVIHU	Excavation of Intermediate Dam Spillway	1	0	Potential TSS release
	Sourcing and transport of borrow material	1	0	Potential TSS release
	Construction of erosion protection in spillway	1	0	Potential TSS release
	Geomembrane and dam raise (gabion) construction	1	0	Potential TSS release
	Removal of vegetation in RCD	1	1	Potential TSS release and/or stream channel disturbances
	Removal of bank sloughs in RCD	1	1	Potential TSS release and/or stream channel disturbances
	Repair of RCD dike	1	1	Potential TSS release
Accessory Activities	Transport fuel and materials	1	1	Potential fuel spill
	Transport of personnel and supplies	1	1	Potential spill of chemical supplies
	Hazardous materials storage and use (reagents, fuel and hydrocarbons)	1	1	Potential spills
	Temporary Camp	1	0	Potential for sewage contamination
	Sourcing and transport of borrow material	1	1	Potential TSS release

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If the IW do not take place, water quality conditions have potential to deteriorate severely. This is illustrated by previous monitoring data for station X2 (NFRC at the mine Access Road), which show how adaptive management led to the detection and remediation of a new zinc load. Water quality in the NFRC improved markedly once the S-Wells SIS was established in 2009. A similar situation evolved in 2013 with monitoring data indicating a new zinc load entering the NFRC at the Haul Road (i.e., the basis of the Adverse effects scenario); this recent situation is also being remediated through adaptive management. Table 7-11 estimates zinc concentrations and loads in North Fork Rose Creek at X2 and Rose Creek at X14 (downstream from the FMC) that could have been expected in the absence of adaptive management actions. The estimates include the zinc load captured at the SIS, which would have migrated to the NFRC if the system had not been installed. The estimates also assume that no action is taken to address the 2013 increase in zinc load at the Haul Road. The data presented in Table 7-11 demonstrate that significant adverse environmental effects on the aquatic environment are very likely to occur in the absence of the proposed IW activities.

TABLE 7-11
Predicted zinc loads and receiving environment concentrations that would be occurring in the absence of contaminant collection at the S-Wells and at an additional source to the NFRC identified in 2013.
Faro Mine Interim Works

Month	X2 Zn Load (kg/mon)	X2 Zn (mg/L)[a]	X14 Zn Load (kg/mon)	X14 Zn (mg/L)[a]
January	2,246	1.74	2,254	1.45
February	2,223	2.34	2,222	2.13
March	2,127	2.23	2,127	2.09
April	2,288	1.98	2,330	1.56
May	3,816	0.39	4,048	0.20
June	2,916	0.35	3,248	0.20
July	2,483	0.50	2,828	0.28
August	2,939	0.75	3,264	0.41
September	2,340	0.61	2,664	0.34
October	2,662	0.97	2,690	0.57
November	2,674	1.71	2,700	1.11
December	2,496	1.68	2,497	1.28

Notes:

kg/mon = kilogram per month

Zn = zinc

[a] The Canadian Water Quality Guideline for zinc is 0.03 mg/L.

The water quality that led to establishment of the S-Wells SIS in 2009, combined with the recent increase in zinc loads in the NFRC (autumn of 2013), demonstrate the ongoing potential for new pathways to develop between contaminant source areas at the FMC and surface waters. The AMP (Appendix 5C) is designed to detect and respond to emerging changes. Even with this important component of the IW, months may lapse between a new condition being identified and a response being developed and implemented. In the meantime, water quality may be unavoidably degraded. This means it may not be possible to consistently control the magnitude of adverse effects, only the duration (i.e., the time between detection and remediation of a sudden change in water quality).

Based on the conditions described above, the situation at the FMC contrasts greatly with an environmental assessment at a Greenfield site, where effects would be mitigated through appropriate design. At the FMC, YG and AANDC are seeking regulatory approval for continued maintenance and management activities that will

mitigate environmental effects, to the degree practicable, while they finalize the FMRP, which will provide longer-term solutions for existing and potential effects.

7.3.4.2 Geographic Scope

Appendix 7C, Analysis of Aquatic Environment Effects, describes and illustrates local and regional study areas for aquatic VCs (Figure 7C-3). The local study area, where effects of the IW are most likely to be realized, comprises the footprint of the former FMC operations and streams within approximately 500 m of the FMC footprint. The regional study area is the maximum area with the potential for measureable project-related effects. This area comprises the drainages downstream from the local study area to the Pelly River, and includes the areas within the Pelly River immediately upstream and downstream from the mouths of Anvil and Vangorda Creeks. For the aquatic effects assessment, the local and regional study areas are not functionally separate. Therefore, the effects assessment uses the same approach to evaluate water quality conditions in both local and regional study areas.

7.3.4.3 Pathways of Effects

Table 7-10 identifies interactions between IW activities and the aquatic VCs (i.e., surface water quality, and fish and fish habitat). There are major interactions for these VCs that are associated with existing mine waste materials storage, contaminated water storage, and treated water releases. These facilities and activities can release contaminants to surface waters downstream from, the FMC via controlled surface discharges (e.g., collection systems and treated effluent), uncontrolled surface discharges (e.g., untreated seepages and runoff), and groundwater. While the IW activities focus on controlling the release of contaminants to the aquatic environment, some contaminants will continue to be released via these pathways. The aquatic effects assessment focuses on the resulting chemical effects on surface water quality and fish and fish habitat.

Table 7-10 also identifies several minor interactions for aquatic VCs that related mainly to potential particulate (soil/sediment) releases. Such releases are of concern with respect to potential physical (e.g., habitat) effects. Particulate releases tend to occur episodically as a result of weather (i.e., precipitation or snowmelt events) or to specific work activities. Such interactions will be minimized by Best Management Practices (BMPs) related to erosion or solids control as well as adherence to regulations protecting fish and fish habitat. BMPs and regulatory requirements for fuel and chemical (e.g., reagent) handling will also mitigate effects associated with fuel or chemical spills during site investigations or accessory project activities. Consequently, the types of interaction in Table 7-10 are rated as a "1." Based on experience at the FMC and professional judgment, such interactions are very unlikely to result in a significant environmental effect, either in the absence of mitigation or with the application of standard mitigation practices. Residual effects of such practices, if any, are expected to be minor, so these interactions are not assessed further.

7.3.4.4 Indicators

The aquatic effects assessment for major interactions considers the combined effects of all contaminant sources on surface water quality by using a water balance and load model that incorporates inputs from all of these sources and estimates resulting contaminant concentrations at key receiving environment locations (Appendix 7B).

Surface water quality has been evaluated by considering relevant water uses. As described in Appendix 7C, protection of aquatic life is the most relevant and sensitive water use at the FMC and in downstream areas. Also, water quality guidelines for the protection of aquatic life tend to be the most stringent of the guidelines respecting various water uses. Therefore, this approach provides a conservative basis for evaluating effects on aquatic VCs. By considering surface water quality relative to guidelines for protection of aquatic life, the surface water quality assessment also addresses potential mine-related chemical effects on fish and fish habitat. In this context, fish habitat includes the aquatic plant and invertebrate communities that contribute to ecosystem function and represent a food source for fish.

By comparison, the potential effects of the IW on the physical characteristics of fish habitats are most likely to occur through particulate loads to surface water bodies. These have potential to increase suspended solids and turbidity concentrations and sedimentation on bottom substrates. As Section 7.3.4.3 noted, interactions involving particulate loads to surface waters are judged to be relatively minor, and will be controlled through BMPs.

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According to the baseline water quality characterization (Appendix 6H, Aquatic Environment Baseline Report), the following mine-related contaminants have been observed at concentrations greater than water quality guidelines for the protection of aquatic life at some surface water stations near, and downstream from, the FMC:

- Cadmium
- Cobalt
- Iron
- Lead
- Manganese
- Sulphate
- Zinc

Modelling described in Appendix 7B predicted future surface water quality for all of these substances except iron. Iron was excluded because elevated concentrations are usually associated with elevated particulate loads caused by snowmelt and rainfall events. This is indicated by the correlation between total iron and TSS concentrations shown in the baseline water quality characterization (Appendix 6H). The baseline characterization also concluded that TSS concentrations are strongly influenced by sources in addition to the FMC. Furthermore, mine-related particulate loads associated with the IW, along with associated iron loads, are expected to be modest and controllable through BMPs.

Therefore, the assessment of surface water quality assessment is based on evaluation of expected sulphate, cadmium, cobalt, lead, manganese, and zinc concentrations, whose downstream concentrations are mainly influenced by loads from the FMC.

Of the mine-related contaminants included in the assessment, zinc is an important indicator of future geochemical changes at the FMC and is the most likely mine-related substance to be observed at concentrations greater than water quality guidelines for the protection of aquatic life. Consequently, zinc is a separate indicator from the other mine-related variables in the effects assessment. However, concentrations of zinc and the other mine-related contaminants were assessed in a similar manner, namely by comparing them to baseline concentrations (2008 to 2012), water quality guidelines for protection of aquatic life, and toxicity data presented in the scientific literature for relevant aquatic species (Appendix 7C).

7.3.4.5 Ecological Objectives and Significance Criteria

As previously mentioned, the FMC is an abandoned mine site storing waste materials with substantial inventories of contaminants. This is an important context for determining the significance for aquatic environmental effects. As Section 1.2 of this IWPP stated, the purposes of the IW are dual, as follows:

- To control and reduce the effects of the existing FMC on human health and safety and the environment
- To compile sufficient site and environmental information to support design, assessment and permitting for the FMRP

Significant adverse environmental effects on the aquatic environment are extremely likely to occur in the absence of the proposed IW activities. The IW aims to protect aquatic VCs by avoiding significant, direct, adverse effects on fish species. Criteria were developed to allow for surface water quality effects to be ranked as Low, Medium, or High based on the magnitude, likelihood, duration, geographic extent, and reversibility of predicted changes in water quality (Table 7-12) (Appendix 7C). Magnitude and likelihood/duration are considered together because potential effects on aquatic biota depend on the combined effects of these exposure characteristics at any given location.

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TABLE 7-12
Assessment criteria for effects on surface water quality and associated chemical effects on fish and fish habitat
Faro Mine Interim Works

Valued Components	Effects Assessment Indicator	Rationale for Selection	Measurements	Effect Attributes	Significance Ranking	Ranking Criteria
Surface Water Quality and Associated Chemical Effects on Fish and Fish Habitat	Water quality (zinc)	Protection of aquatic species is predicated on exposure to water concentrations that do not cause impairment. Water quality concentrations can be predicted and concentrations toxic to aquatic organisms have been characterized in the scientific literature. Mine-related effects on surface water quality are expected to be dominated by zinc.	Concentrations of zinc in fish-bearing reaches relative to baseline and predicted conditions, water quality guidelines, toxicity thresholds.	Magnitude and Likelihood/Duration	Low	Water concentrations, after effluent mixing in the receiver are predicted to usually meet water quality guidelines (i.e., ≥50% of months) and will rarely or never exceed fish toxicity thresholds (<50% of months) throughout the 10-year project period.
					Medium	Concentrations after effluent mixing may frequently exceed water quality guidelines (>50% of months) but will usually not exceed toxicity thresholds for relevant fish (<25% of months). Temporary exceptions may occur when a new source or pathway results in a sudden increase in zinc concentration; during this time fish toxicity thresholds may be temporarily (<1 year) exceeded while a mitigation plan is developed and implemented.
					High	Water concentrations are predicted to be above levels likely to harm fish species in >25% of samples for indefinite periods (>1 year).
				Geographic Extent	Low	"Low" water quality effects will apply to all surface waters within and downstream of the FMC footprint (local and regional study areas).
					Medium	"Medium" water quality effects described above will be limited to the Rose Creek and Vangorda Creek system (i.e., mainly confined to local study, possibly extending to mouths of both creeks). In Anvil Creek and Pelly River, water quality effects are predicted to be "low" as defined above.
					High	"High" water quality effects described above may occur within the Rose Creek or Vangorda Creek system and "medium" or "high" water quality effects described above may extend into Anvil Creek and/or the Pelly River (regional study area).
				Reversibility	Low	Periods of elevated concentrations will naturally be followed by periods of lower concentration as a result of normal seasonal cycles of contaminant release and available dilution.
					Medium	Water quality effects are likely reversible through mitigation, although it may take months for solutions to be found and mitigation to be put in place.
					High	Water quality effects are not expected to be reversible.
	Water quality (sulphate, cadmium, cobalt, lead, manganese)	Protection of aquatic species is predicated on exposure to water concentrations that do not cause impairment. Water quality concentrations can be predicted and concentrations toxic to aquatic organisms have been characterized in the scientific literature. Next to zinc, sulphate, cadmium, cobalt, lead, and manganese are the mine-related variables having greatest potential to adversely influence surface water quality.	Concentrations of sulphate, cadmium, cobalt, lead, manganese, and zinc relative to baseline and predicted conditions, water quality guidelines, toxicity thresholds.	Magnitude and Likelihood/Duration	Low	Water concentrations, after effluent mixing, are predicted to meet water quality guidelines in most (≥95% of) months and are not predicted to exceed toxicity thresholds for relevant fish species throughout the 10-year project period.
					Medium	Concentrations are predicted to often meet water quality guidelines (>50% of months) and rarely or never (<5% of months) exceed concentrations shown in the literature to be harmful to relevant fish species.
					High	Water concentrations are predicted to sometimes or often (>5% of months) exceed levels expected to be harmful to relevant fish species.
				Geographic Extent	Low	"Low" water quality effects will apply to all surface waters within and downstream of the FMC footprint (local and regional study areas).
					Medium	"Medium" water quality effects described above will be limited to the Rose Creek and Vangorda Creek system (i.e., mainly confined to local study, possibly extending to mouths of both creeks). In Anvil Creek and Pelly River, water quality effects are predicted to be "low" as defined above.
					High	"High" water quality effects described above may occur within the Rose Creek or Vangorda Creek system and "medium" or "high" water quality effects described above may extend into Anvil Creek and/or the Pelly River (regional study area).
				Reversibility	Low	Periods of elevated concentrations will naturally be followed by periods of lower concentration as a result of normal seasonal cycles of contaminant release and available dilution.

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TABLE 7-12
Assessment criteria for effects on surface water quality and associated chemical effects on fish and fish habitat
Faro Mine Interim Works

Valued Components	Effects Assessment Indicator	Rationale for Selection	Measurements	Effect Attributes	Significance Ranking	Ranking Criteria
					Medium	Water quality effects are likely reversible through mitigation, although it may take months for solutions to be found and mitigation to be put in place.
					High	Water quality effects are not expected to be reversible.
Fish (particularly Arctic grayling, Chinook salmon, slimy sculpin), and fish habitat.	Aquatic toxicity	Potential toxicity to fish and fish habitat associated with predicted water chemistry are addressed through assessment of effects on water quality, see above.				
	Physical habitat quantity and quality	Loss of aquatic habitat can compromise the success of fish populations, particularly if the affected habitats are critical to life cycle functions and there is limited availability of such habitat. Studies have been undertaken to characterize fish populations and habitat utilization around the FMC, as well as water flows and elevations and conditions at lower trophic levels (periphyton, benthic invertebrates).	Characterize habitat disturbance in terms of size, intensity, timing, and duration of disturbance. Consider both solid habitat and water flows/elevations. Possibly also quantify aquatic productivity and/or habitat details within and around the affected area, depending on context (location and type of expected habitat effect) Periphyton chlorophyll a, taxon richness, diversity, evenness, Benthic invertebrate abundance, taxon richness, diversity, evenness, ecological tolerances	Magnitude and Likelihood/Duration	Low	No alteration, disruption, or destruction of physical aquatic habitat and minimal or no effects on water flows/elevations compared to baseline conditions.
					Medium	Minor habitat effect is possible but will be sufficiently short in duration to have no impact on critical life stages of fish.
					High	Habitat effect could be of sufficient magnitude or duration to impact critical life stages of fish.
				Geographic Extent	Low	No habitat effects are expected that would impact accessibility/utilization by fish.
					Medium	Any habitat effect will be very confined to the local study area and will not include critical habitat.
					High	Critical habitats are likely to be affected.
				Reversibility	Low	Habitat effect will be completely reversible.
					Medium	Habitat effect will be largely reversible.
					High	Habitat will be permanently affected.
	Habitat access/barriers	Another important habitat consideration is maintenance of access by fish to critical habitat for fulfilling key life functions (i.e. spawning, rearing, and over-wintering). Features such as road crossings, rock drains, and culverts, can be barriers to fish access.	Characterize habitat disturbance in context of fish passability.	Magnitude and Likelihood/Duration	Low	The project activities will not affect fish movements relative to baseline conditions.
					Medium	Project activities may temporarily affect fish passage, but will not occur during typical fish migration periods.
					High	Habitat alteration will permanently affect fish passage relative to baseline conditions.
				Geographic Extent	Low	The project activities will not affect fish movements relative to baseline conditions.
					Medium	Any habitat disruption/alteration will be very localized and will avoid critical habitat.
					High	Habitat disruption/alteration may affect critical habitats.
				Reversibility	Low	Habitat effect will be completely reversible.
					Medium	Habitat effect will be largely reversible.
					High	Habitat will be permanently affected.

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Potential zinc effects were considered differently than those associated with the other mine-related contaminants, because zinc is the dominant contaminant of concern at the FMC and a key indicator of changing geochemical conditions. Baseline data indicate zinc concentrations in surface water around the FMC exceed water quality guidelines more often and at more stations than the other mine-related variables (Appendix 6H, Aquatic Baseline Characterization Report). Because the effects on water quality were evaluated by comparing them with guidelines for the protection of aquatic life, and aquatic toxicity thresholds, the assessment addresses chemical effects on both surface water quality, and fish and fish habitat VCs.

To evaluate effects on aquatic VCs, predicted concentrations for indicator parameters were compared with baseline concentrations at representative local and regional monitoring stations and were also compared with water quality guidelines for protection of aquatic life. Some guidelines vary based on water hardness, so station-specific guidelines were developed based on observed water hardness over the baseline period. Table 7-13 lists the guidelines applied for each parameter at each station. Appendix 7C provides details about the rationale for selection of specific guidelines.

For water quality variables listed in Table 7-13 that were predicted to exceed guidelines, the predicted concentrations were also compared with toxicity data for aquatic biota reported in the scientific literature. Data were compiled for both acute (short-term) exposures and chronic (long-term) exposures, as described in Appendix 7C. To be consistent with current Environment Canada protocols (CCME, 2007), short-term exposures were typically defined as follows, depending on the species and life-stage tested:

- Less than one day (algae)
- Less than four days (invertebrates and larval fish)
- Less than seven days (older fish)

However, long-term exposure data are generally considered most relevant and conservative for assessing potential effects of predicted concentrations, because conditions cannot be reliably predicted for periods as brief as hours or a few days. Table 7-14 lists the toxicity thresholds derived for application at the FMC for each indicator parameter, where it is predicted to exceed guidelines.

7.3.4.6 Analysis of Potential Chemical Effects

Prediction of Future Water Quality

As indicated previously, the aquatic VCs effects evaluation considers two scenarios. The assessment focuses mainly on a Normal operating scenario, which uses a water and load balance model to predict water quality conditions in the streams affected by the FMC. An Adverse scenario was also assessed; this considered a localized, rapid increase in zinc load to surface water, which is assumed to temporarily affect water quality until a mitigation solution can be developed and implemented (likely 6 to 8 months). Zinc concentrations for the Adverse scenario are based on data from recent events at the FMC and represent a realistic worst case for assessing the effects of the IW activities.

Appendix 7B describes the methods and results for water quality modelling associated with the 10-year period of the IW for the Normal scenario. Appendix 7C (Attachment Figures A.1 to A.4) shows the results of 200 stochastic simulations for representative mine-related variables (zinc, cadmium, cobalt, manganese), including predicted 5th, 50th, and 95th percentiles for each month over the 10-year period at representative stations. Appendix 7C presents monthly summary statistics derived from all stochastic realizations of the predictions (Attachment A, Tables A.1 through A.9). Annual variations in water quality at the FMC are generally associated with three seasons: winter baseflow, spring freshet, and the summer/autumn ice-free period. Therefore, water quality predictions were further summarized according to season and compared to baseline conditions and water quality guidelines (Appendix 7C, Attachment Tables A.10 through A.18). Table 7-15 compares predicted water quality for the Normal scenario with water quality guidelines for protection of aquatic life. Shaded cells show predicted guideline exceedances.

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TABLE 7-13
Summary of water quality guidelines relevant to selected stations at FMC
Faro Mine Interim Works

Variable	Generic Guideline	Guideline Applied to Each Station for Evaluation of Water Quality Predictions [a] (and median station hardness 2008-12)							
		NF1 (91 mg/L)	X2 (108 mg/L)	X3 (115 mg/L)	X14 (217 mg/L)	R4 (156 mg/L)	V8 (301 mg/L)	A1 (161 mg/L)	P4 (173 mg/L)
Sulphate [b]	0-30 mg/L hardness = 128, 31-75 mg/L hardness = 218, 76-180 mg/L hardness = 309, 181-250 mg/L hardness = 429	309	309	309	429	309	429	309	309
Total Cadmium [c]	$(10^{0.83(\log\{\text{hardness}\})-2.46})/1000$	0.00015	0.00017	0.00018	0.00030	0.00023	0.00040	0.00024	0.00025
Total Cobalt [d]	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Total Lead [c]	$(3.31 + e^{(1.273\ln(\text{mean hardness})-4.704)})/1000$	0.006	0.007	0.007	0.012	0.009	0.016	0.009	0.01
Total Manganese [b]	(0.0044 x hardness) + 0.605	1.0	1.1	1.1	1.6	1.3	1.9	1.3	1.4
Total Zinc [c]	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Notes:

[a] Guideline was adapted to median station hardness, where appropriate, based on generic guideline.

[b] BCMOE (British Columbia Ministry of the Environment). 2013. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia. Accessed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html, November 2013.

[c] CCME (Canadian Council for Ministers of the Environment). 2014a Canadian Water Quality Guidelines for the Protection of Aquatic Life. Accessed at: http://st-ts.ccme.ca, February 2014. The zinc guideline is currently being updated to incorporate relevant scientific literature published since the original guideline was developed (1987) and is expected to be based on water hardness.

[d] Environment Canada. 2013d. Federal Environmental Quality Guidelines: Cobalt. February 2013.

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TABLE 7-14

Water quality guidelines for protection of aquatic life and approximate toxicity thresholds for key mine-related variables at the FMC. Detailed toxicity data for each metal are presented in Attachments B - E

Faro Mine Interim Works

Exposure Duration	Endpoints Considered in Assessing Potential Aquatic Effects	Cobalt (mg/L)	Values Adjusted for Water Hardness of 100 vs. 200 mg/L Water Hardness of 100 vs 200 mg/L					
			Cadmium		Manganese		Zinc	
			100 mg/L	200 mg/L	100 mg/L	200 mg/L	100 mg/L	200 mg/L
Long-term (weeks)	Water Quality Guidelines - CCME (except Co [b])	0.0025[b]	0.00016[a]	0.00028[a]	-	-	0.03[a]	0.03[a]
	Water Quality Guidelines - BCMOE	0.0040[d]	0.00003[c]	0.00006[c]	1.0[d]	1.5[d]	0.015[d]	0.09[d]
	Water Quality Guidelines - USEPA (except Mn [f])	-	0.00027[e]	0.00046[e]	1.7[f]	2.1[f]	-	-
	Possible effects to sensitive plants or invertebrates, but not likely relevant fish species	0.02[h]	0.0005	0.0010	1.6[h]	2.0[h]	0.04	0.07
	Possible threshold for effects to relevant fish species	0.30[h]	0.0017	0.0030	1.6[h]	2.0[h]	0.06	0.11
Short-term (hours, days)	Water Quality Guidelines – CCME [a]	-	0.0021[b]	0.0042[b]	-	-	-	-
	Water Quality Guidelines - BCMOE	0.11[d]	-	-	1.6[d]	2.7[d]	0.04[d]	0.12[d]
	Water Quality Guidelines - USEPA	-	0.0020[e]	0.0043[e]	3.0[f]	3.7[f]	0.12[g]	0.22[g]
	Lethal effects to sensitive plants or invertebrates	0.30[h]	0.0020	0.0035	3.0[h]	5.0[h]	0.04	0.07
	Lethal effects to relevant fish species	0.50[h]	0.0035	0.0071	3.0[h]	5.0[h]	0.15	0.27

Notes:

[a] CCME (Canadian Council for Ministers of the Environment). 2014a. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Accessed at http://st-ts.ccme.ca/, February 2014.

[b] Environment Canada. 2013d. Federal Environmental Quality Guidelines: Cobalt. February 2013.

[c] BCMOE (British Columbia Ministry of the Environment). 2006. A Compendium of Working Water Quality Guidelines for British Columbia. Environmental Protection Division, Victoria, British Columbia.

[d] BCMOE (British Columbia Ministry of the Environment). 2013. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia. Accessed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html, November 2013.

[e] USEPA (United States Environmental Protection Agency). 2001. 2001 Update of Ambient Water Quality Criteria for Cadmium. April 2011. Dissolved conversion factor was not used in calculating criteria.

[f] GEI (GEI Consultants Inc.). 2009. Ambient Water Quality Standards for Manganese. July 2009.

[g] USPEA (United States Environmental Protection Agency). 1996. 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life.

[h] Limited data.

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TABLE 7-15

Current (2008-2012) versus predicted (2014-2023) median (50th percentile) of seasonal water concentrations for key mine-related variables. Shaded values are above the water quality guideline

Faro Mine Interim Works

				Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
Variable	**Station**	**Local (L) versus Regional (R)**	**Guideline [a] (mg/L)**	**Winter (NOV-APR)**	**Spring (MAY-JUN)**	**Summer/ Fall (JUL-OCT)**	**Winter (NOV-APR)**	**Spring (MAY-JUN)**	**Summer/ Fall (JUL-OCT)**
Sulphate	NF1	L	309	19	5	12	24	14	16
	X2	L	309	28	7	12	26	15	18
	X3	L	309	28	8	13	22	12	14
	X14	L	429	277	72	110	212	109	179
	R4	R	309	109	33	52	115	88	143
	R5	R	309	-[b]	-[b]	-[b]	82	45	72
	A1	R	309	54	19	34	70	36	56
	V8	R	429	165	60	100	129	85	193
Total Cadmium	NF1	L	0.00015	0.00003	0.00004	0.00005	0.00005	0.00005	0.00005
	X2	L	0.00017	0.00003	0.00004	0.00002	0.00015	0.00009	0.00010
	X3	L	0.00018	0.00002	0.00003	0.00002	0.00012	0.00007	0.00008
	X14	L	0.00030	0.00009	0.00006	0.00004	0.00015	0.00011	0.00014
	R4	R	0.00023	0.00001	0.00006	0.00003	0.00010	0.00009	0.00012
	R5	R	0.00023	-[b]	-[b]	-[b]	0.00009	0.00007	0.00008
	A1	R	0.00024	0.00002	0.00009	0.00003	0.00008	0.00006	0.00007
	V8	R	0.00040	0.00006	0.00017	0.00008	0.00015	0.00035	0.00032
Total Cobalt	NF1	L	0.0025	0.00037	0.00036	0.00042	0.00030	0.00019	0.00023
	X2	L	0.0025	0.00019	0.00022	0.00010	0.00030	0.00019	0.00023
	X3	L	0.0025	0.00011	0.00014	0.00007	0.00026	0.00017	0.00020

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TABLE 7-15

Current (2008-2012) versus predicted (2014-2023) median (50th percentile) of seasonal water concentrations for key mine-related variables. Shaded values are above the water quality guideline

Faro Mine Interim Works

Variable	Station	Local (L) versus Regional (R)	Guideline [a] (mg/L)	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
				Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
	X14	L	0.0025	0.00304	0.00100	0.00143	0.00215	0.00281	0.00452
	R4	R	0.0025	0.00004	0.00059	0.00034	0.00127	0.00224	0.00363
	R5	R	0.0025	-[b]	-[b]	-[b]	0.00090	0.00111	0.00177
	A1	R	0.0025	0.00003	0.00092	0.00014	0.00078	0.00087	0.00136
	V8	R	0.0025	0.00009	0.00100	0.00017	0.00018	0.00079	0.00042
Total Lead	NF1	L	0.006	0.0015	0.0020	0.0022	0.0013	0.0013	0.0013
	X2	L	0.007	0.0006	0.0026	0.0010	0.0013	0.0013	0.0013
	X3	L	0.007	0.0004	0.0012	0.0006	0.0013	0.0013	0.0013
	X14	L	0.012	0.0004	0.0016	0.0006	0.0017	0.0021	0.0031
	R4	R	0.009	0.0001	0.0029	0.0004	0.0015	0.0019	0.0027
	R5	R	0.007	-[b]	-[b]	-[b]	0.0014	0.0016	0.0019
	A1	R	0.009	0.0001	0.0023	0.0003	0.0014	0.0015	0.0018
	V8	R	0.016	0.0003	0.0031	0.0006	0.0026	0.0050	0.0030
Total Manganese	NF1	L	1.0	0.08	0.04	0.09	0.12	0.05	0.07
	X2	L	1.1	0.08	0.03	0.04	0.13	0.05	0.08
	X3	L	1.1	0.06	0.04	0.03	0.10	0.04	0.05
	X14	L	1.6	3.9	0.62	1.0	2.4	2.5	4.2
	R4	R	1.3	0.03	0.39	0.34	1.3	2.0	3.3
	R5	R	1.3	-[b]	-[b]	-[b]	0.88	0.91	1.6

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TABLE 7-15

Current (2008-2012) versus predicted (2014-2023) median (50th percentile) of seasonal water concentrations for key mine-related variables. Shaded values are above the water quality guideline

Faro Mine Interim Works

				Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
Variable	**Station**	**Local (L) versus Regional (R)**	**Guideline [a] (mg/L)**	**Winter (NOV-APR)**	**Spring (MAY-JUN)**	**Summer/ Fall (JUL-OCT)**	**Winter (NOV-APR)**	**Spring (MAY-JUN)**	**Summer/ Fall (JUL-OCT)**
Total Zinc	A1	R	1.3	0.01	0.18	0.08	0.73	0.68	1.2
	V8	R	1.9	0.01	0.08	0.02	0.03	0.25	0.37
	NF1	L	0.03	0.020	0.009	0.023	0.084	0.028	0.045
	X2	L	0.03	0.027	0.025	0.017	0.088	0.029	0.047
	X3	L	0.03	0.021	0.006	0.008	0.066	0.019	0.030
	X14	L	0.03	0.088	0.040	0.039	0.066	0.032	0.056
	R4	R	0.03	0.006	0.025	0.015	0.038	0.026	0.045
	R5	R	0.03	- [b]	- [b]	- [b]	0.028	0.015	0.025
	A1	R	0.03	0.004	0.011	0.006	0.024	0.013	0.020
	V8	R	0.03	0.013	0.032	0.013	0.013	0.048	0.053

Notes:

[a] Table 7.X4

[b] Insufficient data

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The Adverse scenario considers effects associated with development of new contaminant pathways between mine source areas and surface waters. This scenario only evaluates the effects of zinc, because historical monitoring data indicate that zinc is the most likely contaminant to be associated with the leading edge of developing contaminant source plumes that could cause aquatic effects. New pathways may result in zinc concentrations that temporarily exceed those associated with the Normal operating scenario described herein. Such a condition developed in the S-Wells area, and was detected as a rising trend in winter zinc concentrations in the NFRC, which led to installation of the S-Wells SIS. Subsequent reductions in stream zinc concentrations were apparent in monitoring results. More recently, a new load source to the NFRC has developed near the Haul Road crossing, which has increased zinc concentrations in the NFRC (NF2, X2) and at X14 such that concentrations in November 2013 were greater than the maxima predicted for the normal operating scenario (Table 7-16). For the Adverse scenario, the effects assessment evaluates the effects of the water quality conditions measured in November 2013.

TABLE 7-16
Predicted adverse scenario based on recent observations of new zinc load source to North Fork Rose Creek
Faro Mine Interim Works

Station	November 2013		Predicted water quality during low flow if load stays the same as Nov 2013		Predicted water quality assuming 2x load during low flow	
	Average Zn (mg/L)	Max Zn (mg/L)	Average Zn (mg/L)	Max Zn (mg/L)	Average Zn (mg/L)	Max Zn (mg/L)
NF2	0.48	0.91	1.4	2.7	2.8	5.4
X2	0.34	0.38	1.0	1.1	2.0	2.3
X3A	0.34	0.49	0.7	0.8	1.4	1.6
X14	0.18	0.20	0.7	0.8	1.3	1.5
A1	–	–	0.21	0.24	0.41	0.48
P4	–	–	0.01	0.01	0.02	0.02

Flow Assumptions:

NF2 Nov 28,2013 Discharge (L/s)	570	
X14 Nov 28 Discharge scaled from Oct ratio (L/s)	1,117	
X2 GoldSim low flow (L/s)	193	*compares to NF2 April 4, 2013 - 200 L/s*
X14 GoldSim low flow (L/s)	295	*compares to X14 April discharge average to 2009 - 290 L/s*
A1 GoldSim low flow (L/s)	948	
P4 GoldSim low flow (L/s)	23,856	

Sulphate

Future median surface water concentrations of sulphate are expected to be less than water quality guidelines for protection of aquatic life during winter baseflow, spring freshet, and summer/autumn periods at all stations (Appendix 7C, Table 7C-4 and Attachment Tables A.10 through A.18). Even predicted 95th percentile values for sulphate are not expected to exceed the sulphate guideline (Appendix 7C, Attachment Tables A.1 through A.9). Therefore, no significant adverse effects are expected to aquatic biota as a result of exposure to sulphate, and this substance was not evaluated further.

Cadmium

Appendix 7C, Section 3.2.2 provides details of the effects assessment for the Normal scenario for cadmium. Under the Normal operating scenario, median concentrations of cadmium are predicted to be slightly higher than baseline conditions during the IW, but will still be less than water quality guidelines for the protection of aquatic life (Table 7-15). However, peak concentrations may occasionally exceed the guidelines in lower NFRC (X2), RCD (X3), in Rose Creek immediately downstream from the Faro Mine Area (X14) and in lower Vangorda Creek (V8)

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(Appendix 7C, Attachment Tables A.2 through A.4, A.9). The probabilities of such exceedances range from approximately 3 percent at X14 to 25 percent at X2 (Appendix 7C, Figure 7C-4). However, toxicity to most aquatic species occurs at concentrations of 0.0005 mg/L or more, and fish are typically unaffected until concentrations are at or above approximately 0.0017 mg/L (Table 7-14). Concentrations are not expected to be above 0.0005 mg/L in the Rose-Anvil creek system and will be below 0.0007 mg/L in lower Vangorda Creek (Appendix 7C, Figure 7C-4). Therefore, cadmium concentrations associated with the IW are not expected to affect fish nor most other aquatic biota in either the LSA or RSA.

Cobalt

Appendix 7C, Section 3.2.3 provides details about the effects assessment for the Normal scenario for cobalt. For the Normal operating scenario, median concentrations of cobalt associated with the IW are predicted to be comparable to the range observed during the baseline period at most stations. However, these concentrations may increase in Rose Creek at X14 and R4 during the ice-free period, as well as at V8 (Table 7-15). Environment Canada (2013d) recently developed a water quality guideline for cobalt of 0.0025 mg/L to protect against effects associated with long-term exposure. Concentrations in Rose Creek at X14 and R4 are predicted to exceed the guideline in approximately 45 percent and 35 percent of months, respectively (Appendix 7C, Figure 7C-5).

Appendix 7C (Attachment Table D.3) contains the toxicity data used by Environment Canada (2013d) to derive the long-term-exposure guideline. In addition, toxicity data associated with acute exposures to cobalt were summarized by Nagpal (2004) (Appendix 7C, Attachment Tables D.1 and D.2). Based on the scientific literature, effects to sensitive invertebrates and algae have been reported at cobalt concentrations as low as 0.003 mg/L, but most organisms are not affected at concentrations below 0.02 mg/L (Appendix 7C, Attachment Tables D.1, D.3). Maximum cobalt concentrations are not expected to exceed 0.02 mg/L at any stations during the IW (Appendix 7C, Figure 7C-5). Therefore, cobalt concentrations associated with the IW are not expected to affect fish nor most other aquatic biota.

Furthermore, as Appendix 7C (Section 3.2.3.1) describes, cobalt tends to be associated with particulate phases in aquatic systems. Therefore, although cobalt released at X14 is mainly in the dissolved phase, elevated concentrations in areas farther downstream tend to be more associated with particulates (suspended solids) than the dissolved phase (Appendix 7C, Figure 7C-6). As Appendix 7C describes, metals are more bioavailable to interact with aquatic organisms when in the free ion form than when they are complexed or speciated with other components in water. Therefore, because cobalt tends to partition to suspended and bottom sediments, aquatic cobalt concentrations are expected to be increasingly less bioavailable farther downstream from the FMC.

Based on of the information presented herein, cobalt concentrations associated with the IW are expected to have negligible effects on aquatic biota in the local and regional study areas.

Lead

Future median surface water concentrations of lead are expected to be less than water quality guidelines for the protection of aquatic life during winter baseflow, spring freshet, and summer/autumn periods at all stations (Appendix 7C, Table 7C-4). Even predicted 95th percentile values for lead are not expected to exceed the lead guideline (Appendix 7C, Attachment Tables A.1 through A.18). Therefore, no significant adverse effects to aquatic biota are expected to arise as a result of exposure to lead, and this substance was not evaluated further.

Manganese

Appendix 7C, Section 3.2.4 provides details about the effects assessment for the Normal scenario for manganese. For the Normal operating scenario, manganese concentrations are not predicted to change substantially from baseline conditions, except that concentrations may decrease slightly in winter months and increase slightly in other months at Rose Creek stations at, and downstream from, X14 (Table 7-15). There is no federal water quality guideline for manganese, but British Columbia has established a guideline that varies based on water hardness (Tables 7-13 and 7-14). Manganese concentrations are predicted to be greater than the hardness-adjusted guidelines in a substantial percentage of months at X14 (65 percent) and in an increasingly lower percentage of months at stations farther downstream (Appendix 7C, Figure 7C-7).

Toxicity data for manganese, particularly for long-term exposures, are limited and there are no data for the specific fish species found near the FMC (Appendix 7C, Attachment Tables E.1-E.3). The available data suggest aquatic toxicity could occur at the manganese concentrations predicted at X14 (median 2.4 to 4.2 mg/L) (Table 7-14). However, winter manganese concentrations at X14 averaged 3.9 mg/L over the baseline period (Table 7-15) and baseline biological studies concluded that mine-related effects on aquatic biota (e.g., benthic invertebrate surveys) were undetectable or relatively minor at X14/R2 (Minnow, 2013). Also, the predicted median concentrations at X14 are unlikely to cause acute lethality to fish (Table 7-14).

As Appendix 7C (Section 3.2.4.1) notes, manganese tends to partition to particulate phases of freshwater aquatic systems. Therefore, although manganese released at X14 is largely in the dissolved phase, elevated concentrations in areas farther downstream tend to more associated with particulates (suspended solids) than the dissolved phase (Appendix 7C, Figure 7C-6). As Appendix 7C describes, metals are more bioavailable to interact with aquatic organisms in the free ion form than when complexed or speciated with other components in water. Consequently, any effects associated with manganese are expected to be limited to the area immediately downstream from X14, with gradual reduction of bioavailable manganese concentrations farther downstream as a result of partitioning to suspended and bottom sediments.

Overall, the data indicate that aquatic effects, if any, of manganese in surface waters around the FMC would be limited to the vicinity of X14 (i.e., within the LSA) and would likely be minor in magnitude.

Zinc

Appendix 7C, Section 3.2.5 provides details of the effects assessment for both the Normal and Adverse scenarios for zinc. During the baseline period, median concentrations of zinc were greater than the water quality guideline at only X14 (Table 7-15). However, for the Normal scenario during the 10-year IW period, modelling predicts that winter and summer/autumn concentrations will sometimes exceed guidelines throughout the Rose Creek system, downstream from NF1 to the mouth at Anvil Creek (R4). At these stations, probabilities of monthly guideline exceedance range from 60 percent to 80 percent (Appendix 7C, Figure 7C-8). The exceedance probability declines from 80 percent at X14 to 70 percent at the mouth of Rose Creek (R4). It declines further to 30 percent after the confluence of Rose Creek and Anvil Creek (R5), but remains close to 20 percent even at the mouth of Anvil Creek (A1) (Appendix 7C, Figure 7C-8). Predictions do not assume attenuation with distance downstream, and may therefore be overly conservative. The water quality guideline for zinc is also expected to be exceeded in approximately 30 percent of months at V8, near the mouth of Vangorda Creek, but will not be exceeded at P4 in the Pelly River downstream of Vangorda Creek and Anvil Creek (Appendix 7C, Figure 7C-8).

Aquatic toxicity data associated with water hardness around 100 mg/L indicate that toxicity to sensitive aquatic species may occur at zinc concentrations that are only slightly greater than the water quality guideline of 0.03 mg/L (Table 7-14). However, winter zinc concentrations at X14 during the baseline period averaged more than double this value, at approximately 0.08 mg/L (Table 7-15). In addition, baseline studies concluded that mine-related effects on biota (e.g., benthic invertebrate surveys) have been undetectable or relatively minor at X14/R2 (Appendix 6H). Although median zinc concentrations are expected to increase at most stations in the Rose-Anvil creek system relative to baseline conditions, they are predicted to be comparable to or less than those observed at X14 between 2008 and 2012, depending on the season (Table 7-15). Also, the predicted median concentrations are unlikely to cause acute lethality to fish (Table 7-14).

There is a very small potential for periodic lethal effects to fish in NFRC during winter based on predicted winter 95th percentile concentrations of up to 0.23 mg/L compared to baseline maxima of 0.13 mg/L (Appendix 7C, Attachment Tables A.10, A.11). Overall, the data indicate aquatic effects for the Normal scenario in surface waters around the FMC would generally be comparable to those currently observed at X14 (i.e., relatively minor) and aquatic toxicity would be unlikely outside of the local study area.

For the Adverse scenario, zinc concentrations are expected to temporarily exceed those associated with the Normal operating scenario, with concentrations of zinc up to those listed in Table 7-16. Average zinc concentrations of 0.2 mg/L or more, such as were observed in November 2013 (Table 7-16), are in the range for potential lethal effects on biota, including fish. However, a study tracking Arctic grayling around the FMC local and

regional study areas using radio telemetry showed two active grayling in the RCD on December 10 (EDI, 2013), where November concentrations averaged 0.34 mg/L (at X3A) (Table 7-16). As Appendix 7C described, the literature suggests concentrations of approximately 0.24 mg/L may be acutely lethal to Arctic grayling, but also shows that fish can acclimate to low-level zinc exposure levels so that their tolerance to subsequently elevated zinc exposure concentrations also increases.

Consistent with the AMP, the elevated zinc in the NFRC and downstream areas is being monitored closely while a remedial solution is developed and implemented. During the IW, under this type of scenario, there is increased potential for temporary toxicity to aquatic biota (approximately 6 to 8 months), possibly including toxicity to fish, until remediation can be implemented. Thereafter, concentrations are expected to return to those associated with the Normal operating scenario, with associated recovery of biological communities to conditions typically associated with normal operations.

7.3.4.7 Analysis of Potential Physical Effects on Fish and Fish Habitat

Fish habitat includes the physical structure of the areas inhabited by fish, such as stream and bank morphology; substrate and cover characteristics; and water quality, depth and elevation; as well as the aquatic plant and invertebrate communities that contribute to ecosystem function and represent a food source for fish. Potential chemical effects associated with the IW on fish and on the biological components of fish habitat were described above in Section 7.3.4.6. The IW's potential effects on physical aspects of fish habitat will be minimal, relating mainly to potential mobilization of particulates into surface waters. Such effects will be mitigated through BMPs for erosion control and sediment transport. Fish habitat may also be disrupted temporarily during the IW; for example, if a new road crossing is required to transport site investigation equipment (e.g., drill rigs) to appropriate locations. The effects on fish habitat will be mitigated by controlling particulate release during associated construction and by adhering to applicable sections of the federal *Fisheries Act.* No other aspects of the IW are expected to affect physical characteristics of fish habitat (e.g., diversions, channel realignment, flow alterations). Therefore, no residual effects are anticipated on physical fish habitat. Proposed monitoring will track the condition of physical and biological aspects of fish habitat during the IW (Appendix 5B, EMSRP).

7.3.4.8 Mitigation of Aquatic Effects

Beyond the activities proposed as part of the IW, no additional, standard mitigation practices are available that could be expected to lessen chemical loads from the FMC to surface waters during the IW. More permanent forms of mitigation will be undertaken as part of the FMRP, but planning, design, permitting, and procurement are required before these measures can be implemented. An objective of IW site investigations will be to identify opportunities for further mitigation or remediation that could be implemented as part of the long-term mine closure plan.

7.3.4.9 Significance of Aquatic Effects

Neither sulphate nor lead concentrations are expected to exceed water quality guidelines for the protection of aquatic life during the IW. Median concentrations of cadmium will be less than the hardness-adjusted water quality guidelines in all local and regional study areas, but the guidelines may sometimes be exceeded in localized stream reaches within the local study area (e.g., NFRC and in Rose Creek immediately downstream from the Faro Mine Area). However, the predicted concentrations are not expected to be toxic to fish and effects on other aquatic biota are expected to be minimal. Cobalt concentrations are expected to exceed the water quality guideline in Rose Creek at X14 and R4 in approximately 45 percent and 35 percent of months, particularly during the ice-free seasons. However, predicted concentrations are not expected to be toxic to fish and effects on other aquatic biota are expected to be minimal. Manganese concentrations are not predicted to change substantially from baseline conditions, except that they may decrease slightly in winter months and increase slightly in other months at Rose Creek stations at, and downstream from, X14. Overall, manganese concentrations are predicted to be greater than the hardness-adjusted guidelines in approximately 65 percent of months at X14 and in an increasingly lower percentage of months at stations farther downstream. The available data indicate that aquatic effects of manganese in surface waters around the FMC would be limited to the vicinity of X14 (i.e., within the LSA) and would likely be minor in magnitude.

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During the 10-year IW period, it is predicted that, under Normal operating conditions, winter and summer/autumn zinc concentrations will exceed guidelines throughout the Rose Creek system downstream of NF1 to the mouth at Anvil Creek (R4). At these stations, probabilities of monthly guideline exceedance range from 60 percent to 80 percent but decline from 80 percent at X14 to 70 percent at the mouth of Rose Creek (R4). They further decline to 30 percent after the confluence with Anvil Creek (R5), and to 20 percent at the Anvil Creek mouth (A1). The water quality guideline for zinc is also expected to be exceeded in approximately 30 percent of months at V8, near the mouth of Vangorda Creek, but will not be exceeded at P4 in the Pelly River downstream of either Vangorda Creek or Anvil Creek. Despite these elevated zinc conditions, the available data indicate aquatic effects in surface waters around the FMC would be comparable to those currently observed at X14. This means concentrations would rarely exceed fish toxicity thresholds, effects to other aquatic biota would be minor (i.e., affecting only a few sensitive species), and the effects would be limited to the LSA.

There is potential for periodic, unpredictable, and unpreventable breakthroughs of contamination to surface waters from mine sources via new groundwater pathways, which is currently occurring in the NFRC. Under such conditions, increased toxicity may temporarily occur (approximately 6 to 8 months), possibly including toxicity to fish, until remediation can be implemented. Thereafter, concentrations are expected to return to those associated with the Normal operating scenario, with associated recovery of biological communities to conditions typically associated with Normal operations.

Predicted changes in water quality associated with the IW correspond with significance rankings of Low to Medium for all relevant chemical variables (sulphate, cadmium, cobalt, lead, manganese, and zinc) and all relevant effect attributes (magnitude, likelihood and duration, geographic extent, and reversibility) as defined in Table 7-12.

7.3.4.10 Monitoring of Aquatic Effects

The aquatic environment will be monitored to confirm predicted environmental performance and demonstrate compliance with regulatory requirements. Monitoring results will be presented in comprehensive reports that will assess conditions relative to predictions and provide recommendations for future actions allowing for adaptive management of the FMC. The proposed aquatic monitoring program for the IW is summarized in Appendix 7C (Section 3.6) with additional detail provided in Appendix 5B, the Environmental Monitoring, Surveillance and Reporting Plan.

7.3.5 Wildlife and Wildlife Habitat Effects Assessment

This section describes the results of the detailed analysis of the IW's potential effects on wildlife and wildlife habitat. As identified in Table 7-4, this effects assessment has identified a series of interactions between project activities and wildlife and wildlife habitat, including four major interactions (i.e., ranked as "2" in the interaction matrix). These interactions occur through effects pathways including contaminant transport and uptake, wildlife physical safety risks or disturbances, destruction of habitat and direct contaminant contact. Each of these effects pathways were considered in the context of all project activities to develop the interactions noted previously.

The following sections outline the methods and results of the effects assessment specific to wildlife and wildlife habitat in relation to the project, where the identified project interactions and pathways are described using a series of wildlife and wildlife habitat indicators. Each of these indicators has a set of ecological objectives specifically related to IW activities. An analysis of potential project effects and associated mitigation measures are presented, as well as a description of effect significance as described in Section 7.2.3.

7.3.5.1 Wildlife and Wildlife Habitat – Pathways of Effects

Pathways of effects are the linkages of mechanism through which project activities result in effects to a project VC. Pathways can be of a physical, chemical, environmental, or other nature, and form the cause-effect link through which effects are realized.

Effects on wildlife and wildlife habitats as a result of project activities are anticipated to occur via five main pathways (Table 7-17). Each identified pathway is subsequently described in terms of linkages to project activities and potential effects.

TABLE 7-17
Wildlife and Wildlife Habitat Pathways of Effects
Faro Mine Interim Works

Pathway	Potential Effects
Permanent or temporary destruction (loss) or alteration of habitat.	Habitat loss Nest disturbance Disruption of nesting
Metals uptake through feeding or exposure.	Sublethal health effects or mortality
Entrapment / drowning.	Mortality
Vehicle collisions with wildlife or equipment trauma.	Mortality
Sensory Disturbance (visual, olfactory, auditory).	Disturbance, disruption or avoidance

Habitat Destruction or Alteration

Site access, maintenance, and route development activities have the potential to destroy or alter wildlife habitats. This pathway may result from any activity that includes ground or vegetation disturbance, most often through the use of heavy equipment to remove vegetation, scarify land, clear access trails or move earth. These activities can reduce or remove the value of land as habitat for wildlife through physical disturbance, removal of vegetation or other cover, or the removal or alteration of nests, feeding/foraging areas or travel pathways. Habitat destruction or alteration can have direct and/or indirect adverse effects. For example, in the case of nesting, nest disturbance can have direct effects through the mortality of eggs or hatchlings in nests. Effects can also be indirect through habitat loss (less nesting habitat available for a particular species) or disruption of nesting (individuals are forced from nests or blocked from nesting in a particular area).

Metals Uptake

Tailings storage and water management activities related to site maintenance can result in pathways of metals uptake to wildlife. Tailings stored at the RCTA become mobile in the environment by wind transfer, creating fugitive dust that settles on and can increase the metal concentrations in vegetation and soils. Metals contaminated water is present in pits, ponds, seepage pathways, and other wet environments at the FMC, and can be taken up by vegetation in these areas. Once mobilized in the environment, the contaminant pathway is realized when wildlife species uptake contaminated sediment, soil, vegetation, animal/invertebrate tissue, or water. In addition, direct contact (e.g., skin exposure) with vegetation, soil, water, and tailings sediment may also be another pathway of uptake. Depending on factors such as the concentrations of chemicals, exposure duration, and uptake rates, sublethal or behavioural effects may also result from the accumulation of heavy metals in body systems.

Entrapment and Drowning

Entrapment and drowning were identified as pathways that have the potential to result from waste and water management activities that specifically include the storage of tailings material in the RCTA and the diversion of clean water around site facilities. The tailings materials in the RCTA cover a large area and are open to the environment. The physical nature of the stored materials may be variable across the storage facility area and may pose a risk to wildlife that walk across it, particularly where the materials are unconsolidated. The resulting direct effect can include entrapment of an individual that has sufficient mass (i.e., moose) to sink into tailings where it is unconsolidated. Similarly, the current clean water diversions may result in wildlife entrapment when wildlife attempt to cross them. For example, the Vangorda Creek Diversion includes a half-culvert flume that may restrict the ability for wildlife to escape. Entrapment in the diversion structures may result in injury from escape attempts or mortality from drowning. Furthermore, entrapment within a structure could increase an individual's vulnerability and potential risk of predation.

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Vehicle and Equipment Collisions or Trauma

Vehicle and equipment collisions or trauma are pathways that were identified as having the potential to result from supporting activities involving vehicle and equipment use, including those relating to transporting fuel, materials, personnel and supplies, as well as snow and site clearing and general onsite traffic. These activities result in interactions between motorized traffic or equipment and wildlife that use the FMC. The resulting interaction can be a collision between vehicle and wildlife individuals and can have the direct effect of mortality. In the case where a collision does not result in direct mortality, physical trauma from the collision may hinder or reduce the individual's ability to survive (e.g., reduced motility or ability to feed) and may therefore indirectly result in mortality by increasing an individual's vulnerability and potential risk of predation.

Sensory Disturbance

Sensory disturbance is a pathway that was identified as having the potential to result from many of the activities and physical works proposed for the IW, including on-land construction, waste and water management, supporting and site investigation activities, ID spillway upgrades, and RCD modifications. Sensory disturbance can result from any activities that stimulate and disrupt the visual, olfactory, and auditory senses of wildlife, including machine operation, blasting or drilling, earthmoving, and vegetation clearing. Personnel, machines, and equipment (e.g., work crews, trucks, excavators, and drill rigs) create temporary noise (e.g., engine operation, blasting, or verbal communication) and also unnatural odours (e.g., exhaust fumes, crew food, and cigarette smoke). These disturbances may directly engage an avoidance or stress response in wildlife species, leading to the disruption of a migration route/movement trajectory or abandonment of activities and habitat related to breeding, nesting, resting, feeding, or shelter/cover. Indirect effects may include increased essential energy consumption burning fat stores necessary for winter months, the displacement from habitats near to project activities, cessation in breeding, nesting and feeding, and exposure and vulnerability to predators.

7.3.5.2 Wildlife Species and Wildlife Habitat – Indicators

Effects on wildlife and wildlife habitat can manifest themselves through a variety of pathways, and on a multitude of local species or species groups. Consequently, it is not feasible to assess the potential effects of the IW on wildlife and wildlife habitat for all species occurring within the area of influence of the FMC (LSA or RSA). To adequately describe potential effects applicable to a wide variety of species, six indicators of wildlife and wildlife habitat were chosen on which to conduct a detailed assessment of potential project effects. Indicator species were chosen based on their relative high local value or cultural significance, their effectiveness as key receptors for a particular project interaction, and specific habitat requirements that exemplified the potential interactions of many other species. Indicator habitats were chosen based on their importance to sustain a specific life function for a broad group of species, or on the importance of specific key habitats to support species or species groups (Table 7-18).

Together, these six indicators are considered to represent the identified effect pathways and the wildlife and wildlife habitats occurring in the vicinity of the FMC.

TABLE 7-18
Wildlife Species and Wildlife Habitat Indicators
Faro Mine Interim Works

Indicator	Rationale
Moose	Moose are an important species ecologically and socioeconomically, and are harvested in the FMC area. While they are abundant in the RSA and occur in the LSA, there are concerns over potential overharvest that may be developing in the area (Clarke et al., 2012).
Thinhorn sheep	Thinhorn sheep are an important species ecologically and socioeconomically in the FMC and YT. This species is sensitive to disturbances, particularly during their lambing season and during winter. A migration corridor connecting summer and winter habitats intersects with the FMC, and therefore sheep occur relatively regularly in the LSA. Sheep are a good indicator species to represent disturbance effects on other ungulate species.

TABLE 7-18
Wildlife Species and Wildlife Habitat Indicators
Faro Mine Interim Works

Indicator	Rationale
Grizzly bear	Grizzly bear are listed as a species of Special Concern under *SARA*, and are of ecological, cultural and socio-economic importance. Grizzly bear use a variety of specific habitats seasonally and are wide ranging. This species is a good indicator of ecosystem integrity, as well as an indicator of local wildlife-human interactions. Grizzly bear are a good indicator species to represent effects on other large-ranging carnivores and omnivores.
Avian nesting habitat	Passerines (small terrestrial migratory or non-migratory birds) are abundant within the FMC LSA, including several passerine SAR that may be present (olive-sided flycatcher, bank swallow and rusty blackbird). Passerines have relatively specialized nesting habitat requirements and are ubiquitous to nearly all habitats at the FMC due to the broad variety of species present. Accordingly, avian nesting habitat was chosen as an indicator for the effects of local habitat loss or disturbance.
Waterfowl	Waterfowl are known to use the pits and ponds at the FMC at least seasonally, including several species at risk (e.g. harlequin duck, horned grebe and trumpeter swan). Waterfowl using the pits and ponds have the potential for exposure to contaminant pathways through drinking of water or feeding, and therefore provide a representative indicator for wildlife that may use the pits and ponds of the FMC either regularly or occasionally.
Small Mammals	Several species of small mammals are ubiquitous to the FMC area and form a primary food source for other wildlife species. As small mammals generally have limited home ranges and forage on vegetative materials, they are good indicators of local conditions and form a potential link for environmental contaminants to enter the food chain and reach higher trophic levels.

Consideration of Species at Risk in Indicator Selection

SAR occurring in the LSA and RSA include caribou, wolverine, grizzly bear, olive-sided flycatcher, bank swallow and rusty blackbird (as identified in Appendix 6J). Not all SAR occurring or potentially occurring in the LSA or RSA were included as indicators; however, the habitat requirements and sensitivities of the selected indicator species are considered to adequately represent potential impacts to these SAR.

Caribou are listed under Schedule 1 of *SARA* as a species of special concern and do occur in the project area, although not frequently (as described in Appendix 6J). A total of 13 caribou observations have been recorded over a five-year period at the FMC (as compared to 263 observations of moose), and the LSA does not overlap with key habitats for caribou. Based on these data, effects on caribou are not predicted to result from the IW, and are believed to be adequately represented by moose (for caribou moving through the LSA area) or thinhorn sheep (for effects in alpine areas during the calving and post-calving areas).

Wolverine are listed as a species of Special Concern by COSEWIC, and are stable in YT. While wolverine do occur in the LSA, their presence is rare (two observations in five years at the FMC), likely due to very large home ranges and nomadic behaviours. Wolverine are sensitive to anthropogenic disturbances on habitat; however, effects on this species are considered to be adequately represented by grizzly bear for the purposes of this assessment.

Several avian SAR also have the potential to occur in the IW LSA area, including the olive-sided flycatcher (*SARA* Schedule 1 - threatened), the bank swallow (COSEWIC - threatened) and the rusty blackbird (*SARA* Schedule 1 - special concern). One potential nesting area for bank swallow was identified near the ID and CVD Pond; while olive-sided flycatcher and rusty blackbird have not been confirmed as occurring in the LSA. While not specifically identified as project indicators, effects on these avian SAR were considered to be adequately represented through the assessment of effects on avian nesting habitat.

7.3.5.3 Wildlife and Wildlife Habitat – Ecological Objectives

The following series of ecological objectives were developed for the IW to define acceptable thresholds or limits resulting from the identified pathways and project-related effects on wildlife and wildlife habitat. Ecological objectives will assist in determining the significance of effects and guide the development of project-specific mitigation measures in the FMC LSA.

Ecological objectives considered for the IW include those related to habitat use, habitat availability or acceptable loss, metals concentrations or rates of uptake, as well as acceptable rates of project-related wildlife mortality (categories that best define the potential project effects). Ecological objectives for the project are described for the chosen indicators in terms of these four broad categories, and are summarized according to indicator in Table 7-19.

TABLE 7-19
Wildlife Species and Wildlife Habitat Indicators
Faro Mine Interim Works

Indicator	Category	Specific Ecological Objective
Moose	Habitat Loss	No objective defined.
	Mortality	No onsite mortality of moose.
	Local Site Use	Maintain current frequency of site usage by moose. Maintain existing connectivity (travel corridors) amongst habitat areas.
	Metals Uptake	No increase in contaminant uptake related to LSA habitat use.
Thinhorn Sheep	Habitat Loss	No objective defined.
	Mortality	No onsite mortality of sheep.
	Local Site Use	Maintain connectivity between existing habitat patches and maintain corridors between seasonal habitat ranges. Avoid disturbance in the Wildlife Key Area that traverse the FMC during migratory period. Maintain current frequency and rate of site use by thinhorn sheep.
	Metals Uptake	No increase in contaminant update related to LSA habitat use.
Grizzly Bear	Habitat Loss	No objective defined.
	Mortality	Zero human-bear incidents on site and zero mortality on site due to human-bear incidents.
	Local Site Use	Maintain existing travel corridors or connectivity between existing habitat patches. Maintain current frequency of site use by grizzly bear.
	Metals Uptake	No objective defined.
Avian Nesting Habitat	Habitat Loss	Minimize losses of avian nesting habitat. No habitat loss during active nesting window for migratory and non-migratory birds.
	Mortality	No mortality of nesting birds, eggs, or hatchlings.
	Local Site Use	No objective defined.
	Metals Uptake	No objective defined.
Waterfowl	Habitat Loss	No objective defined.
	Mortality	No project-associated mortality of waterfowl
	Local Site Use	Net decrease, or no net increase in local site use by waterfowl during the project term.
	Metals Uptake	No increase in contaminant uptake related to LSA habitat use.
Small Mammals	Habitat Loss	Minimize losses of small mammal habitat within the LSA.
	Mortality	Minimize mortality to small mammals in LSA.
	Local Site Use	Limited disruption to site use and change in population size.
	Metals Uptake	No increase in contaminant uptake related to LSA or RSA habitat use.

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Habitat Loss Objectives

There are no specific legislative guidelines or thresholds protecting the habitat of most wildlife habitat, including the habitat of wildlife that occur within FMC LSA. While critical habitat vital to the survival or recovery of wildlife species at risk is afforded legal protection, such habitats to not occur within the project area. Accordingly, no specific (area-based) threshold for habitat loss is applied to define habitat loss. Rather, the ecological objective defined for habitat loss aims to conserve habitat in the LSA. This is consistent with the overall ecological objective, to maintain the current rate of wildlife use, which from a habitat perspective, translates to minimizing habitat loss.

Mortality Objectives

For the purpose of the IW assessment, objectives for wildlife mortality are based on both legal requirements and more general ecological objectives.

An objective of zero mortality for nesting birds, eggs, or hatchlings was identified based on legislation in both the *Migratory Birds Convention Act* and the Yukon *Wildlife Act*. Under the former, it is illegal to disturb or destroy an egg or nest of a migratory bird without a permit. Under the latter, it is illegal to destroy, take, or possess any egg or nest of a bird that is wild by nature but that is not migratory (as defined by being subject to the *Migratory Birds Convention Act*). Accordingly, the ecological objective for the IW is to avoid any mortality of nesting migratory or non-migratory birds.

Moose, sheep, and grizzly bear are all regulated under the Yukon *Wildlife Act*, which states that it is only legal to kill these species by licensed hunters within season, in an area where hunting is permitted, and according to the terms detailed in the Yukon *Wildlife Act*. Killing of wildlife is also permitted under the Yukon *Wildlife Act* where there is an imminent threat of grievous bodily harm or irrecoverable and substantial damage to property and other practical means have been exhausted. Correspondingly, no hunting or intentional killing of wildlife will be tolerated by site personnel at the FMC during the 10-year period of the IW. The potential destruction of grizzly bear, black bear, or other wildlife that are threatening the safety of humans onsite will be deferred to as a last resort. Any other potential wildlife mortalities are anticipated to be associated with accidental interactions (e.g., vehicle collisions, entrapment, drowning). Accordingly, a zero mortality objective has been established for moose, sheep, and grizzly bear.

Local Site Use Objectives

The LSA and RSA provide suitable habitats for a variety of wildlife. The footprint of the FMC totals approximately 20 percent of the LSA, and includes land altered from a pre-disturbance condition in some way (i.e., pits, waste rock piles, roads or other infrastructure). These disturbed areas were cleared of vegetation during the mine development process. Although some natural revegetation has occurred since original disturbance, these areas are sparsely vegetated with pioneering species including grasses, herbs, shrubs, and aspen or balsam poplar. In addition, vegetation re-established on contaminated soils or water may have elevated metal concentrations, particularly on the periphery of the site ponds or waste rock piles.

The remaining 80 percent of the LSA surrounding the FMC footprint is composed of a variety of relatively natural habitats that are used by a variety of ungulates, birds, carnivores, small mammals and amphibians. Wildlife are present in the LSA, moving through the footprint area, and also throughout the RSA through larger undisturbed habitat patches or via corridors between smaller habitat patches (e.g., riparian corridors). The LSA is not considered to provide any limiting or key regional habitats, but does contribute to regional habitat both by supporting local species and by allowing regional connectivity.

Wildlife habitat use objectives at the FMC are not based on specific guidelines or legislation, but rather are defined qualitatively by considering the desired outcomes for local habitat use. For ungulate species such as moose or sheep, and carnivores such as grizzly bear, ensuring the LSA continues to function as part of the regional landscape is a desired outcome. Accordingly, the ecological objective for the IW is to maintain current rates of site usage (e.g., frequency of occurrence at the site) by terrestrial wildlife. Trends in local site usage by wildlife can

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also be assessed semi-quantitatively, and is to be assessed through trends in incidental wildlife reporting which is completed as part of the site operations program.

Contrary to the general objective for wildlife use, for waterfowl species using pits or ponds at the FMC LSA that are contaminated there is a desire to reduce the degree of site use during the term of the IW. Risks associated with metals uptake is likely related to the degree of site usage (specifically feeding or stopover on pits and ponds, as described in further detail below), and therefore the objective for reducing site use during the temporal span of the IW is established to help curb metals uptake.

Metals Uptake Objectives

The storage of metals contaminated water and tailings at the FMC presents the potential for contaminant uptake by local wildlife. Concentrations of metals in wildlife tissues are influenced by numerous factors including, but not limited to, the following:

- Metals concentrations in ingested materials/prey (animals and plants)
- Chemical bioavailability (ability to be absorbed into tissues)
- Metabolic pathways and species-specific physiology
- Biotic and abiotic factors in the contaminated environments
- Volume of contaminated material ingested
- Feeding rates, or frequency and duration of exposure

It is not practical to monitor actual contaminant concentrations in most wildlife as lethal sampling techniques are required to harvest tissues needed for metals analysis. Lethal sampling techniques are not practical or accepted for larger wildlife (i.e., ungulates), waterfowl, or small mammals. Furthermore, wide-ranging wildlife such as waterfowl or ungulates would not be appropriate study species for monitoring tissue metals concentrations and contaminant uptake from a localized area such as the FMC. The diversity of habitats and conditions these far-ranging species encounter hinder the ability to correlate metal toxicity or loading back to a single (or localized) area. Accordingly, as it is not practicable to set an absolute objective for metal uptake, a qualitative objective of no net increase in metals uptake was established for the IW. The corresponding ecological objective for the contaminant uptake pathway of effects is therefore to maintain or reduce the frequency of contact between wildlife and contaminants, including: water, vegetation or other food sources, or sediment. These means are discussed further in Sections 7.3.5.4 and 7.3.5.5.

7.3.5.4 Wildlife and Wildlife Habitat – Analysis of Potential Effects

Table 7-20 identifies the various interactions between IW activities and wildlife and wildlife habitat VCs. Four significant (i.e., ranked as a "2") interactions between the IW activities and indicators of wildlife and wildlife habitat were identified. For each of these interactions, an analysis of potential effects is provided below which describes the specific pathways and scenarios whereby an effect may potentially occur, and describes the characteristics of each potential effect. This analysis of effects is organized according to indicator.

Moose

Moose may be affected by the IW activities identified in Table 7-4, specifically the diversion of clean water around site facilities as part of the waste and water management activities. These activities are identified as a major interaction (ranked as a "2"), where the potential interaction may result in an effect that is not mitigable through standard mitigations or BMPs.

The existing clean water diversions at the FMC consist of the RCD, FCD and VCD. Of these, the VCD poses a potential hazard to wildlife as it is composed of an 800 m open half-round steel pipe 2,400 mm in diameter, which is partially-buried (i.e., half-culvert). Alternate opportunities to safely cross this confined channel are on road crossings at the upstream and downstream extents of the diversion. It is anticipated that some wildlife species[1]

[1] Although it is possible that other species, including sheep and grizzly bears, may also access the VCD, it is assumed that each of these species are more agile and better climbers than moose and are likely better equipped to climb out of the channel. In addition, for the purposes of the effects assessment, the least capable climber and subsequently the species most vulnerable to entrapment was used here for simplicity. It is assumed that measures intended to minimize effects for moose will be equally or more effective for these other species.

may attempt to cross the channel along its length. Although an individual may be able to enter the channel, the steep and slippery side walls of the pipe provide little traction for a large hoofed animal, preventing easy exit leading to entrapment. The potential resulting effect may include injury to moose and potential mortality through exhaustion, drowning or predation if entrapped in the channel.

Any mortality of moose as a result of the project (in this case entrapment within the VCD) would not meet the ecological objective of zero-mortality identified for the project. Accordingly, measures and guidelines have been developed to mitigate the potential for this effect to occur and to ensure that there is no loss of life as a result of this interaction (Section 7.3.5.5).

Avian Nesting Habitat

IW activities have the potential to result in effects on avian nesting habitat. The only major interaction identified (which was ranked as a "2") may occur between avian nesting habitat and project activities, specifically related to the development of access routes for site investigations or borrow development (Table 7-20). Although some aspects of these works will be conducted on existing footprint areas, some site clearing and removal of vegetation will occur in previously undisturbed areas. Approximately 5 km of 4 m-wide route development requiring site clearing is planned over the 10-year project duration. Up to 10 km of line cutting for surface geophysics is also to be conducted (up to 1.5 m wide). These two activities may result in the clearing of up to 0.025 km^2 of vegetation, or roughly 0.0003 percent of the LSA area (81.5 km^2). Finally, various site works have the potential to result in ground disturbances within footprint areas. Not all effects can be mitigated through the use of BMPs, and are discussed here.

Naturally vegetated areas tend to provide the higher quality nesting habitat relative to disturbed areas. In the LSA, naturally vegetated areas include graminoid (i.e., grass), riparian shrub, boreal woodland (e.g., white spruce - willow, mixed coniferous-deciduous and pine), and subalpine (e.g., dwarf birch - subalpine fir) ecosystems (Appendix 6I). These ecosystems provide suitable nesting and foraging habitats for ground shrub and tree-nesting species. Mid-elevation northern coniferous forests ecosystems may provide suitable breeding habitat for the olive-sided flycatcher, although this species is not confirmed to occur in the FMC.

In addition to the high value of undisturbed areas onsite, previously disturbed sites can also contribute to available nesting habitat onsite. For example, a road cut silt and sand cliff near the ID and CVD Pond provides suitable habitat for bank nesters such as the bank swallow.

Equipment used to conduct site investigation activities could affect avian nesting habitat through two means. The first potential effect is direct mortality of individuals realized through nest disturbance whereby eggs or hatchlings in nests are mechanically destroyed. The second is indirect mortality, realized by the disruption of nesting behaviours such as brooding, whereby any sensory disturbance (e.g., visual, audible or olfactory) is anticipated to keep the avian parents away (e.g., abandonment) from their nest thereby reducing the viability of the eggs or hatchlings.

Federal and territorial legislation states that is it illegal to disturb or destroy active nests, eggs, or individuals of migratory and non-migratory avian species without a permit. Accordingly, the primary objective with respect to avian nesting habitat is preventing mortality, as defined in Section 7.3.5.3. Accordingly, measures and guidelines have been developed to mitigate the potential for this effect to occur and to ensure that there is no loss of life as a result of this interaction, and are discussed in Section 7.3.5.5.

Waterfowl

A variety of waterfowl species frequent the FMC and project-related activities will potentially negatively interact with waterfowl activity on-site. The only major interaction identified (which was ranked as a "2") for waterfowl is related to the storage of contaminated water in the ponds on the FMC. (Table 7-20).

Observations from the FMC show that waterfowl use pits and ponds in the FMC at least seasonally, and that waterfowl appear to be drinking water or attempting foraging while present (Appendix 6J). These waterfowl activities are concentrated within the man-made pits and ponds onsite that store metals contaminated waters, as well as in the altered habitats of the NFRC and RCD areas. Existing site data indicates that some pits and ponds

contain water, vegetation, and sediment that are elevated in metals, including aluminum, cadmium, arsenic, copper, iron, nickel, lead, titanium, uranium and zinc, sometime above recognized guideline levels (e.g., CCME Canadian Sediment Quality Guidelines for the Protection of Aquatic Life). The use of these habitats by waterfowl presents a potential pathway for metals uptake and subsequent accumulation within body tissues. The ingestion of these metals above the tolerance limits of waterfowl can influence physiology, morphology and reproductive success (Flint, 1997; Kalisinska, 2004; ELR, 2013a). The degree of habitat use by waterfowl at the FMC varies, and the overall volume of water or forage consumed by waterfowl and associated contaminant concentrations are not known. As a result, the degree of actual exposure cannot be determined, only the potential for exposure and/or effect.

Diving species like goldeneyes observed on the SPP, harlequins observed on the SPP and Grum SCP and shorebirds, such as the sandpiper observed on the Grum SCP, all filter sediment to glean benthic invertebrates. This filtration results in contact with elevated metals in water, invertebrates and sediment. Sediment samples collected from the SPP exceeded the CCME guidelines for sediment for cadmium, mercury, lead, arsenic and zinc. The Grum SCP sediment samples report elevated concentrations of cadmium, lead, arsenic, and zinc. While the bioavailability of these metals is not known, waterfowl are both in contact and ingesting sediment and potentially invertebrates with significantly elevated metal concentrations.

Dabbling species such as American wigeons forage on aquatic and riparian vegetation, and have been observed at the IP. Feeding on aquatic plant species can involve the inadvertent ingestion of contaminated sediment along with the metal-laden bulbs of the plants, adding to the concentration of metals ingested. Aquatic vegetation and suitable forage occurs at the CVD Pond, Grum SCP, SPP, and Grum Settling Pond. At these sites, vegetation and sediment were found to be elevated in metals. Specifically, copper, chromium, cadmium, mercury, lead, arsenic, and zinc concentrations were elevated at the CVD Pond. Cadmium, mercury, lead, arsenic, and zinc concentrations were elevated at the SPP. Arsenic, cadmium, lead, and zinc concentrations were elevated at the Grum SCP.

The duration of exposure and the volume of sediment, vegetation and water consumed will influence the rate of uptake of metals, and therefore the long-term effects of elevated metals on waterfowl health. For example, a review of literature resources suggests an observable effect on waterfowl health is possible in less than 10 days of chronic exposure to lead at concentrations equivalent to those present in some FMC ponds (Kalisinska, 2004; Flint, 1997; Cook, 1966). These reported timelines are of a single metal at an elevated concentration, rather than elevated concentrations of numerous metals from multiple sources. Further, the toxicity and availability of each of these metals are often strongly correlated with other water chemistry parameters, such as total hardness or pH (Scheuhammer, 1991; Babich, 1983).

The potential for synergistic or additive relationships must be considered when assessing the overall threat or potential for effect on migrating waterfowl. Synergistic interactions between cadmium and lead, and lead and iron, can influence waterfowl metabolism and result in deficiencies of other essential elements such as calcium, zinc and iron (Kalisinska, 2004; Scheuhammer, 1987).

The continued uptake of metals by waterfowl using the pits and ponds of the FMC would not meet the ecological objective of a decrease in metals update over the term of the IW. Accordingly, measures have been developed to mitigate the potential for this effect to occur, as discussed in Section 7.3.5.5.

Small Mammals

The LSA and RSA provide habitat for a variety of small mammal species, and IW activities have the potential to affect their health, abundance and diversity. Minor project interactions where potential effects are expected to be mitigated through BMPs (ranked as a “1”) as proposed in Table 7-20. The only project activity identified as having the potential to result in effects on small mammals not mitigated by standard best practices (ranked as “2”) is the storage of tailings in the RCTA. A description of the anticipated interaction and potential effects are provided in the following section.

The storage of tailings material in the RCTA generates fugitive dust which is in turn deposited on vegetation and soils in both the LSA and RSA, thereby increasing metal concentrations in vegetation in depositional areas.

Currently, vegetation in both the RSA and the LSA is reported to possess elevated metal concentrations which are confirmed to be a result of past project activities (C.E. Jones and Associates Ltd., 2003; GLL, 2006). Trends in lead deposition outside of the FMC footprint indicate that prevailing winds and water in the RCTA and Rose Creek transport contaminants to the west and northwest into the Anvil Creek basin and onwards north towards the Pelly River. Samples taken from specific areas within the FMC footprint were up to 450-times greater than reference sites for some metals. In addition, between 61 and 100 percent of lead detected in the LSA and 65 to 90 percent detected in Anvil Creek was a result of ore dust deposits (GLL, 2006). There is also the potential that fluvial and airborne transport of tailings material will continue, increasing the affected area over time. Within the FMC footprint area, vegetation has also been found to be elevated in lead, arsenic, zinc, mercury and cadmium (ELR, 2013b).

Vegetation (in particular seed-producing plants) provides a food source for small mammals, and may result in a contaminant pathway in small mammals that could continue through accumulation in higher level predators (GLL, 2006; Hunter, Johnson, and Thompson 1987; Johnson et al., 1978). Metals can also have effects directly on small mammals consuming metals. For example, lead or cadmium intake can be correlated with renal disorders and histopathological changes (Johnson, et al. 1978). Further, zinc can ameliorate the potential toxicity of elevated cadmium concentrations due to competing enzyme and metabolic processes (Johnson et al., 1978; Hunter, Johnson, and Thompson, 1987). The toxicity of these metals is largely dependent on the volume and contaminant concentrations of contaminated materials ingested over specific periods of time.

Metal concentrations in small mammal tissues collected as part of the 2005 terrestrial effects monitoring program did not show a significant correlation with mine activity (GLL, 2006); however, the sample size was insufficient to determine statistical significance. Therefore, the toxicity of metals at the concentrations reported in the LSA and RSA is difficult to determine without tissue samples from exposed animals correlated with metal concentrations in food resources.

The continued uptake of metals by small mammals in the LSA or RSA would not meet the ecological objective of a decrease in metals update over the term of the IW. Accordingly, measures have been developed to mitigate the potential for this effect to occur, as discussed in Section 7.3.5.5.

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TABLE 7-20
Wildlife and Wildlife Habitat Interactions Summary by Indicator
Faro Mine Interim Works

	Project Activities/Physical Works	Wildlife and Wildlife Habitat Indicators: Moose	Thinhorn Sheep	Grizzly Bear	Waterfowl	Avian Nesting Habitat	Small Mammals and Habitat	Description of Interaction / Effects	Mitigation Measures
Waste and Water Management	Tailings Storage n the RCTA	1	0	0	1	0	2	• Deposition of fugitive dust from the RCTA has the potential to increase vegetation metal concentrations, creating a pathway of uptake and transfer up the food chain. • Direct contact with riparian vegetation and tailings sediment may create a local pathway of uptake. • Potential for entrapment and mortality in tailings by ungulates.	• Employment of tackifiers at the RCTA to control dust erosion. • Control of vegetation in the vicinity of tailings to reduce habitat value. • Additional mitigation measures to be implemented through site BMPs.
	Clean water diversion	2	1	1	0	0	0	• Potential for wildlife entrapment, injury, or mortality in VCD.	• Potential use of fencing to limit wildlife access to the VCD.
	Contaminated water storage in pit lakes and backfilled pits (Faro, Vangorda, Grum, and Zone II)	0	1	0	1	0	0	• Potential for uptake of metals contaminated water, leading to potential accumulation and sublethal effects.	• Mitigation measures to be implemented through site BMPs.
	Contaminated water storage in LCD Pond, ID Pond, CVD Pond, SPP, Moose Pond, Grum Settling Pond, Grum Pit SCP, Vangorda Water Treatment Pond, and all other ponds	1	1	0	2	0	1	• Potential for uptake of metals contaminated water, vegetation, sediment, or food sources, leading to accumulation and sublethal effects. • Direct contact with riparian vegetation and tailings sediment may create a local pathway of uptake.	• Control of vegetation in the riparian zone of ponds to discourage wildlife use and remove potential pathways. • Use of control mechanisms to limit waterfowl use (e.g., pyrotechnics or report shells. • Additional patrols during migration season to employ deterrents. • Additional mitigation measures to be implemented through site BMPs.
	Diversions and site drainage containment system maintenance (dams, spillways, dikes, berms, collection ponds)	0	0	0	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
Site Investigation Activities	Boreholes/test pits	1	1	1	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	Monitoring equipment installation including wells, thermistors, flow measurement facility	1	1	1	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	Access route development (may include stream crossings)	1	1	1	0	2	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust)	• Areas of vegetation clearing to be limited, and timing of vegetation clearing to coordinated to minimize potential effects. • Additional mitigation measures to be implemented through site BMPs.
	Helicopter / aircraft use	0	1	0	0	0	0	• Potential for disturbance of wildlife from aircraft use. Potential for effects most pronounced during and post calving / lambing period or during winter.	Mitigation measures to be implemented through site BMPs.
DVIHU	Excavation of ID Spillway	0	0	0	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	Borrow material sourcing and transport	1	1	1	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	Removal of vegetation in RCD	0	0	0	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction.	Mitigation measures to be implemented through site BMPs.

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Wildlife and Wildlife Habitat Interactions Summary by Indicator
Faro Mine Interim Works

		Wildlife and Wildlife Habitat Indicators							
	Project Activities/Physical Works	Moose	Thinhorn Sheep	Grizzly Bear	Waterfowl	Avian Nesting Habitat	Small Mammals and Habitat	Description of Interaction / Effects	Mitigation Measures
								• Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	
	Removal of bank sloughs in RCD	0	0	0	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	Repair of RCD Dike	0	0	0	0	1	1	• Potential minor localized loss of habitat, or mortality of species with low motility. • -Potential of avian nest disruption or destruction. • Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
Accessory Activities	Transport fuel and materials	1	1	1	0	0	1	• Potential for injury or mortality due to wildlife vehicle collisions. • Potential Avoidance of habitat in travel corridors due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	Transport of personnel and supplies	1	1	1	0	0	1	• Potential for injury or mortality due to wildlife vehicle collisions. • Potential Avoidance of habitat in travel corridors due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	Waste management (disposal to landfills), include domestic waste	0	0	1	0	0	0	• Potential of wildlife attraction to waste sources resulting in conflict/risk to humans, and eventual mortality (wildlife destruction to mitigate risk).	Mitigation measures to be implemented through site BMPs.
	Snow clearing and stockpiling	0	1	0	0	0	0	• Potential for disruption of sheep migration pathways by snowbanks. May limit movement across road corridors or trap sheep on roadways, thereby increasing the risk of displacement along the roadway or vehicle collisions.	Mitigation measures to be implemented through site BMPs.
	Temporary camp	0	0	1	0	0	0	• Potential of wildlife attraction to waste sources resulting in conflict/risk to humans, and eventual mortality (wildlife destruction to mitigate risk).	Mitigation measures to be implemented through site BMPs.
	Sourcing and transport of borrow material	1	1	1	0	0	0	• Avoidance of work areas by wildlife due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.
	General project-related traffic	1	1	1	0	0	1	• Potential for injury or mortality due to wildlife vehicle collisions. • Potential avoidance of habitat in travel corridors due to sensory disturbance (e.g. sound, visual, dust).	Mitigation measures to be implemented through site BMPs.

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7.3.5.5 Wildlife and Wildlife Habitat – Mitigation

Moose

Standard mitigation measures typically included in BMPs and environmental management guidelines are not anticipated to be adequate to prevent mortalities to moose that become entrapped in the VCD. Accordingly, the following additional mitigation measure is recommended: the use of fencing or wildlife deterrent mechanisms may be used to limit access to the VCD.

The installation of fencing may be used to deter wildlife from crossing from the VCD should wildlife mortality occur. Fencing could either be installed to exclude wildlife from the VCD, or to discourage crossings within the constructed diversion area. If installed, the interim installations should be monitored daily (at a minimum) to ensure that they are functioning effectively.

Avian Nesting Habitat

Several standard mitigations measures will be employed to limit effects on avian nesting habitat, including best management practices directed at preventing avian mortality during the bird nesting season, as regulated by the *Migratory Bird Convention Act* and the Yukon *Wildlife Act*. These will focus on scheduling construction activities to fall outside of the migratory bird nesting window, or pre-clearing of vegetation from construction areas during the non-nesting season. The following additional mitigation measures are recommended:

- Avian nest searches will be conducted within proposed clearing areas prior to commencing works if works must be completed during the bird nesting window; and,
- A survey of key footprint area nesting sites will be conducted, and any areas identified are to be marked and identified to reduce the risk of project conflicts.

Avian nest search would be conducted during the bird nesting window (June 1 to July 30) according to standard nest search protocols and would include three survey passes conducted by a crew of two biologists over a three-day period (i.e., one pass per day) to ensure adequate opportunity for nest detection. Surveys must be performed between the period of 04:30 and 09:30 when birds are most active. Active nests will be flagged using an appropriate buffer distance within which no clearing is to occur until after the close of the bird nesting window. Clearing activities must commence no more than 24 hours following the completion of the final survey pass to ensure no new nests are initiated after that time.

Similarly, any footprint areas in the vicinity of active works would be surveyed during the bird nesting window and between the hours of 04:30 and 09:30. Protective measures (e.g., area flagged and barricaded) should be implemented if evidence of active nesting is observed, in order to limit disturbance and prevent mechanical damage to the bank thereby preventing any mortality of brooding adults, eggs, nestlings or a fledglings.

Waterfowl

The primary objective of mitigation measures developed to minimize the potential and degree of contaminant pathways in waterfowl is to limit the accessibility and time spent on contaminated habitats in the FMC. Based on current data regarding waterfowl habitat use and behaviors at pits and ponds in the FMC, it is likely that the FMC is primarily used as a stop-over point during migration; therefore, reducing the availability or attractiveness of the habitats during that time will help to reduce waterfowl use and therefore the potential for contaminant exposure.

Employing the following mitigation measures either in combination or individually, will assist in reducing waterfowl use of pond and pit habitats in the FMC.

- Riparian vegetation around the perimeter of pond habitats will be managed to reduce vegetative cover which can provide nesting, loafing and foraging habitats for various species of waterfowl.
- Shore or bank restoration at the FMC will be limited to only that which is required to stabilize the features for erosion. If planting occurs, alternative ground covers such as unpalatable mulches or geotextile are to be used rather than vegetation.

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- Pyrotechnics, air cannons, or report shells should be deployed by site staff during key migratory periods, particularly during peak migratory periods in April, May, August, and September to create an inhospitable environment and deter establishment or temporary stop-over.
- Other deterrents (e.g., BirdBalls or a Goosenator robot) will be deployed if necessary to assist in deterring waterfowl from landing, foraging, or breeding in the pits and ponds.
- Wildlife patrols will be conducted during key migratory periods to monitor the effectiveness of deterrents and supplement deterrent effectiveness, if required, with non-lethal shooting.

Riparian areas associated with many of the pond habitats, provide suitable foraging, nesting and stop-over habitats for both resident and migratory waterfowl species. Grasses and sedges provide attractive nesting habitat for many species of ducks, swans and other shorebird species. Taller shrub and treed riparian areas provide cover and protection for nesting and rearing of young. Many of the plant species recorded in these areas are suitable food for many waterfowl species. Removal or trimming of the riparian vegetation prior to the breeding and nesting seasons will reduce the suitability for nesting, encouraging waterfowl to seek habitats in less-disturbed areas outside of the FMC footprint.

For waterfowl that still stop at FMC pits or ponds, auditory disturbances such as air cannons or report shells deployed during key migratory periods and at inconsistent intervals can deter waterfowl from using (for example, nesting and foraging) any of the habitats in the FMC. These tools can be reinforced during seasonal wildlife patrols with non-lethal shooting.

Migrating waterfowl look for large bodies of open water for stop-over habitats, such as those provided by the three pits, the CVD Pond and IP. The steep walls of the pits provide shelter from high winds, and the large expanses of open water allow for suitable space for easy landing and takeoff by diving ducks and larger species such as swans and geese. To deter rafts of waterfowl, deploying BirdBalls will make the open water less visible to migrating birds and decreasing the available landing/takeoff area required. BirdBalls are hollow plastic balls that camouflage water surfaces, preventing birds from alighting on ponds. Alternatively, deploying a remote-controlled robot when rafts are observed, will encourage birds to seek alternative habitats. The Goosenator is a remote-controlled robot that acts as a scare-tactic discouraging waterfowl from remaining on ponds.

Small Mammals

The deposition of fugitive dust generated from the RCTA is identified to be a key potential contaminant pathway for small mammals. The implementation of the following mitigation measures will serve to reduce the deposition of contaminated dust and minimize the potential for contact leading to a toxicological pathway in small mammals.

- Vegetation will be managed in the areas immediately within the RCTA where vegetation metal concentrations are significantly elevated.
- Regular application of tackifiers will minimize the generation and subsequent deposition of fugitive dust on vegetation within the LSA and the RSA.

Consistent with the removal and management of riparian vegetation for waterfowl, the management of grasses and other seed-producing plants and the reduction of structural diversity in riparian areas adjacent to the RCTA will reduce the value of habitat for small mammals in the critical deposition areas. Without sufficient food resources and suitable habitat, the potential for a contaminant pathway can be reduced.

Regular application of tackifiers on tailings material, and the application of water on roads in close proximity to the mill and historic mine operations will reduce fugitive dust generation. The reduction of dust from the FMC footprint will reduce the subsequent contamination of soil, vegetation and waterways in the LSA and RSA, reducing the potential for transport away from the footprint. Over time, the reduction of additional or continued deposition of metals will result in decreases to metals contamination of surrounding areas.

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TABLE 7-21
Wildlife and Wildlife Habitat Significance Assessment Criteria
Faro Mine Interim Works

Valued Components	Effects Assessment Indicator	Rationale for Selection	Measurements	Effect Attributes	Significance Ranking	Ranking Criteria
Wildlife	Moose	Moose are an important species ecologically and socioeconomically that are harvested in the FMC area. They are abundant in the RSA but there are local concerns over potential overharvest.	Rates of observations of moose in the FMC LSA (as recorded through site wildlife log), rates of occurrences of human interactions or mortality onsite.	Magnitude and Likelihood/Duration	Low	No reduction in the frequency of occurrence on site during the 10-year period. Zero road mortalities; No disruption to movements on FMC roads (including Main Access and Haul Roads). No detectable change in local/regional population density (based on 5-year trend analysis typically used by EY wildlife managers to assess population trends.
					Medium	Periodic movement disruption and infrequent road mortality (vehicle collisions). Less than a 50% reduction in the frequency of occurrence on site as observed through wildlife logs. No detectable change in local/regional population density (based on 5-year trend analysis typically used by EY wildlife managers to assess population trends).
					High	Frequent movement disruption and road mortality (vehicle collisions). Greater than a 50% reduction in the frequency of occurrence on site as observed through wildlife logs. Detectable change in local/regional population density (based on 5-year trend analysis typically used by EY wildlife managers to assess population trends).
				Geographic Extent	Low	Changes affect individual moose at the LSA level (i.e., Faro Mine, Vangorda/Grum Area, Haul Road, and Main Access Road).
					Medium	Changes affect moose at the GMS level, and effects apply to the GMSs that overlap with the FMC.
					High	Changes affect moose at the regional population level (RSA), and effects apply to the regional area surveyed by YG in 2011.
				Reversibility	Low	Not applicable as there is no change from baseline (i.e., there is no condition to reverse).
					Medium	Population effects are reversible; time to reverse is dependent on time required to develop and implement an adaptive management plan.
					High	Population effects are not reversible.
	Thinhorn Sheep	Thinhorn sheep are an important species both ecologically and socioeconomically. This species is susceptible to disturbances and sensitive during their lambing season. Sheep are a good indicator species to represent disturbance effects.	Rates of onsite mortality or occurrence onsite (as recorded through site wildlife log). Area or regional surveys of population size and structure.	Magnitude and Likelihood/Duration	Low	No reduction in the frequency of occurrence on site during the 10-year period. Zero road mortalities; No disruption to movements on FMC roads (including Main Access and Haul Roads).
					Medium	Only infrequent movement disruption and infrequent road mortality (fewer than one per five-year period). Less than a 50% reduction in the frequency of occurrence on site as observed through wildlife logs.
					High	Frequent of movement disruption and road mortality. Greater than a 50% reduction in the frequency of occurrence on site as observed through wildlife logs.
				Geographic Extent	Low	Changes affect individual sheep at the FMC level (i.e., Faro Mine, Vangorda/Grum Area, Haul Road, and Main Access Road).
					Medium	Changes affect sheep using mountain habitats adjacent to the FMC and effects apply to the mountain blocks adjacent to FMC.
					High	Changes affect sheep at the Faro region sheep population level, and effects apply to the regional area surveyed by YG in 2011 during the lambing surveys.
				Reversibility	Low	Not applicable as there is no change from baseline (i.e., there is no condition to reverse).
					Medium	Population effects are reversible; time to reverse is dependent on time required to develop and implement an adaptive management plan.
					High	Population effects are not reversible.
	Grizzly Bear	Grizzly bear are of ecological, cultural and socio-economic importance. This species is an indicator of ecosystem integrity, as well as an indicator of local wildlife human interactions.	Rates of observations of grizzly bear in the FMC LSA (as recorded through site wildlife log), and rates of occurrences of bear-related incidents at the FMC.	Magnitude and Likelihood/Duration	Low	No reduction in the frequency of occurrence on site during the 10-year period. Zero human-bear conflicts and zero road or human-conflict mortalities.
					Medium	Infrequent human-bear conflict and rare mortality due to conflict or road collision (fewer than one per 5-year period). Less than a 50% reduction in the frequency of occurrence on site as observed through wildlife logs.
					High	Frequent human-bear conflicts at the FMC resulting in problem bear mortalities, and/or frequent mortality due to road collisions. Greater than a 50% reduction in the frequency of occurrence on site as observed through wildlife logs.
				Geographic Extent	Low	Changes affect individual bear(s) at the FMC level (i.e., Faro Mine, Vangorda/Grum Area, Haul Road and Main Access Road).
					Medium	Changes affect bears at the GMS level, and effects apply to the GMSs that overlap with the FMC.
					High	Changes affect bears at the regional population level, and effects apply to the FMC RSA.
				Reversibility	Low	Not applicable as there is no change from baseline (i.e., there is no condition to reverse).
					Medium	Population effects are reversible; time to reverse is dependent on time required to develop and implement an AMP.
					High	Population effects are not reversible.

TABLE 7-21
Wildlife and Wildlife Habitat Significance Assessment Criteria
Faro Mine Interim Works

Valued Components	Effects Assessment Indicator	Rationale for Selection	Measurements	Effect Attributes	Significance Ranking	Ranking Criteria
	Avifauna (Nesting Habitat)	Passerines are abundant within the FMC LSA, including the potential for several species at risk. Passerines are ubiquitous to nearly all habitats at the FMC, and have relatively specialized nesting habitat requirements. Accordingly, avian nesting habitat was chosen as an indicator for local habitat loss or disturbance.	The level of compliance with site mitigations effective at limiting disturbance-related nesting disturbance or mortality.	Magnitude and Likelihood/Duration	Low	No alteration, disruption, or destruction of nesting habitat during the avian nesting season. No destruction or avian mortalities as work will be completed outside of nesting season, or nest surveys will be conducted prior to clearing activities to avoid disturbing or destroying active nests.
					Medium	Minor disruption to nesting avifauna or loss of habitat will occur due to vegetation clearing during the breeding bird season. Works will be completed outside of the nesting season, or nest surveys will be conducted prior to clearing activities to avoid disturbing or destroying active nests. Some minor habitat loss or disruption of nests will occur due to incomplete application of mitigations or unforeseen nests
					High	Habitat and disturbance effect of clearing activities could be of sufficient magnitude or duration to impact local avian populations.
				Geographic Extent	Low	Effects on avifauna and habitat will be local and isolated (i.e. site level).
					Medium	Effects on avifauna and habitat will be localized and more widespread (i.e. LSA level).
					High	Effects on avifauna and habitat will be regional and widespread (i.e. RSA level).
				Reversibility	Low	Habitat effect will be completely reversible.
					Medium	Habitat effect will be temporary but reversible within some length of time (e.g., alternate habitat are available, vegetation will recover over time).
					High	Habitat effect will be permanent.
	Avifauna (Waterfowl)	Waterfowl use of pits and ponds at the FMC, including several species at risk (e.g. harlequin duck, horned grebe and trumpeter swan). Waterfowl provide a good indicator for wildlife using the pits and ponds of the FMC.	Degree of metal uptake to waterfowl from water and/or food sources.	Magnitude and Likelihood/Duration	Low	Waterfowl use of pits and ponds is limited and temporary (i.e., stop-over only). Decreases, or no increases in metal uptake by waterfowl over the 10-year project period as indicated by a net reduction in waterfowl use of pits and ponds, and a reduction in available pathways.
					Medium	Waterfowl use of pits and ponds is limited and temporary, including stop-over and limited feeding. Slight to moderate increases in metal uptake by waterfowl over the 10-year project period.
					High	Increase in waterfowl use of pits and ponds, including seasonal resident waterfowl feeding locally. Significant increases in metal update by waterfowl over the 10-year project period.
				Geographic Extent	Low	Project effects will be limited to a specific site or area at the FMC (i.e., ID Pond).
					Medium	Project effects will be site-wide at the FMC.
					High	Project effects will be site-wide at the FMC, and some population scale effects may occur offsite.
				Reversibility	Low	Not applicable as there is no change from baseline (i.e., there is no condition to reverse).
					Medium	Projects effects will be short-term/temporary and largely reversible (e.g., avian individuals' visit will be brief and will recover following departure from FMC).
					High	Project effects are irreversible. Individual avian health will be compromised and will lead to reduced reproductive success and/or direct mortality.
	Small Mammals (Rodents)	Small mammals are ubiquitous to the FMC area and are a primary food source. As small mammals have a small home range and are eaten by a variety of animals, they forms a potential link for environmental contaminants to higher trophic levels.	Health of local small mammal populations and concentrations of heavy metals in tissue.	Magnitude and Likelihood/Duration	Low	No increase in tissue heavy metal concentrations over the 10-year project period. No measurable decrease in local small mammal population density in LSA.
					Medium	Minor increase in tissue heavy metal concentrations over the 10-year project period. Slight to moderate decrease in small mammal population density in LSA.
					High	Significant increase in tissue heavy metal concentrations over the 10-year project period. Significant decrease in small mammal population density in LSA.
				Geographic Extent	Low	Changes to affect small mammal populations local to FMC infrastructure only (i.e. project footprint area).
					Medium	Changes to affect small mammal populations within the FMC LSA.
					High	Changes to affect small mammal populations at a regional scale (RSA, or within zone of dust deposition from the FMC infrastructure).
				Reversibility	Low	Not applicable as there is no change from baseline (i.e., there is no condition to reverse).
					Medium	Population and physical effects are reversible over time once factors resulting in effect are removed.
					High	Population effects are not reversible.

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7.3.5.6 Wildlife and Wildlife Habitat – Significance of Effects

A series of criteria were established based on which to evaluate the significance of project effects on wildlife. These criteria were developed in terms of magnitude and likelihood/duration, geographic extent, and reversibility. For each of the six identified wildlife and wildlife habitat indicators, specific ranking criteria were developed in terms of the ecological objectives defined above in Section 7.3.5.3. Table 7-21 provides these ranking criteria in terms of indicator-specific end points or changes. During the assessment process, the ranking criteria were reviewed for each indicator, and according to each project activity. Table 7-22 provides an overall summary of their residual effects for the major project interactions.

Moose

The IW effects on moose are expected to be limited to disturbance effects around roadways and infrastructure, as well as the potential for site-related mortality from vehicle collisions or entrapment in site infrastructure. Contaminant uptake from the site is expected to be minimal. Following the implementation of site mitigations, effects on moose are expected to be Low to Medium in magnitude and limited to the project duration (10 years). The geographic extent is expected to be Low (LSA area), with effects being fully reversible (Low to Medium). Overall, project effects on moose are expected to have a low significance.

Thinhorn Sheep

The IW effects on thinhorn sheep are expected to be limited to Minor interactions (ranked as "1") that involve minor sensory disturbance or avoidance, minor metals uptake, and potential mortality due to site activities. Following the implementation of project mitigations, effects on thinhorn sheep are expected to be low in magnitude and limited to the project duration (10 years). The geographic extent of effects is expected to be low (limited to the LSA area), with effects being fully reversible (Low to Medium). Overall, project effects on thinhorn sheep are expected to have a low significance.

Grizzly Bear

The IW effects on grizzly bear are expected to be limited to Minor interactions (ranked as "1") that involve potential mortality or changes in local site use due to sensory disturbance or habitat disruption. Following the implementation of project mitigations, effects on grizzly bear are expected to be Low to Medium in magnitude and limited to the project duration (10 years). The geographic extent of effects is expected to be Low (limited to the FMC and individual bears), with effects being of Low to Medium reversibility. Overall, project effects on grizzly bear are expected to have low significance.

Avian Nesting Habitat

The IW effects on avian nesting habitat are expected to be limited primarily to Minor interactions (ranked as "1") that involve minor losses of available nesting habitat on site or mortalities of nesting birds, eggs, or young. When assessed in the context of access development for the project, these effects were ranked more highly ("2") due to the extent of access trail development over the span of the project. Following the implementation of project mitigations, effects on avian nesting habitat and birds are expected to be Low to Medium in magnitude. Effects may continue beyond the project lifespan, but are reversible (as vegetation regrows). The geographic extent of effects is expected to be Low (site level). Overall, project effects on avian nesting habitat are expected to have low significance.

Waterfowl

The IW effects on waterfowl are expected to be limited to potential metals uptake related to usage of pit and pond habitats on site, with no associated habitat effects. Following the implementation of project mitigations, effects on avian nesting habitat and birds are expected to be Low to Medium in magnitude and limited to the lifespan of the project (10 years). The geographic extent of effects is expected to be Low to Medium in extent, with effects being of Low to Medium reversibility. Overall, project effects on waterfowl are expected to have low significance.

Small Mammals

The IW effects on small mammals are expected to primarily be limited to minor interactions (ranked as "1") that involve minor site disturbances, mortality, or losses of habitat. When assessed in the context of tailings storage for the project, effects of potential metals uptake were more highly ranked ("2") due to the potential for contaminant accumulation. Following the implementation of project mitigations, effects on small mammals are expected to be Low in magnitude and limited to the lifespan of the project or a short duration thereafter. The geographic extent of effects is expected to be Medium to High in extent, with the effects being of Low to Medium reversibility. Overall, project effects on small mammals are expected to have low overall significance.

7.3.5.7 Wildlife and Wildlife Habitat – Monitoring

Three techniques will be employed to monitor the effects of the project on wildlife and wildlife habitat: monitoring of site use by waterfowl, monitoring of general wildlife use within the FMC footprint area, and monitoring of small mammal contaminants levels in relation to the FMC.

Additional monitoring of site use by waterfowl is to be employed in years one through three of the project to determine whether mitigation measures focussed on reducing waterfowl presence at the FMC are effective. This monitoring will employ specific efforts to quantify the rate of site use.

The FMC incidental wildlife log program is to continue to be employed on site to monitor the degree of wildlife occurrence on site as measured through observations made by personnel on site.

A small mammal contaminants monitoring program is to be conducted in years five and ten of the project to determine whether the level of tissue contaminants in small mammals within the LSA is decreasing, stable, or increasing. This program will be in addition to a year zero program that is planned as part of a baseline study program.

These wildlife monitoring techniques are outlined in detail in Appendix 5E.

7.3.6 Socio-economic Effects Assessment

7.3.6.1 Introduction

This section describes the potential socio-economic effects that could result from the IW. The four IW components—site operations, site investigations, DVIHU and accessory activities (see Section 5.0, Project Description)—could each result in different socio-economic effects at different times and in different places.

The IWPP considers potential IW effects on a number of socio-economic values consistent with YESAA's definition of socio-economic effects, which includes "effects on economies, health, culture, traditions, lifestyles and heritage resources."(Government of Canada, 2003)

The socio-economic assessment team identified VCs and relevant indicators, as well as the geographic scope of potential effects, and the pathways the IW's effects may follow to affect the values. The assessment describes potential effects on the FMC, the Town of Faro, and the affected First Nations identified in the Yukon Devolution Transfer Agreement (YG, 2001).

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TABLE 7-22
Wildlife and Wildlife Habitat Effects Summary, Significance, and Residual Effects for Major Project Interactions
Faro Mine Interim Works

Project Activities / Physical Works		Indicator	Description of Interaction / Effect	Recommended Mitigation Measures or Best Management Practices	Residual Effect	Significance of Residual Effect
Waste and Water Management	Storage of Tailings Material in the RCTA	Small Mammals and their Habitats	Uptake and transfer of heavy metals resulting from contact and ingestion of plant material contaminated by fugitive dust	Manage vegetation in the critical deposition areas to limit the feeding opportunities and overall habitat value in the areas immediately within the RCTA where vegetation metal concentrations are significantly elevated. Regular application of tackifiers will minimize the generation and subsequent deposition of fugitive dust on vegetation within the LSA and the RSA.	Zero mortalities No increase in tissue metal concentrations.	Low
	Diversion of clean water around site facilities	Moose	Direct mortalities due to entrapment in the VCD channel	Replace existing VCD channel using a wildlife friendly design. Install wildlife deterrent mechanisms until the existing structure can be replaced. Regularly monitor the VCD to ensure that no wildlife species are trapped within the steel pipe diversion structure prior to and during the installation of the wildlife deterrent mechanism.	Zero mortalities.	Low
	Storage of contaminated water in pits and ponds	Waterfowl	Direct contact with contaminated water Ingestion of contaminated water, sediment and vegetation	Manage riparian vegetation around the perimeter of pond habitats to reduce vegetative cover which provides nesting, loafing and foraging habitats for various species of waterfowl. Limit any shore or bank restoration to only that which is required to stabilize the features for erosion, and use alternative ground covers such as unpalatable mulches or geotextile rather than vegetation. Deploy pyrotechnics, air cannons or report shells during key migratory periods, particularly in April, May, August, and September when flocks will be traveling through the LSA, to create an inhospitable environment and deter establishment or temporary stop-over. Deploy BirdBalls or Goosenator robots to deter waterfowl from landing, foraging or breeding on the pits and ponds. Complete wildlife patrols during key migratory periods to monitor effectiveness of deterrents and supplement with non-lethal shooting to reinforce automated systems.	No increase in tissue metal concentrations.	Low
Site Investigation Activities	Access route development, including stream crossings	Avifauna	Direct effect of mortality of individuals through nest disturbance (mortality of eggs or hatchlings in nests) from mechanized removal of vegetation during clearing activities Indirect effect of disruption to nesting (individuals are forced from nests or blocked from nesting in a particular area), potentially leading to mortality of eggs or hatchlings in nests	Conduct avian nest searches within the proposed clearing area prior to commencing works if works must be done during the bird nesting window. Survey key footprint area nesting sites, and mark any identified areas to reduce the risk of project conflicts.	Zero mortalities.	Low

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7.3.6.2 Geographic Scope

Based on the scope of activities proposed for the IW, the assessment team identified the following First Nations and communities for the socio-economic effects assessment:

- RRDC, primarily located in Ross River
- SFN, primarily located in Pelly Crossing
- LFN, primarily located in Watson Lake
- KDC
- Community of Faro (Town of Faro)

The assessment team collected and synthesized the available secondary data for these First Nations' and communities' VCs (refer to Appendix 6L for the baseline conditions). The Ross River Dena reside primarily in Ross River, where they maintain their offices of governance. The SFN is centred in Pelly Crossing. LFN members reside primarily in the community of Watson Lake. The KDC is a society formed to advance the interests of Kaska individuals in the five Kaska First Nations in British Columbia and Yukon. RRDC and LFN are the Kaska First Nations members of KDC that are centred in Yukon.

The assessment considered effects in three distinct study areas including:

- Site study area: the FMC site
- LSA that includes the FMC, Town of Faro, and Ross River
- RSA that includes the FMC, Faro, Ross River, Pelly Crossing, and Watson Lake

The socio-economic effects assessment identified pathways through which the IW could affect the VCs in each of the study areas and communities. The assessment team provided explanations for the pathways identified and then characterized the potential socio-economic effects related to each pathway. For the human health and safety VC, now major interactions were noted (Table 7-4). However, a qualitative assessment of effects was complete and is also presented in Section 7.3.6.10.

7.3.6.3 Socio-Economic Valued Components

As stated in Section 7.1.2, the assessment considered the following socio-economic VCs:

- Economy and employment
- Community stability and well-being
- Infrastructure and services
- Land use and access
- Culture and heritage
- Human health and safety

The assessment team identified indicators, which could be used to quantitatively or qualitatively measure each value. Table 7-23 describes the VCs, their indicators, and the rationale for their inclusion in the assessment.

TABLE 7-23
Socio-economic Valued Components and Indicators
Faro Mine Interim Works

Valued Component	Indicators	Rationale for Inclusion
Economy and Employment	Business development	The IW may stimulate local economies, and could increase employment and lead to skills development, training, and education in local communities. This value evaluates (1) the community's ability to adapt to economic growth, (2) the effects of increased disposable income, the distribution of costs/benefits among affected people (adverse effect/income equity), and (3) the effects on local and regional cost of living.
	Economic diversification	
	Employment opportunities and income	
	Education and training	

TABLE 7-23
Socio-economic Valued Components and Indicators
Faro Mine Interim Works

Valued Component	Indicators	Rationale for Inclusion
Community Stability and Well-being	Demographics	The influx of temporary workforce during each project component may influence community makeup, including demographics and mobility, such as effects of migration (in and out), changes in social and cultural makeups of communities, and influences on individual, family, and community health.
	Cultural well-being	
	Social cohesion	
Infrastructure and Services	Roads and traffic	The potential influx of temporary workforce may strain community infrastructure, housing, and emergency and health services. The IW construction and maintenance activities may increase traffic, which could in turn affect local road safety and cause wear to road infrastructure.
	Housing	
	Health services	
	Emergency services	
	Community infrastructure (water, sewer, garbage education, and education and recreation facilities)	
Land Use and Access	Traditional land use	The IW may affect how existing land users and First Nations traditionally access the FMC and surrounding areas (for hunting, trapping, and gathering). IW construction and maintenance activities might also affect access for commercial and recreation land users.
	Hunting and fishing (recreational and commercial)	
	Recreation	
	Tourism	
	Forestry	
Culture and Heritage	Traditional culture and use	The IW may affect known or unknown heritage resources when clearing previously undisturbed land within the FMC. The IW may indirectly affect traditional culture if land use and access is affected.
	Heritage resources	
	Culture (language, traditions)	

Along with the above socio-economic VCs, human health and safety is also considered a VC. The potential effects on both the community and worker health and safety are also discussed in this section.

7.3.6.4 Pathways of Effects

To understand which project activities could potentially interact with the socio-economic VCs and result in socio-economic effects, the assessment team developed an interaction matrix. Table 7-24 provides the results of this analysis for the socio-economic VCs. The interaction matrix classifies the activity/VC interactions according to the criteria described in Section 7.2.1.

For interactions identified as a “0,” the assessment team does not anticipate the IW will interact with the VC in a measurable way, and the IWPP does not further consider these interactions. For interactions identified as a “1”, suitable mitigation of the effects of the IW relies on the effective development and application of appropriate strategies such as BMPs. The Section 5 appendices provide mitigation and management plans that describe the BMPs and provide a framework for the administrative structure that will be established to assure the plans are followed. Table 7-5 identifies the specific mitigation and management plans for each of the activities that make up the IW. By applying these mitigation and management plans, the assessment team concluded that “1” interactions, when considered individually, will not cause significant adverse socio-economic effects.

For interactions identified as a "2", this assessment further investigated and characterized the socio-economic effect that could arise as a result of the interaction. Sections 7.3.6.5 through 7.3.6.8 present these assessments for each VC.

TABLE 7-24
Project-Valued Component Interactions
Faro Mine Interim Works

Project Activity or Physical Work	Economy and Employment	Community Stability and Well-being	Infrastructure and Services	Land Use and Access	Culture and Heritage
Site Operations					
Site operations workforce management; employment; contracts; and taxes	2	1	0	0	0
Tailings storage in the RCTA	0	1	0	0	0
Site Investigations					
Site investigation workforce management; employment; contracts; and taxes	2	1	0	0	0
Access route development (may include stream crossings)	0	0	0	2	1
Surface geophysics	0	0	0	2	1
DVIHU					
Construction workforce management; employment; contracts; and taxes	2	1	0	0	0
ID Spillway excavation	0	1	0	0	0
Ancillary Activities					
Waste management (disposal to landfills), including domestic waste	0	0	2	0	0
Site access control	0	0	0	2	0
Housing in Town of Faro	0	0	1	0	0
Potable water supply	0	0	2	0	0
Sewage treatment and discharge	0	0	2	0	0

Table 7-4 does not identify any "major" interactions for the Human Health and Safety VC, as the IW focuses on minimizing contaminants released from the site. However, because of concerns expressed by local communities and people a qualitative assessment of potential affects and mitigation measures is also included in this section.

7.3.6.5 Economy and Employment Effects Assessment

Economy and employment were identified as VCs because the economic activity generated as a result of IW may influence how income and capital is distributed through individuals, families, First Nations, businesses and communities in the RSA.

Indicators

The assessment uses indicators, or key characteristics, to measure expected changes in the VCs due to the IW. The assessment team has identified the following four indicators for the economy and employment VCs:

- **Business development:** A change in the number of businesses and associated employment in local economies.
- **Economic diversification:** The capture and distribution of supply and service opportunities in local economies.

- **Employment and income levels:** The capture and distribution of employment opportunities for skilled and unskilled labour.
- **Education and training:** The leveraging of training and skill development opportunities associated with project activities.

Study Area

The assessment team collected and synthesized baseline socio-economic information from available secondary data sources related to the economy and employment VC across the RSA.

Initially, the assessment considered potential IW effects on economy and employment for all study areas. As the IW will not affect every community in the same way, the assessment focused on those communities where potential pathways for IW effects were identified.

The co-proponents are committed to providing equal opportunities for affected First Nations to benefit from employment and economic opportunities associated with the FMC. This approach creates pathways for the IW to affect the economy and employment in each community. The FMC does not house full-time residents, businesses, or governments, so an assessment of potential effects on economy or employment was not conducted for the site study area. Table 7-25 summarizes which communities were assessed for effects on economy and employment.

TABLE 7-25
Study Areas for Socio-economic Effects Assessment – Economy and Employment
Faro Mine Interim Works

Value	FMC	Faro	Ross River	Pelly Crossing	Watson Lake
Economy and employment		✓	✓	✓	✓

Pathways of Effects

For each economic and employment indicator identified in Table 7-23, there will be a variety of potential interactions with the proposed activities. Table 7-26 summarizes the pathways for these interactions.

TABLE 7-26
Pathways for Effects for Economy and Employment
Faro Mine Interim Works

Project Component	Project Activity and Potential Interaction
Site Operations	Employment activities and purchase of supplies
Site Investigations	Employment activities and purchase of supplies
DVIHU	Employment activities, equipment operation, and purchase of supplies and materials

Analysis of Potential Effects

The IW is scheduled to take place over 10 years, with its four components requiring different types and amounts of labour, depending on the season and the year. The activities will also generate different economic inputs, depending on the season and the year. The assessment explores the potential effects of each IW activity on the economy and employment VCs.

Site Operations

Data on anticipated employment and labour income expenditures are available for site operations in 2014. These are expected to remain relatively consistent for the remainder of the project timeframe.

Figure 7-1 presents the estimated average number of site operations employees anticipated at the FMC in 2014, broken down by month and job type. The site operations are expected to require similar levels and types of employment for the remainder of the project. Site operations employment will be highly seasonal, staffing positions for 8 months a year. Each year, the average number of site operations employees will peak in July, at 52. The site operations position with the most staff will be that of WTP operator, peaking at 16 from July through to September. The majority of staff onsite between November and March (approximately 25 people) are included under the management and administration.

Non-local workforce for site operations will likely be housed in a mix of hotel/B&B accommodation and leased or rental housing in Faro. Consultation with Faro is occurring to assess the availability of possible rental units and other housing accommodation solutions to meet the anticipated accommodation needs. (Section 5.7.2)

Labour incomes (which include both salary and wage incomes) associated with site operations employment (excluding payroll burden) are expected to total about $2.1 million in 2014 (Table 7-27).

TABLE 7-27
2014 Site Operations – Labour Income by Job Type
Faro Mine Interim Works

Job Type	Labour Income ($)
Automotive and Light Duty Mechanic	22,642
Certified Electrician	127,965
Certified Journeyman (various)	45,936
Certified Millwright	99,760
Chemist	57,931
Environmental Coordinator	5,915
Environmental Technologist	56,430
Licensed Welder	96,773
Security / Safety Personnel	199,818
Skilled Labour / Equipment Operator	239,461
Student	108,688
Supervisor / Foreperson	210,834
Unskilled Labour	97,604
Water Treatment Plant Operator	720,852
Total Labour Income	**2,090,608**

Note: Labour Income include both salary and wage incomes and does not represent individual salaries

During each month of 2014, an estimated $76,472 will be spent on management fees for site operations. The total management fees for 2014 will be $917,668. Management fees cover positions such as the superintendent, site manager, and project managers. Monthly expenditures for site operations administration fees are estimated at $182,921, and the total administration fees for 2014 will be about $2,195,050. Administration fees cover all office staff at the FMC and accountants from the head office.

Site Investigations

Employment, labour income, and supplies, materials, and equipment expenditures for site investigations activities are expected to peak in 2014 due to a more extensive field program. The IW will require lower levels of labour and resources (about $2 million annually) for the rest of the project.

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Spending associated with site investigations for the IW will amount to several million dollars in 2014. However, these activities may have limited effects on the local communities, as they will focus on geotechnical investigations and field surveys. The workforce for most site investigations is anticipated to combine non-local technical experts with Whitehorse-based and local support. The co-proponents emphasize the use of local available workforce when contracting this site work and the prime contractor for this work has developed a participation plan focused on AYFN and Yukoners (CH2M HILL, 2013d).

Figure 7-2 presents the estimated average number of employees for FMC site investigations in 2014, broken down by month and job type. Site investigations jobs will be highly seasonal, and the average number of employees will peak in July, at 41. The site investigations position with the most staff will be that of field engineer/scientist, peaking at 12 from June until October.

Labour incomes associated with site investigations employment (excluding payroll burden) are expected to total about $8.5 million in 2014 (Table 7-28). Annual IW site investigations are expected to continue through the remaining 9 years of the project, though they will only require about one-fifth of the 2014 resources.

TABLE 7-28
2014 Site Investigations – Labour Income by Job Type
Faro Mine Interim Works

Job Type	Labour Income ($)
Drillers	2,159,992
Environmental Pit Lake Sampling Staff	64,000
Equipment Manager	252,000
Field Engineers/Scientists	2,772,000
Health and Safety Manager	270,000
Operations Manager	342,000
Pump Testing Staff	290,000
Quality Manager	270,000
Site Field Manager	270,000
Staffing Manager	252,000
Surveyors	408,000
Task Manager	342,000
Test Pit Excavations Staff	228,000
Utility Locator Staff	60,000
Vegetation Survey Staff	313,832
Wildlife Survey Staff	171,204
Total Labour Income	8,465,028

Non-local technical staff are expected to make up the majority of the 2014 site investigations workforce. These staff will likely be housed in Faro and, if required, in a temporary camp in the old Pelly Camp area, located off the Grum Access Road. The site investigations' labour requirements are highly seasonal and most positions will only be required onsite during summer 2014. The site investigations' labour requirements are not expected to result in an inflow of permanent residents to Faro. As a result, the total value of labour incomes captured in the local economies of Faro, Ross River, Pelly Crossing, and Watson Lake is expected to be limited.

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Expenditures on site investigation supplies are expected to total about $1.3 million in 2014. Table 7-29 outlines expenditures by supply type.

TABLE 7-29
2014 Site Investigations – Supply Expenditures by Type
Faro Mine Interim Works

Supply Type	Expenditures ($)
Air transport	216,000
Communications (e.g., phone)	30,000
Diesel/gasoline	24,000
Expediting/shipping	6,000
Janitorial supplies/subcontract	4,800
Office supplies	1,800
Per diem and lodging	784,080
Propane fuel	5,100
Rental equipment	3,000
Safety and training supplies	12,000
Shop supplies	1,200
Vehicle rental	180,000
Total Supply Expenditures	**1,267,980**

Down Valley Interim Hydraulic Upgrades

The DVIHU field construction activities are expected to be completed in summer 2016, with potential economic and employment effects expected to be largely experienced in that period. Data on employment, labour income, and supplies and equipment expenditures for DVIHU activities are provided in Tables 7-30, 7-31, and 7-32.

Figure 7-3 presents the labour requirements for the DVIHU in 2016; that is, the estimated average number of employees, broken down by month and job type. DVIHU jobs will be highly seasonal, with most employment occurring from April through September. The average number of DVIHU employees will peak in June at 26. The job type with the highest number of positions is Labour - General, reaching a peak of five for the 5-month period from May to September.

The non-local workforce for the DVIHU will likely be housed in Faro and, if required, in a temporary camp in the old Pelly Camp area, located off the Grum Access Road. However, the DVIHU labour requirements are highly seasonal and most positions will only be required onsite during 2016. The DVIHU labour requirements are not expected to result in an inflow of permanent residents to Faro.

Labour incomes associated with DVIHU activities employment (excluding payroll burden) are expected to total approximately $1.1 million in 2016 (Table 7-30). In addition, the DVIHU construction activities expect to generate about $948,000 in per diem to non-local staff in 2016.

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TABLE 7-30
Faro Interim Works: 2016 DVIHU – Labour Income by Job Type
Faro Mine Interim Works

Job Type	Labour Income ($)
Administrative Assistant	2,919
Cost/Schedule Engineer	2,140
Junior Staff Engineer	2,496
Labour Foreman	4,698
Labour General	266,767
Labour Pipelayer	29,236
Operator Blade Finish	14,057
Operator Blade Rough	16,457
Operator Compactor	27,514
Operator Crane 20-50	3,177
Operator Crane 51-90	35,739
Operator Dozer Large	42,856
Operator Dozer Small	2,782
Operator Forklift	24,423
Operator Grade Check	33,636
Operator Hydraulic Backhoe	53,112
Operator Loader Wheel Type 1	52,556
Operator Loader Wheel Type 2	68,913
Operator Mechanic Heavy	58,970
Operator Screen Belt	35,552
Operating Foreman	151,734
Project Engineer	12,667
Quality Manager	2,154
Safety Engineer	2,502
Teamster Dump 29	41,426
Teamster Flatrack	44,086
Teamster High-Lo	16,076
Teamster Dump Truck 6-1	88,728
Total Labour Income	**1,134,871**

Expenditures on supplies for DVIHU activities are expected to total about $1.6 million in 2016. Table 7-31 outlines expenditures by supply type. The timing of these expenditures is expected to prior to or during the April to September timeframe of the DVIHU construction.

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TABLE 7-31
Faro Interim Works: 2016 DVIHU – Supply Expenditures
Faro Mine Interim Works

Supply Type	Expenditure ($)
84-inch Manhole	7,080
Backfill Material	14,355
Bond Costs	109,351
Concrete Redimix	1,180
Document Material	4,307
Field Office Trailer	1,770
Gabion Baskets	507,295
Gabion Material & Equipment	28,679
Gabion Mattress	318,682
Geomembrane	36,860
Grading ST&S	4,134
HDPE Pipe (750 mm)	232,608
HDPE Pipe (1,200 mm)	25,488
Hydraulic Fill Box	16,190
Insurance Costs	54,675
Miscellaneous Materials	7,611
Miscellaneous Mobilization Costs	17,700
Office Equipment & Supplies	1,770
Pipe Anchors	413
Polystyrene Insulation (0.15 m)	7,222
Porta John	1,272
PPE	69,000
PPE Level D	12,390
QC Testing Sub	8,850
ST&S	56,442
Survey Sub	8,850
SWPP Material	3,540
Temp Shoring	1,062
Underground ST&S	4,314
Total Supply Expenditures	**1,563,089**

Notes:
QC = quality control
ST&S = Small Tools and Supplies
SWPP = Storm Water Pollution Prevention Plan

Since heavy equipment will be used extensively during the DVIHU, equipment expenditures were also calculated and are expected to total approximately $1.7 Million. Table 7-32 outlines equipment expenditures by type (including fuel and exclusive of labour). The equipment expenditures will take place during the April to September timeframe of the DVIHU construction during 2016.

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TABLE 7-32
Faro Interim Works: 2016 DVIHU – Equipment Expenditures by Type
Faro Mine Interim Works

Equipment Type	Expenditure ($)
Backhoe Loaders	6,724
Boom Truck (28,000lb Capacity)	4,187
Bottom Dump Trailer (12 CY)	8,904
Bulldozers	157,528
Compactors	59,219
Compressor (185 CFM)	6,663
Conveyor (300 TPH)	31,071
Crane Grove (RT525E 25 T)	4,836
Crane Terex (HC 60 T)	81,753
Crusher Jaw	53,216
Excavators	241,255
Flatbed Truck (15 K)	35,769
Forklifts	24,565
Generator (100 kW)	28,528
Graders	49,762
HDPE Pipe Weld	1,506
Loaders	307,770
Lowbed Trailer (60 TN)	9,041
Mechanics Truck (35 KGVW)	73,333
Off Road Articulated Dump Truck (Cat 730)	141,534
Pickup Trucks	48,087
Radial Stackers	31,135
Screen Double Deck	26,518
Tandem Truck (12 CY)	64,317
Tractor (400 HP)	79,469
Vib Griz Feeder	27,524
Water Truck (4,000 Gal)	58,073
Wood Chipper Vermeer (12-in. Cap.)	4,313
Total Equipment Expenditures	**1,666,599**

Notes:
CFM = cubic foot per minute
CY = cubic yard
Gal = gallon
in = inch
K = kilo, 1,000
KGVW = K_ gross vehicle weight
lb = pound
T = tonne
TN = ton = (imperial ton: 2,000 pounds per ton)
TPH = tonnes per hour

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Ancillary Activities

The IWPP has identified a number of ancillary activities that are intended to support site operations, site investigations, and the DVIHU, including the following:

- Establishing a temporary camp for up to 20 people at the FMC, to house site investigation and construction crews
- Hauling and storing fuel
- Managing waste

A temporary camp would be constructed if the amount of local accommodation is exceeded by seasonal summer workforce in 2014 (site investigations) and 2016 (DVIHU). The purchasing of fuel is identified in the supply needs for the IW, and a pathway for waste management to affect the economy and employment VC has not been identified. As a result, the ancillary activities are not expected to result in material interactions with the economy and employment VC in the communities of Faro, Ross River, Pelly Crossing, or Watson Lake (Table 7-2).

Predicted Change from Baseline

Business Development

As previously mentioned, labour incomes from site operations and site investigations are expected to total $10.6 million in 2014 (excluding payroll burden). Site operations entails activities that are currently occurring on the FMC. As a result, there is little incremental potential for local businesses to supply contract labour above what is being provided already and the potential for local business development is predicted to be correspondingly small. Labour incomes for site investigations activities peak in 2014 and are focussed on technical job types that are unlikely to be economically maintained by local businesses. Ongoing site investigations at a decreased scale through 2023 could support very limited and targeted business development.

Labour incomes for DVIHU activities are estimated at about $1.1 million in 2016. Similar to site operations and site investigations, there is little potential that local businesses will supply contract labour and therefore, little potential for local business development. The Town of Faro and Ross River are closer to the FMC than the other communities and can be accessed via year-round roads, so they are expected to experience a greater potential for business development than other communities in the RSA. The DVIHU activities are expected to have limited benefits on business development. The short duration of the DVIHU activities does not provide incentive for long-term business development.

Economic Diversification

Expenditures on supplies for site investigation activities are expected to total about $1.3 million in 2014. As some categories of goods and services are available in local communities, there is some potential for the Town of Faro to capture supply and service retail opportunities (this potential also applies to Ross River, Pelly Crossing, and Watson Lake, to a lesser extent). The long-term housing of site operations workforce in Faro is expected to support limited community diversification or expansion into the provision of accommodations in that community. Expenditures on supplies and equipment for the DVIHU are expected to total about $3.2 million in 2016. As most of the supplies and equipment will be imported into the project area, limited potential for economic diversification is predicted. The DVIHU is expected to generate almost $1 million in per diem to the non-resident workforce in 2016, some of which is expected to stay within the LSA. The DVIHU will provide income to some local businesses and services in 2016, and could result in limited beneficial effects on economic diversification.

Employment and Income Levels

As previously mentioned, average monthly employment is expected to range between 36 and 52 employees for site operations from April until October 2014, with additional management and administrative staff year-round. Site investigations will require between 13 and 41 employees, also during the summer period. Average monthly employment is expected to range from 6 to 26 employees for the DVIHU (April 2016 to September 2016 field season).

In 2014, aggregate labour income is estimated at $2.1 million for site operations activities and $8.5 million for site investigations activities. Aggregate labour income for DVIHU is estimated to be $1.1 million in 2016.

While the IW will provide employment opportunities (and resulting labour incomes) for a range of job types, in most cases, these jobs will require specialized skill sets. As a result, the communities in the RSA are expected to capture a relatively small portion of the employment opportunities. The potential indirect beneficial effects of employment income on local businesses and services are discussed above under Business Development and Economic Diversification.

Education and Training

As noted, the IW will provide a range of employment opportunities. The 10-year duration of site operations activities provides incentive for local residents to commit to education or training programs to qualify for these jobs. The annual, seasonal employment opportunities for the site investigations and DVIHU are expected to be too short to encourage local residents to attend Yukon College to acquire equipment operator skill development and training, in order to take advantage of the employment opportunities.

The co-proponents and the assessment team can apply lessons learned related to local skill development and training opportunities for the IW to the full-scale FMRP, which is expected to begin in 2020.

Mitigation and Enhancements

The IW scope - site operations, site investigations, and the DVIHU and ancillary activities - is expected to have generally positive economic and employment effects over the study areas considered. The challenge for First Nations and communities of Faro, Ross River, Pelly Crossing, and Watson Lake will be to maximize the capture of as many of the IW-associated employment and economic benefits as possible. The job and expenditures types and amounts outlined previously in this section – and the corresponding incomes and expenditures – can be used as a starting point to develop a benefit-capture strategy.

YG, through its primary contractors at the FMC (CH2M HILL and TEES), is committed to contributing to maximizing local and Yukon socio-economic benefits in three participation areas; employment, contracting and subcontracting, and training and capacity building (CH2M HILL, 2013d). In 2014, this commitment will be demonstrated by activities such as visiting First Nations communities, participating in job fairs, coordinating training with Yukon College, hiring field staff for FMC Field Office, and awarding field support services to local vendors (CH2M HILL, 2013d).

Continued engagement will allow First Nations and communities to develop a more detailed understanding of the potential for capturing employment opportunities and associated incomes locally.

Significance of Effects

Overall, IW effects on the economic and employment VCs are generally positive and low magnitude. Significant adverse effects on economic and employment values are not predicted. Section 7.3.6.11provides further detail on the determination of significance.

7.3.6.6 Community Stability and Well-being Effects Assessment

Community stability and well-being was identified as a VC because an influx of temporary workforce as a result of IW may influence community makeup, including demographics and mobility. This effects assessment considered the effects of migration (in and out), changes to social and cultural makeup of communities, and influences on individual, family, and community health.

Indicators

The assessment uses indicators to measure expected changes in the VCs due to the IW. The assessment team has identified the following three indicators for changes in the community stability and well-being VC:

- **Community Demographics:** A change in the population of a community or in the distribution of genders, ages or ethnicity (e.g., aboriginal vs. non-aboriginal) of the residents in a community

- **Social Cohesion:** Changes to the length of time residents stay in a community (mobility status) and to family stability like marital status and family structure
- **Cultural Well-being:** A change in local crime rate or the AANDC community well-being index

Study Area

The assessment team collected and synthesized baseline socio-economic information from available secondary data sources related to the community stability and well-being VC across local and regional study areas.

Initially, the assessment considered potential IW effects on community stability and well-being for all study areas. As the IW will not affect every community in the same way, the assessment focused on those communities where potential pathways for IW effects were identified.

The IW proposes to accommodate non-local staff in the Town of Faro, with seasonal overflow in a temporary camp on the FMC. As a result, the assessment team identified a pathway for these workers to interact with communities in the LSA. Non-local IW workforce is not anticipated to reside in Watson Lake and a pathway to effects on the community stability and well-being of Watson Lake was not identified. In Pelly Crossing, community stability and well-being is considered as it relates to downstream and down-wind effects of contaminants on the local environment. The FMC does not contain a community, or any full-time residents, so the assessment of potential effects on community stability and well-being was not conducted for the site study area. Table 7-33 summarizes which communities were assessed for effects on community stability and well-being.

TABLE 7-33
Study Areas for Socio-economic Effects Assessment – Community Stability and Well-being
Faro Mine Interim Works

Value	FMC	Faro	Ross River	Pelly Crossing	Watson Lake
Community stability and well-being		✓	✓	✓	

Pathways of Effects

For each community stability and well-being indicator identified, there will be a variety of potential interactions with the proposed activities. Table 7-34 summarizes these potential interactions.

TABLE 7-34
Pathways of Effects for Community Stability and Well-being
Faro Mine Interim Works

Project Component	Project Activity and Potential Interaction
Site Operations	Site operations workforce management; employment; contracts and taxes – influx of workers into Faro and Ross River
	Storage of tailings in the RCTA; the perception of health effects from contaminants in dust and water
Site Investigations	Site investigations workforce management; employment; contracts and taxes – influx of workers into Faro and Ross River
DVIHU	Construction workforce management; employment; contracts and taxes - influx of workers into Faro and Ross River
	Excavation of Intermediate Dam spillway; upgrades to dam will increase security and safety of watershed

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Analysis of Potential Effects

Site Operations

Site operations primarily consist of site care and maintenance activities that are already underway at the FMC. Interactions between these operations and the VC could include an influx of employees in the Town Faro (estimated to peak at 52 during July). The same interaction is possible to a lesser extent in Ross River. The relatively small number of any incremental Full-time Equivalent positions required to maintain, monitor, and repair the FMC are not expected to result in new IW staff or their families relocating to the Town of Faro or Ross River.

Site operations activities also include storing tailings in the RCTA. Hunters and harvesters active around the FMC have expressed concern regarding the dispersion of dust from this facility on local plants and on whether there would be a human health risk to eating plant matter affected by this dust or wildlife affected through bioaccumulation. The FMC operator adheres to a Dust Management Plan to address these issues; however, the perception of risks to human health can affect community well-being, such as a resulting fear of eating country foods (i.e., local berries and moose). Refer to Section 7.3.7 for a detailed discussion about risks to human health.

Site Investigations

The workforce for most site investigations will likely consist of non-local technical experts and local support. The co-proponents emphasize the importance of using the local workforce for this onsite work. Technical positions that cannot be filled locally because of a lack of specific skills will be filled by workers from outside the RSA.

The non-local workforce for the site investigations will likely be housed in a mix of hotel/B&B accommodation and leased or rental housing in Faro. Consultation with Faro is occurring to assess the availability of possible rental units and other housing accommodation solutions to the anticipated accommodation needs. Should additional capacity be required, a temporary camp may be constructed in the old Pelly Camp area, located off the Grum Access Road. It is unlikely that workers will permanently relocate to Faro or Ross River as a result of site investigations labour opportunities.

Down Valley Interim Hydraulic Upgrades

The RCTA includes dams and diversions constructed to retain tailings in the Rose Creek Valley. The DVIHU activities are all intended to reduce risks associated with extreme flood events. Increasing the robustness of this infrastructure is important to downstream water and aquatic resource users. These upgrade activities will likely increase the confidence of local and downstream water users that the site operators have decreased the risk of infrastructure failing during extreme events which could transport contaminants downstream.

The non-local construction workforce required for the DVIHU is anticipated to live in Faro during the 2016 construction season. The interactions between this workforce and the community could result in effects on community stability and well-being. The IW proposal for accommodating seasonal workforce in Faro and potentially in a temporary camp is presented above under Site Investigations.

Ancillary Activities

The assessment team did not identify any pathways for the ancillary activities described in the IW to the community stability and well-being characteristics of the communities in the RSA (Table 7-2). As a result this aspect of the assessment was discontinued.

Predicted Change from Baseline

Community Demographics

As Section 7.3.6.5 noted, the average monthly employment is expected to range from 36 to 52 employees for site operations from April until October 2014, with similar levels maintained for the remainder of the IW. Labour needs supporting the site operations represent the most important longer-term employment opportunities that could draw workers and their families to relocate to the LSA. However, staff are already in place conducting care and maintenance activities for the FMC. These positions are not expected to change substantially during site

operations. As a result, only minor, if any, increases in staff numbers are anticipated due to site operations and little or no corresponding changes are expected in community demographics.

It is expected that the number of employees for site investigations will range between 13 and 41 during the summer of 2014. Average monthly employment is expected to range between 6 and 26 employees for the DVIHU, from April to September 2016. One year of seasonal employment is not expected to encourage workers to relocate to communities in the LSA or RSA.

Given the predicted numbers of Full-time Equivalents for site operations, site investigations, and the DVIHU, the IW will likely not result in an influx of permanent residents into Faro or Ross River. Therefore, no changes are expected to the baseline demographics of residents in these communities.

Social Cohesion

The IW is not expected to result in a meaningful increase in the number of permanent or temporary residents into Faro or Ross River. Faro has experienced significant changes in population from over 2000 residents in the early 1980s to less than 400 currently. Population changes have been related to the level of mining activity at the FMC (Town of Faro, 2014). The IW are not predicted to change the baseline conditions in social cohesion.

Cultural Well-being

The IW will result in an influx of non-local workers using temporary accommodation in Faro. These workers will be housed in available accommodation, including the Studio Hotel and at least three B&Bs (Bears Den B&B, Far-O-Way Guest House, and the Valley B&B) and leased or rental housing (Section 5). Labour needs for site operations are expected to result in little or no increase in resident population. Labour for the site investigations and DVIHU will be seasonal and occur over a short duration in 2014 and 2016 respectively.

IW labour residing temporarily in Faro is not expected to result in an increase in crime rate over the LSA or a decrease in community well-being index. Worker behaviours that could potentially adversely affect community well-being will be managed through workforce guidelines.

As progress on the FMC remediation plans is demonstrated to the Town of Faro, Ross River, and Pelly Crossing communities, community wellness may be positively affected, relieving the longstanding burden of a large-scale, nearby contaminated site. Pelly Crossing is expected to perceive the DVIHU activities as important, because the upgrades will decrease the environmental risks associated with infrastructure failing during extreme events.

Mitigation Measures

The following list summarizes mitigation for addressing potential adverse effects on community well-being and stability.

- Dust Management Plan – A Dust Management Plan is currently in place for ongoing site activities. It is important for this plan to continue, to address community concerns over airborne contaminants. This will continue to promote positive effects on community well-being.
- Workforce Guidelines –The number of employees and the duration of their stay in the Town of Faro increases the potential for a community member to have a negative experience with a project employee. The co-proponents have appropriate expectations of employees for their behaviour (set forth in guidelines such as an employee code of conduct) at the FMC and in the Town of Faro. These expectations should continue to be upheld.
- Communications on Accommodation – The co-proponents have committed to engage the Town of Faro to develop options for workforce accommodation that meet the needs of the community and the IW.
- Temporary Camp –Additional labour is required for the 2014 site investigations and 2016 DVIHU programs. These staff may be accommodated in a temporary camp established at the FMC.

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Significance of Effects

Faro, in particular, has experienced dramatic historic variability in resident populations and is expected to have some level of resilience to these changes. Overall, no significant effects are anticipated on community stability and well-being VC. The IW is expected to result in a decreased risk of downstream and downwind effects on the environment and a slight beneficial effect to the community stability and well-being VC. Section 7.3.6.10 provides more details about the significance of effects.

7.3.6.7 Infrastructure and Services Effects Assessment

The influx of the workforce associated with some components of the IW may strain infrastructure (e.g., sewage, water supply, and electricity) and services (e.g., health, education, social services, and emergency services) in the LSA. Increased traffic from IW-related construction and maintenance activities may affect local road safety and cause wear to road infrastructure. The effects assessment identified interactions between proposed project activities and community infrastructure and services in the LSA. It also identified potential effects on community infrastructure and services, and possible mitigation measures.

Indicators

The following infrastructure and services indicators were assessed for the IW:

- **Roads and Traffic -** Highway usage and maintenance (frequency and need)
- **Housing -** Local and regional housing price and availability
- **Health Services -** Local and regional health services and capacity
- **Emergency Services -** Local and regional emergency services and capacity
- **Community Infrastructure -** Community sewage, electricity capacity and maintenance, recreation services, child care, and support services

Study Area

The assessment team collected and synthesized baseline socio-economic information from available secondary data sources related to the infrastructure and services VC across local and regional study areas.

Initially, the assessment considered potential IW effects on infrastructure and services for all study areas. As the IW will not affect every community in the same way, the assessment focused on those communities where potential pathways for IW effects were identified.

The IW proposes to use infrastructure and services from the LSA (e.g., housing, nursing station, and airport in the Town of Faro). Pathways were not identified for the IW to interact with infrastructure and services of Watson Lake and Pelly Crossing so that portion of the assessment was discontinued. Public infrastructure and services on the FMC are limited to an access road between Faro and the FMC. Effects related to access management are considered in Section 7.3.6.8, so the assessment of potential effects on infrastructure and services was discontinued for the site study area. These conclusions are presented in Table 7-35.

TABLE 7-35
Study Areas for Socio-economic Effects Assessment – Infrastructure and Services
Faro Mine Interim Works

Value	FMC	Faro	Ross River	Pelly Crossing	Watson Lake
Infrastructure and services		✓	✓		

Pathways of Effects

Each identified infrastructure and services indicator could interact with proposed IW in a variety of ways. Table 7-36 summarizes the anticipated interactions and pathways of effects.

TABLE 7-36
Pathways of Effects for Infrastructure and Services
Faro Mine Interim Works

Project Component	Project Activity and Potential Interaction
Ancillary Activities	Waste management (disposal to landfills): The site may use Town of Faro facilities for disposal of domestic waste.
Ancillary Activities	Housing in Faro: the seasonal non-local workforce will likely be housed in a mix of hotel/B&B accommodation and leased or rental housing in Faro. A temporary camp on the FMC might be established.
Ancillary Activities	Sewage treatment and discharge: IW staff will require suitable wastewater treatment and discharge capacity associated with their accommodations in Faro.

Analysis of Potential Effects

Site Operations

Site operations include activities that are currently being undertaken as care and maintenance over the FMC. Site operations are anticipated to result in little or no increase in the number of employees residing in Faro. It is anticipated that there will be little change in baseline infrastructure and services demand due to the IW workforce, but existing demands from the workforce will continue for the duration of the IW.

Highway usage as a result of the site operations is also not expected to change from baseline conditions.

Site Investigations

Proposed site investigations during the IW will cost $8.5 million in labour in 2014, the majority of which will occur from April to September that year. Site investigations are anticipated to continue for the remainder of the project requiring less than $2 million dollars annually. Employees will be housed in temporary accommodation in the Town of Faro, unless peak demands in 2014 require the establishment of a temporary camp on the FMC.

Additional workforce will require local accommodation, potable water, wastewater disposal, and solid waste disposal, which could affect local infrastructure and services.

Down Valley Interim Hydraulic Upgrades

The proposed DVIHU are intended to reduce risks associated with extreme flood events. The DVIHU activities will result in between 6 and 26 additional employees onsite per month during the summer of 2016. The DVIHU workforce will be housed in temporary accommodation in Faro, unless peak demands in 2016 require the establishment of a temporary camp on the FMC.

The frequency of over-sized vehicle traffic is expected to increase slightly in the LSA during equipment mobilization and de-mobilization in support of the DVIHU construction.

Ancillary Activities

The following ancillary activities have been identified as part of the IW:

- Establishing a temporary 20-person camp at the FMC to house site investigation and construction crews
- Hauling and storing fuel
- Managing waste

A temporary 20-person camp will require potable water, wastewater disposal, and solid waste disposal, which could affect local infrastructure and services.

The equipment proposed to construct the DVIHU will require additional diesel fuel. The transport of this fuel is anticipated to increase the frequency of fuel trucks on LSA roads during the summer of 2016.

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Predicted Change from Baseline

Roads and Traffic

Traffic related to IW site operations is expected to be similar to that generated by ongoing FMC care and maintenance activities. Site access for staff, equipment, and materials will continue over an aging road network, originally designed and built to support a much higher load (both vehicle weight and frequency) of heavy truck traffic from the FMC. As a result, traffic baseline conditions are not expected to change dramatically because of site operations.

The DVIHU construction in 2016 is expected to temporarily increase the frequency of over-sized vehicle traffic during equipment mobilization and de-mobilization. This effect is expected to occur on roads over the LSA, including the Robert Campbell Highway. If the DVIHU equipment moves to the site at a similar time, the disturbance to other road users could be higher, but for a shorter duration. If the equipment mobilizes over a broader timeframe, the additional traffic is less likely to be significantly different from baseline conditions. Heavier vehicles have the potential to increase the rate of road damage.

The site investigations and DVIHU are expected to require additional staff onsite during the summer months of 2016. It is expected that most employees will be housed onsite in a 20-person camp. Onsite lodging will greatly decrease vehicle travel that would otherwise be required to move these staff from accommodations (most likely in the Town of Faro) to the FMC. A limited to low increase in traffic is anticipated in the Town of Faro, and no increase in traffic is expected in Ross River.

Housing

The site investigations and DVIHU require accommodation for additional staff in the summers of 2014 and 2016 respectively. These seasonal staff will be housed in temporary accommodation in the Town of Faro.

During the IW, there are several periods when staffing levels may exceed the supply of rooms available in the Town of Faro. In addition, it is understood that there are competing demands for the available accommodations. Visitors and service providers who travel to the community, such as health care providers or non-FMC related construction workers (e.g., highways crews or forest fire crews), also require lodging. This competition for accommodation is highlighted by the same seasonal use requirements by the IW workforce as the seasonal use for tourism and non-FMC construction work. Therefore, the seasonal non-local workforce will likely be housed in a mix of hotel/B&B accommodation and leased or rental housing in the Town of Faro. Consultation with the Town of Faro is occurring to assess the availability of possible rental units and other housing accommodation solutions to the anticipated accommodation needs.

A temporary camp may be required in order to provide facilities for accommodation of workers for various components of the IW including construction activities and field investigation programs. If required, the proposed location for this temporary camp is the old Pelly Camp area, located off the Grum Access Road. Potable water supply for this temporary camp would be provided by a well located adjacent to the Grum Office Building.

These staff will only be active onsite seasonally, and are not expected to purchase houses. Little or no increase in demand on Town of Faro or Ross River housing is anticipated as a result of the proposed project.

Health Services and Emergency Services

Site operations are similar to ongoing care and maintenance activities and are not expected to increase the demand on health or emergency services in the Town of Faro. During DVIHU construction, increased personnel and use of heavy equipment could increase risks onsite. However, accident/emergency response is expected to effectively respond to an unlikely accident during construction activities by following these steps, as necessary: (1) accessing onsite First Aid, (2) escalating the response to the Faro Nursing Station, and (3) travelling via air medivac from Faro airport to Whitehorse or a southern hospital. During the IW, and in the event of an emergency, resources in Ross River are not anticipated to be accessed, so the IW are not expected to affect health and emergency services in Ross River.

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Community Infrastructure

IW site operations staff numbers are expected to be similar to those conducting existing care and maintenance activities. Little or no change is expected in their use of community infrastructure in Faro or Ross River. Much of the community infrastructure in Faro is designed and built to support a residential population hundreds above the current 345 (YG, 2013). The population of the Town of Faro peaked in 1981 at just under 2,000 residents (Town of Faro, 2014).

The workforce to support the site investigations and DVIHU activities will temporarily be housed in Faro. If the entire workforce for both activities is housed in Faro, they would place an additional maximum 68-person demand on infrastructure designed and built for hundreds of more residents. For example, wastewater is treated in Faro through a multi-celled lagoon. This lagoon is operating well below capacity servicing the less than 400 residents in the town. If the lagoon reached capacity it would discharge to the Pelly River. The lagoon has not discharged since 1994 (YG, 2009). The total IW personnel would produce wastewater volumes well within the documented operating capacity of the Town of Faro wastewater infrastructure.

Should the temporary season accommodation needs of the site investigations in 2014 and the DVIHU in 2016 exceed the temporary housing capacity of the Town Faro, the IW proposes to establish a temporary camp on the FMC. Establishing and servicing this camp is expected to require onsite and Town of Faro infrastructure. The FMC has a septic tank and there is an existing septic system in place at the old Pelly Camp that has sufficient capacity to handle potential sewage flows generated by the temporary camp.

Potable water supply for this temporary camp would be provided by a well located adjacent to the Grum Office Building and would not affect Faro potable water supply infrastructure. Potable water would be required for the camp and to conduct the IW.

Non-organic solid waste from the proposed activities will be landfilled onsite and organic waste will be deposited in the Faro Solid Waste Facility. The landfill life was estimated in 2009 at 13+ years (YG, 2009). The limited amount of solid waste produced at the camp during the summer season and by the limited number of personnel (20 IW personnel versus 450 landfill users in 2009) would have a low or negligible effect on the Faro Solid Waste Facility.

Mitigation Measures

A temporary onsite camp for site investigations (in 2014) and for DVIHU (in 2016) personnel will mitigate the potential project effects on infrastructure and services. The proponent will follow a Traffic Management Plan and a Spill Contingency Plan as further mitigation measures.

Significance of Effects

The potential effects on infrastructure and services are related to short-term increases in personnel to complete the site investigations and DVIHU. The construction and use of an onsite camp decreases the magnitude of effects, which are already low in both magnitude and duration. Extending services to provide for the anticipated number of IW staff is well-within Faro's current infrastructure capacity. No significant adverse residual effects are expected on infrastructure and services. Section 7.3.6.10 provides further details about the significance of effects.

7.3.6.8 Land Use and Access Effects Assessment

The FMC covers a large area (25 square km^2 or 2,500 hectares) and includes a total of 70 million tonnes of tailings and approximately 376 million tonnes of waste rock (YG, 2011). Current land use activities on the site are primarily related to the ongoing maintenance and operations of existing facilities to manage and monitor the tailings and waste rock. However, other land use activities take place either on, or adjacent to, the FMC; these may be affected by the activities outlined in the IWPP. This section describes these activities as well as their interaction with the proposed activities, and assesses their potential effects on land use and access values.

Indicators

Key characteristics, or indicators, of changes to land use and access would be changes to the frequency of land users passing through the FMC, perceived changes to accessibility of parts of the FMC, or perceived changes to access through the FMC to other destinations. Site access is not anticipated to change. An Access Management Plan has been developed for the site and will be implemented as part of the IW.

The following key land use indicators were assessed for the IW:

- **Traditional Land Use –** This characteristic includes traditional land use activities currently conducted by First Nations people in the region. Specifically, it refers to the use of existing cabins, harvest areas (including berry picking), and medicinal/spiritual areas.
- **Hunting and Fishing –** This characteristic describes harvest location and numbers of key fish and wildlife species, broken down by harvesters (First Nation, resident, and non-resident hunters).
- **Recreation –** This characteristic identifies popular recreation areas and activities located within the FMC.
- **Tourism –** This characteristic includes a profile of local tourism operators or activities promoted within the region around the FMC.
- **Forestry –** This characteristic includes the current location and description of forestry activities in the FMC.

Study Area

The assessment team collected and synthesized baseline socio-economic information from available secondary data sources related to the land use and access VC across local and regional study areas.

Initially, the assessment considered potential IW effects on land use and access for all study areas. As the IW will not affect every area in the same way, the assessment focused on those study areas where potential pathways for IW effects were identified.

Land use and access is a value directly related to the footprint of the FMC. IW activities could interact with land use and access within the footprint, or in the immediate vicinity, of the FMC. Individuals from the Town of Faro and Ross River, closer communities with direct all-weather road links, are more likely to access and use the FMC. Nonetheless, the assessment team recognized that individuals from Watson Lake and Pelly Crossing could potentially access and use the areas over and around the FMC. As a result, all the communities in the RSA were carried through into the assessment. These conclusions are presented in Table 7-37.

TABLE 7-37
Study Areas for Socio-economic Effects Assessment – Land Use and Access
Faro Mine Interim Works

Value	FMC	Faro	Ross River	Pelly Crossing	Watson Lake
Land use and access	✓	✓	✓	✓	✓

Pathways of Effects

For each identified land use characteristic, a variety of potential interactions are anticipated with the proposed IW. Table 7-38 summarizes the anticipated interactions between these characteristics and the IW. Individuals from Faro and the RRDC are known to use parts of the FMC. Effects associated with the IW on health and food security are related to land use activities and are described in Section 7.3.7, Human Health and Safety Effects Assessment.

TABLE 7-38
Pathways of Effects for Traditional land Use and Access
Faro Mine Interim Works

Project Component	Project Activity and Potential Interaction
Site Investigations	Access Route Development: Short trails to re-position machinery will be required to access new borehole locations.
Site Investigations	Surface Geophysics: Trails (<1.5 m wide) up to an estimated total of 5 km of clearing will be created throughout the FMC.
Ancillary Activities	Site Access Control: A new reserve designation has been established for the FMC that will allow for more effective site access control, including enforcement for infractions. The Access Management Plan developed as part of the IW does not change the overall approach to site access management.

Analysis of Potential Effects

Site Operations

Site operations include FMC care and maintenance activities that are currently ongoing and considered baseline conditions. Land use activities are anticipated to continue to have minimal interaction. Dust control activities at the RCTA are expected to continue, and to mitigate community concerns related to food security for local harvesters (refer to Section 7.3.7 on human health and safety for more details). At present, site operations are likely not a major factor affecting specific land use activities.

Site Investigations

Site investigations include ongoing monitoring activities and remediation research. Some land use activities may be affected by cutting lines or clearing drilling areas. These activities may increase accessibility to parts of the FMC, depending on the location and type of clearing. However, it is anticipated that clearing for site investigations would generally not be suitable for non-IW related off-road traffic.

Down Valley Interim Hydraulic Upgrades

The DVIHU includes temporary construction activities associated with a secondary spillway and upgrades to the RCD. Given the location and timing of this construction, land users (mostly moose hunters) might have temporary difficulty accessing areas of Rose Creek, downstream from the FMC. The DVIHU is designed to decrease risk of infrastructure failure and so increase the sense of security for downstream and downwind fish and wildlife users.

Ancillary Activities

Ancillary activities are those related to more than one IW activity. Enforcing an Access Management Plan is the primary ancillary activity that could lead to socio-economic effects on the land use and access VC. The rules and conditions of access are not anticipated to change; however, more active enforcement could lead to the perception that they have.

Predicted Change from Baseline

Traditional Use

Construction and site investigation activities related to the IW may temporarily affect access to, and use of, traditionally used sites on the FMC. This includes access to a known cabin location and its associated infrastructure (Ecofor, 2013a). However, the use of these areas is not predicted to change from the baseline.

People, mostly hunters, use clearings and trails over the FMC to access the hinterland/wilderness area outside the FMC's footprint. Off-road vehicle drivers are the most frequent users of these trails and cleared areas. IW site investigations will require new trails to be cleared, to support a variety of drilling and sampling activities. The new trails could be used as additional access routes across the FMC. However, these trails will be relatively short, and most will end at drill sites or sampling locations. Generally, it is expected that the new trails will be less desirable for third-party users, and will deter off-road vehicle passage. These access trails are not expected to be used regularly, or to become permanent off-road vehicle trails.

The IW is not expected to in long-term or permanent changes to people's ability to visit or use sites within or around the FMC. The IW includes the implementation of an Access Management Plan for the FMC. This document intends to clarify understandings and perceptions about FMC access.

Harvest

The IW are expected to cause small-magnitude and temporary changes to the accessibility of localized hunting opportunities.

The DVIHU includes temporary construction activities that could interact with land users (mostly moose hunters) accessing areas around Rose Creek, downstream from the FMC. Though licensed moose harvesting can begin on August 1 in permitted Game Management Zones, most hunting activities take place after male moose enter the rut, generally after September 15 (YG, 2013). By September, construction-related traffic control will decrease, and

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short-term access constraints are expected to be minimal. The IW are anticipated to have temporary, small-magnitude, and completely reversible effects on land use.

Local outfitters and trappers will continue to be able to access their concessions via the FMC.

Recreation

Frequency and location of recreational land use is not predicted to change from baseline conditions. People's ability to access recreation areas via the FMC will be maintained, and the proposed IW are not anticipated to affect adjacent recreation sites.

Tourism

Tourism is not predicted to change from baseline conditions. As with other land uses, access through the FMC will not change. The proposed IW are not anticipated to affect local or regional tourism activities.

Forestry

Forestry in the FMC is not predicted to change from baseline conditions. A new reserve status identified new land management authorities, who may need to review access to timber harvest areas within the reserve; however, this is not anticipated to be a major issue.

Mitigation Measures

The co-proponents will follow the Access Management Plan in order to consistently manage access across the FMC during the IW. RRDC will be contacted regarding potential overlap of IW activities and use of the known cabin and associated infrastructure.

Significance of Effects

The IW is not anticipated to directly adversely affect land use and access values. Potential effects on land use and access are related to access management activities at the FMC. This IWPP identifies an Access Management Plan, which will not change the way access is managed at the FMC. Enforcement activities may, however, be more active. Section 7.3.6.10 contains additional details about determining the significance of effects.

7.3.6.9 Culture and Heritage Effects Assessment

This section describes the results of the analysis of the IW's potential effects on culture and heritage values. The FMC is located within the traditional territories of the RRDC and the LFN. Land use activities related to cultural and heritage values have been documented in the pre-mining FMC area (Ecofor, 2013a).

Appendix 6K summarized the project area's cultural history. The FMC is located within the traditional territory of the RRDC and the LFN; both First Nations are part of the KDC and do not have settled land claims. Baseline conditions included routes through the FMC that were used to access harvesting locations, and limited third-party land use within the FMC footprint (please refer to Section 6.3.4, Land Use and Access) (Ecofor, 2013a). There is no year-round accommodation or settlement within the FMC footprint, and the closest communities are the Town of Faro (primarily non-First Nations residents) and Ross River (primarily Ross River Dena). Pelly Crossing, the home of SFN, is downstream from the FMC, along the Pelly River. Watson Lake, the home of LFN, is about 425 km southeast of the FMC along the Robert Campbell Highway.

Heritage Values

The Umbrella Final Agreement (Government of Canada, 1993) defines Heritage Resources as including Moveable Heritage Resources and Heritage Sites:

> *"Heritage Site means an area of land which contains Moveable Heritage Resources, or which is of value for aesthetic or cultural reasons…Moveable Heritage Resources means moveable non-documentary works or assemblies of works of people or of nature that are of scientific or cultural value for their archaeological, palaeontological, ethnological, prehistoric, historic or aesthetic features, including moveable structures and objects."*
>
> Government of Canada, 1993

Within the footprint of the FMC, historical mining activities have already substantially altered or destroyed heritage resources. Until 2013, there were no recorded heritage sites within or near the IW assessment areas, and no others recorded in the larger vicinity, primarily because little work had taken place to evaluate heritage values (Ecofor, 2013a). Fieldwork was undertaken to support a Heritage Resource Impact Assessment for the IW; this work identified sites containing lithic fragments and a known cabin location (and associated infrastructure) (Ecofor, 2013a). The fieldwork focused on areas that may be disturbed when developing sources of borrow materials for the IW. The sites located in the 2013 investigations may contain as-yet unidentified heritage resources.

Historical mining activities extremely modified much of the FMC. As a result, much of the area now represents limited cultural value. Heritage resources that would have been present in the mining-impacted areas would have been altered or destroyed. However, some activities outlined in this IWPP will take place in relatively undisturbed areas within the FMC, and could affect culture and heritage values.

Indicators

Indicators for cultural values include traditional First Nations' culture, such as language and traditions. The loss of First Nations' languages or culture would be considered an adverse effect of the IW.

Indicators for heritage values include heritage resources. The *Historic Resources Act* (YG, 2002) and Chapter 13 of the Umbrella Final Agreement (Government of Canada, 1993) aim to protect and preserve/conserve heritage resources. The IW could impact heritage resources by disturbing or destroying them, which would be considered an adverse effect.

Study Area

The assessment team collected and synthesized baseline socio-economic information from available secondary data sources related to the culture and heritage VC across local and regional study areas.

Heritage values are closely related to specific locations and landscapes so the assessment team concluded that the site study area was the most important study area for the assessment of potential IW effects on heritage resources.

The assessment team considered the secondary information sources available (e.g., Weinstein, 1992; Ecofor, 2013a) to link cultural values to the FMC and create pathways between the IW and First Nation/community-based study areas. Pathways were identified for Faro and Ross River, the communities in the LSA. Pathways were not clearly identified for Pelly Crossing and Watson Lake. The assessment team were confident that analyses for the LSA would be at least partly relevant for the RSA. As a result, the assessment of cultural effects on Pelly Crossing and Watson Lake was discontinued. Conclusions are presented in Table 7-39.

TABLE 7-39
Study Areas for Socio-economic Effects Assessment – Culture and Heritage
Faro Mine Interim Works

Value	FMC	Faro	Ross River	Pelly Crossing	Watson Lake
Cultural and heritage values	✓	✓	✓		

Pathways of Effects

Table 7-39 summarizes several pathways through which the IW could affect cultural and heritage values. The pathways for these interactions are associated with accessing area for site investigations and then conducting those site investigations (e.g., surface geophysical investigations) and the perceived change in how access to the FMC will be controlled and enforced.

The proposed site investigations include surface geophysics and other information gathering (e.g., sampling). To facilitate these activities, some access trails will be cleared to install drilling and testing equipment. Narrower trails will also be cleared to lay geophysical cable. Areas for drill pads, operating equipment, and test pitting/re-

filling will be cleared. Clearing trails and areas could potentially disturb, destroy, or alter heritage resources within the clearing footprint.

Cultural values in an area can be related to how the area is used. Clearing the new access trails to facilitate the IW could increase access to areas within the FMC footprint. Implementing an Access Management Plan could lead to the perception that the rules for accessing the FMC have changed. Table 7-40 identifies these pathways between the IW and the culture and heritage VC. Section 7.3.6.7 discusses IW effects related to changes in land use and access.

TABLE 7-40
Pathways of Effects for Culture and Heritage
Faro Mine Interim Works

Project Component	Project Activity and Potential Interaction
Site Investigations	Access Route Development: The development of new access routes could disturb heritage sites.
Site Investigations	Surface geophysics**:** Clearing required for the surface geophysics work could disturb heritage sites.

Analysis of Potential Effects

Post-mining baseline conditions at the FMC include open pits, more than 300 million tonnes of waste rock, roads, tailings, and water conveyance infrastructure. These post-mining landscape features are dramatically different from the pre-mining landscape, and have altered the local aesthetics. The changed landscape and mining infrastructure is not suitable for traditional, pre-mining activities (Weinstein, 1992).

The lack of a year-round settlement and limited third-party land use within the FMC footprint (Ecofor, 2013a) suggests a baseline condition of extremely limited First Nations language on the FMC (both frequency and amount). As a result, the IW are anticipated to have a very low or negligible effect on First Nations language.

Where trails and areas must be cleared to support the site investigations, the IW could disturb, alter, or destroy heritage resources within the footprint of that clearing. To decrease the amount of new clearing, where possible, site investigation areas will be accessed via previously disturbed ground. The new access trails will branch off existing access trails and will be less than 1.5 m wide, where possible. Clearing will also be confined within the FMC footprint, where possible. During clearing, vegetation will be removed to permit personnel and equipment passage. Depending on conditions and passage requirements, the vegetation may not be cleared down to ground level (e.g., surface geophysics). Where there is minimal soil disturbance, activities will be less likely to disturb or destroy unidentified heritage resources. If site workers encounter a potential movable heritage resource while clearing, the Heritage Resources Management Plan (HRMP) for the FMC (Appendix 5H) will be activated to protect that potential resource from damage by the IW.

Mitigation

The most important tool for mitigating potential effects related to minor interactions between the IW and culture and heritage values is an HRMP (Appendix 5H). The HRMP is designed “to ensure the immediate and ongoing protection and management of heritage resources within their existing developments and planned work at Faro” (Ecofor, 2013b). The HRMP will do the following:

- Provide adaptive management actions and communication protocols to assist project staff, their contractors, and subcontractors in managing known, and as-yet unidentified, heritage resources within the FMC.
- Flag known heritage sites, educate onsite workers, and provide instructions if new potential resources are encountered. Where ground disturbance activities are scheduled but a Heritage Resource Impact Assessment did not take place, heritage staff must review the HRMP before activities begin.
- Set out a process to communicate and record new potential resources. The HRMP requires AAM, their contractors, and their subcontractors to inform the Heritage Resources Unit and relevant First Nations of

identified heritage resources, as well as of planned and accidental impacts to heritage resources. If a plan is in place to affect sites, individual heritage site mitigation plans will be developed and implemented.

By implementing the HRMP, the IW should not result in unmanaged effects on heritage resources and is not expected to have significant residual effects on cultural and heritage values. Regardless, the HRMP describes an adaptive management approach, in case heritage resources are identified during IW.

Significance of Effects

Clearing of access trails and areas for IW may adversely affect heritage resources. By locating these trails near existing disturbance, limiting trail length and width (footprint), and minimizing soil disturbance during clearing, it is unlikely that these activities will affect heritage resources significantly. Where potential sites are discovered during field work, the HRMP protocols will be triggered and guide efforts to preserve the uncovered resource.

The HRMP further decreases the likelihood of as-yet unidentified heritage resources being disturbed, altered, or destroyed. The geographic extent of these potential effects is low, as it is limited to the footprint of previously undisturbed areas in the FMC that must be cleared for the IW. The destruction of a movable heritage resource is considered irreversible and is important to both First Nations' and territorial governments. Overall, considering the provisions set forth by the HRMP and the low likelihood of interaction, the IW are unlikely to significantly adversely affect cultural and heritage values. Section 7.3.6.10 provides further detail on the significance of effects.

7.3.6.10 Human Health and Safety Effects Assessment

Table 7-4 does not identify any major interactions for the Human Health and Safety VC, in part because the IW focuses on minimizing contaminant release from the site. However, communities and local people frequently express concern about potential human health effects associated with contaminants from the FMC. In order to address this concern, this section describes a qualitative assessment of potential human health effects associated with proposed IW. It builds on the reported potential effects of the IW on air quality, water quality, fish, and wildlife.

Human health risks onsite because of the presence of chemicals in environmental media at the FMC are considered to be low or insignificant during the IW, understanding that occupational health and safety best practices are in place. Potential health risks to offsite individuals and communities are considered low or insignificant as a result of IW activities since the IW are understood to result in minimal effects on the presence of chemicals in the environment offsite.

Human Health Risk Effects Assessment

The potential for human health risks can be assessed by considering how the following three components interact:

- **Chemicals** present in the environment (e.g., soil, water, or air) at concentrations that may cause a health effect
- **Receptors,** which are people such as construction or remediation workers, nearby residents, or populations
- **Pathways of exposure** where chemicals from the environment can find their way to a receptor and into their body.

When all three components are present, risks are possible, and the potential risk can be evaluated. If one component is missing, there is no risk.

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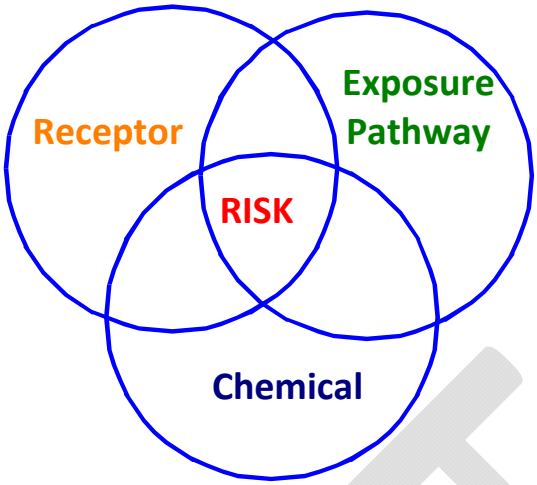

Where a potential risk is identified, the risk can be managed by affecting a change to any one of the three risk components.

In this assessment, potential effects identified on air quality, water quality, or wildlife from the IW activities will be examined qualitatively to determine the potential risk to likely human receptor groups. If there is a potential for significant risk, suggestions for risk management are provided.

Receptor Assumptions

Two groups of receptors have been identified for this assessment:

- Onsite workers at the FMC: For example, construction workers carrying out IW activities, maintenance and support-type workers, and other occupational workers including administrative or office workers. These types of workers are assumed to be onsite up to 50 hours per week, 50 weeks per year.
- Regional receptors: For example, members of the public working and living in nearby towns or communities or using the area for subsistence harvest or recreational purposes.

Exposure Route Assumptions

To represent a hazard, chemicals in environmental media (air, soil, dust, water, food derived from local wildlife) need to enter the body at concentrations that can cause a harmful effect. Chemicals can enter the body through any of three main routes:

- Through ingestion (eating) or for some things like dust (containing chemicals) incidental or accidental ingestion
- Through inhalation (breathing into the lungs)
- Through dermal contact and absorption of chemicals across the skin

For onsite receptors, administrative controls, engineering controls, and occupational health and safety requirements reduce or eliminate the opportunity for some of these exposure routes to be present. For example, use of dust control equipment (engineering control), eliminates inhalation of dust. Provision of hygiene facilities reduces or can eliminates potential dermal exposures.

Effects from each of the major disciplines (air quality, water quality, aquatic biota, and wildlife) are examined in the context of the potential for exposure pathways and routes of uptake to qualitatively assess the potential health risk for onsite and offsite human receptors.

Health Effects Assessment for Air Quality

The Air Quality Effects Report (Appendix 7A) identified the potential for localized air quality effects onsite only, in the immediate areas of IW activities. The assessment was considered to be conservative.

For human health considerations, inhalation of dust particulates (and possibly constituent metals in dust) is the primary pathway of exposure. In assessing predicted conditions onsite, the potential for human health effects arising from air quality effects are likely to be limited to occupational receptors in those localized areas. Through the use of dust control, engineering controls and the requirement to implement legislated occupational health and safety requirements for worker exposure, it anticipated that health effects from air quality issues will be mitigated and prevented by essentially removing the pathway of exposure.

The conservative air quality assessment predicted no effects for offsite or regional air quality. While members of the public frequently access areas near the proposed DVIHU construction works, access to that area will be managed during active construction. Therefore, no health effects are expected for offsite receptors from the inhalation pathway.

A minor, secondary pathway of exposure for human receptors is incidental ingestion of dust and dermal contact with dust deposited on surfaces. Based on Appendix 6E (Air Quality Baseline Report), dust generated is likely to settle quickly near the point of emission, limiting the contribution of metals to existing soils and surfaces. Considering that the local environment has elevated concentrations of minerals it is unlikely that dust deposition associated with the IW will have a significant effect on onsite concentrations in soil and on surfaces, and therefore unlikely to have a significant effect on human health. Furthermore, occupational health and safety requirements and the use of best practices (e.g., workers required to maintain hygiene, provided with sanitation / hand washing facilities, dust control on tailings) will reduce or eliminate this minor contribution to human receptors' exposure onsite. This secondary exposure pathway is expected to be negligible or absent for offsite human receptors.

The overall significance to human health effects arising from air quality effects associated with Faro IW is low.

Health Effects Assessment for Water Quality

For human health considerations, ingestion of surface water containing chemicals/parameters is the primary pathway of exposure. Surface water onsite that may be affected by the IW is not used for drinking water; therefore, the potential for onsite human exposure and human health effect arising from drinking surface water onsite is considered to be non-existent over the time period of the IW. Drinking water for workers and other human receptors is supplied from treated water sources. Similarly, surface water conditions onsite are not considered a potable source for nearby offsite communities. Offsite community water supplies are based groundwater wells and municipal treatment and distribution systems.

A minor pathway considered for onsite receptors is incidental or accidental direct contact exposure to surface water, where a very small amount of water is accidentally ingested (via hand-to-mouth contact) or skin contact with surface water occurs during a brief time period. Potential effects from this exposure is considered negligible because of either the very low probability of such an event or, in situations where dermal contact is more probable or expected to be frequent, onsite receptors are required to employ health and safety best practices to be protected from exposure using personal protective equipment such as gloves.

The proposed access management approach indicates that some recreational (hunting/hiking) or traditional users of the FMC area can collect water from two location that appears to be upgradient or upstream from areas that may be affected by the IW. The limited use of this water supply, if used at all, is unlikely to have a significant effect on health owing to limited and infrequent use. Best practice would be to communicate through access management that recreational or traditional users of the site should avoid the use of surface water on the site, and encourage the use of bottled water brought to site during such activities.

The overall significance to human health effects arising from water quality effects associated with Faro IW is low.

Health Effects Assessment for Fish Consumption

The Analysis of Aquatic Environment Effects (Appendix 7C) identified limited effect on water quality for the following chemicals/parameters in terms of effect on fish or fish habitat:

- Hardness (calculated using calcium and magnesium)
- Cadmium

- Cobalt
- Lead
- Manganese
- Sulphate
- Zinc

Recreational and traditional fishing uses are known to take place in the areas surrounding FMC. Fish consumption by members of the community represents a potential ingestion exposure pathway to metals in fish tissue. Thus two risk components (receptors and pathways) are likely present.

Based on Appendix 7C, metals (cadmium, cobalt, manganese, and zinc) with the greatest potential for effects in surface water, are not likely to present lasting effects, if any, to fish and other aquatic biota under the conditions of the IW in either the local or regional study areas. The assessment also indicates that locally relevant species (such as Chinook salmon and grayling) harvested during recreation or traditional fishing are not limited to the local or regional study areas. These species can travel large distances between seasonal habitats and the resulting tissue metal concentrations of fish may not relate to the water and habitat conditions where they are caught. Effects during the 10-year period of IW on fish are generally expected to be insignificant or low and limited to the local study area. Effects would be further reduced as relevant fish species are expected to have a larger habitat range diminishing the influence of local study area on fish metal tissue concentrations. Furthermore, metal uptake into various fish tissue is known to be variable with fish muscle (typically the edible portion) having the lowest uptake, and other tissues such as the gills and liver having higher uptake of metals.

Given the assessment that water quality during the IW will have a limited or low significant effect on fish, the habitat range of the fish (relevant for traditional uses) may be greater than any local affected area in the FMC, and tissue metal concentrations of the edible portions of fish are likely the lowest of impacted fish tissues, the overall significance to human health effects arising from consumption of fish impacted by Faro IW is low.

Health Effects Assessment for Game Consumption

The Wildlife and Wildlife Habitat Effects Assessment (Section 7.3.5) included consideration of birds, waterfowl, small mammals (e.g., voles), and large mammals (e.g., grizzly bear, moose, and thinhorn sheep). Of these, moose and possibly waterfowl are relevant from a traditional use, recreational hunting and harvesting, perspective. Moose and waterfowl can be exposed to metals in environmental media (e.g., soil and water) and vegetation affected by IW activities. Exposure can lead to uptake of metals into animal tissues. Subsequent consumption of game may expose people to tissue metal concentrations and potential health effects.

Based on Section 7.3.5, tissue metal concentrations in moose are unlikely to be affected by IW activities. The relatively large range of these animals minimizes the duration and frequency in the LSA where the potential for greater exposures to metals in environmental media and vegetation exists. As was the case with some of the relevant fish species, tissue concentrations in moose hunted and caught in the LSA or RSA may not reflect local conditions associated with the IW. Furthermore, best practice and management activities during IW that reduce the impact of metals on water and vegetation in the LSA will limit the potential for metal uptake by moose that make use of the site and region. Human health effects associated with the consumption of moose are expected to be insignificant as metal tissue concentrations are unlikely to be affected over the life of the IW.

Waterfowl are known to seasonally use some of the pits and ponds associated with FMC. Exposure to water and biota with metal concentrations could lead to metal uptake. Water quality management and reduction of impacts is part of the IW; it is therefore unlikely that IW activities would have a significant effect, if any, on tissue metal concentrations in waterfowl. Furthermore, Section 7.3.5 suggested additional management of the local areas that may be prone to seasonal use by waterfowl, such that these areas are less inviting or available to waterfowl. Overall, waterfowl would have less opportunity for contact with impacted environmental media and reduced contaminant exposure. Consumption of waterfowl caught in the RSA is unlikely to have significant effect on human health as a result of IW activities affecting waterfowl.

The significance of human health effects arising from consumption of game during the period of the IW is low.

Management of Worker Health and Safety

As described previously, onsite workers may have limited opportunity for exposure to dust and surface water. These pathways are mitigated through the implementation and adherence to health and safety plans, best management practices, and legislated requirements for worker hygiene. These practices protect human health.

A number of operational safety risks have been identified for the activities at the FMC during IW. Therefore, the use of legislated requirements and best practices are also key components for maintaining worker safety during the various IW activities. Worker health and safety protocols will be developed (or adopted) and implemented to support the various activities (such demolition, construction, or remediation) likely to occur during IW. Strict adherence to safety regulation, safety protocols and industry best practice (e.g., the use of task hazard analysis, implementation of programs for confined spaces, site access, site and building security, traffic control, waste management, or industrial hygiene) will be key to reducing exposures, controlling and/or eliminating worker safety risks.

Conclusion

The risk assessment paradigm (three components of risk) facilitates risk management by the identification of hazards (safety risk or chemical exposure risk) and the pathways of exposure to human receptors. Where possible, risks can be mitigated during the IW through reduction in hazards (e.g., reducing number of hazardous situations; reducing dust concentrations), and minimizing the frequency and duration of exposure (e.g., reducing consumption of water, wildlife, and fish). Continuing to monitoring air and water concentrations will support rapid response to a change in hazards.

7.3.6.11 Significance of Residual Socio-economic Effects

Table 7-41 details the rationale for the determination for the significance of the socio-economic effects, while. Table 7-42 rates the significance of residual socio-economic effects. With respect to human health and safety no major potential effects were identified.

TABLE 7-41
Characterization/Attributes of Residual Effects
Faro Mine Interim Works

Characterization/ Attribute	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The ultimate long-term trend of the socio-economic effect (positive or negative), relative to the baseline conditions.	▪ **Negative** (or Adverse) – VC would change for the worse. ▪ **Positive** (or Beneficial) – Change in VC would be an improvement. ▪ **Neutral** – No change in VC.
Socio-economic Context	Experience with previous projects, or socio-economic resiliency and ability to cope/adapt.	▪ **Low** – Community(s) has little or no experience with development, or is less resilient and has little capacity to adapt to change. ▪ **Moderate** – Community(s) has some experience with development, or is somewhat resilient and has some capacity to adapt to change ▪ **High**– Community(s) has considerable experience with development, or is resilient and able to adapt to change
Magnitude/Duration	The amount of change, relative to baseline conditions. The period of time required until the VC or indicator returns to its baseline condition, or until the effect can no longer be measured or otherwise perceived.	▪ **Low** – Effect occurs but may or may not be detectable; effect limited to <1 year ▪ **Moderate** – Effect occurs and is detectable; effect occurs >1 year and <10 years ▪ **High** – Effect represents a substantial change from baseline conditions; effect extends 10 to 25 years
Geographical Extent	The geographic area within which a socio-economic effect occurs.	▪ **LSA**– FMC, Town of Faro, Ross River ▪ **RSA** – FMC, Town of Faro, Ross River, Pelly Crossing, Watson Lake

TABLE 7-41
Characterization/Attributes of Residual Effects
Faro Mine Interim Works

Characterization/ Attribute	Description	Quantitative Measure or Definition of Qualitative Categories
Probability/Frequency	Professional judgement regarding the probability that an effect will occur, and how often.	**Probability** ▪ **Low –** Unlikely to occur ▪ **Moderate –**May occur ▪ **High –**Likely to occur **Frequency** ▪ **Low** - seldom or never ▪ **Moderate** – occasionally ▪ **High** – continuously

TABLE 7-42
Socio-economic Effects Rating Table
Faro Mine Interim Works

Valued Component	Indicator	Rationale	Measure	Effects Attributes	Effect Rating
Economy and Employment	Business development	Evaluates community's ability to adapt to economic growth, effects of increased disposable income, distribution of costs/benefits among affected people (adverse effect/income equity), and effects on local and regional cost of living. IW may stimulate local economies, and could increase employment, and develop skills, training, and education in local communities.	Change in the number of businesses and associated employment in local economies.	Direction	Positive
				SE Context	Moderate
				Magnitude/Duration	Moderate
				Geographic Extent	RSA
				Frequency/Probability	Moderate
	Economic diversification		Capture and distribution of supply and service opportunities in local economies.	Direction	Positive
				SE Context	Moderate
				Magnitude/Duration	Moderate
				Geographic Extent	RSA
				Frequency/Probability	Moderate
	Employment opportunities and income		Capture and distribution of employment opportunities for skilled and unskilled labour.	Direction	Positive
				SE Context	Moderate
				Magnitude/Duration	Moderate
				Geographic Extent	RSA
				Frequency/Probability	Moderate
	Education and training		Leverage of training and skill development opportunities associated with project activities.	Direction	Positive
				SE Context	Moderate
				Magnitude/Duration	Moderate
				Geographic Extent	RSA
				Frequency/Probability	Moderate
Community Stability and Well-being	Community demographics	Influx of temporary workforce during IW components may influence community makeup, including demographics and mobility such as effects of migration (in and out); changes in social and cultural makeup of communities; and influence on individual, family, and community health.	Demographic profile showing age, ethnicity, mobility of local communities.	Direction	Neutral
				SE Context	Moderate
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Community well-being		Families, and community institutions, including recreation and cultural activities.	Direction	Neutral or Positive
				SE Context	Moderate
				Magnitude/Duration	Low
				Geographic Extent	RSA
				Frequency/Probability	Low
	Social cohesion		Common community vision and a sense of belonging; diversity in backgrounds and circumstances appreciated and valued; equal opportunity; strong and positive relationships between groups.	Direction	Neutral
				SE Context	Moderate
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low

TABLE 7-42
Socio-economic Effects Rating Table
Faro Mine Interim Works

Valued Component	Indicator	Rationale	Measure	Effects Attributes	Effect Rating
Infrastructure and Services	Roads and traffic	Potential influx of temporary workforce strain community infrastructure, housing, and emergency and health services. Increased traffic from IW construction and maintenance may affect local road safety and cause wear to road infrastructure.	Wear and tear on roads, increases in levels of traffic	Direction	Neutral
				SE Context	High
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Housing		Demand on local housing; availability of rental homes and homes for purchase	Direction	Neutral
				SE Context	High
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Health services		Increased demand on health services	Direction	Neutral
				SE Context	High
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Emergency services		Increased demand on emergency services	Direction	Neutral
				SE Context	High
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Community infrastructure		Wear and tear on infrastructure such as water and sewer systems and landfills	Direction	Neutral
				SE Context	High
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
Land Use and Access	Traditional use	Land use and effects on existing land use from the IW. Potential effects to First Nations traditional land use (for hunting, trapping, and gathering), as well as effects to access for commercial and recreation land users due to IW construction/ maintenance.	Change in the number of traditional activities carried out in the Project area	Direction	Neutral
				SE Context	Moderate
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Harvest		Changes in access for harvesters	Direction	Neutral
				SE Context	Moderate
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Recreation		Changes in access for recreation activities	Direction	Neutral
				SE Context	Moderate
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Tourism		Number of tourism operators in the area	Direction	Neutral
				SE Context	Moderate
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
Culture and Heritage	Traditional culture and use	Potential effects to First Nations traditional culture, use, heritage, archaeological, and spiritual resources; as well as effects on traditional language, education, laws, and	Reduction in ability access traditional use areas	Direction	Negative or Neutral
				SE Context	High
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low
	Heritage resources		Damage or destruction to heritage resources	Direction	Negative
				SE Context	Low
				Magnitude/Duration	Low

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TABLE 7-42
Socio-economic Effects Rating Table
Faro Mine Interim Works

Valued Component	Indicator	Rationale	Measure	Effects Attributes	Effect Rating
		traditions from IW construction and maintenance.		Geographic Extent	LSA
				Frequency/Probability	Low
	Culture		Loss of traditional languages and other traditions	Direction	Negative or Neutral
				SE Context	High
				Magnitude/Duration	Low
				Geographic Extent	LSA
				Frequency/Probability	Low

Notes:
SE = socio-economic

7.3.7 Effects of Extreme Events

To address the YESAA paragraph 42(1)(c) requirement to evaluate the effects of malfunctions and accidents, the IW environmental and socio-economic assessment relies on risk assessment approaches to characterize the potential effects of extreme events. Risk assessment is an effective tool for evaluating these potential effects because it considers both likelihood and consequences of potential failure events. Some risk events can only be managed by reducing the likelihood of the events, while other can be addressed through reducing both consequences and likelihood. Risk assessment provides a systematic approach for identifying appropriate management responses.

The environmental and socio-economic assessment considers two types of risk events: external factors (i.e., floods, earthquakes and forest fires), and malfunctions and accidents. Formal, annual risk assessments, as described in Appendix 5D, address operational and physical risks associated with FMC facilities and operations. For the IW, the assessment team supplemented the results of the annual risk assessment by specifically evaluating risks associated with proposed IW activities.

Based on the risk assessment results and risk management approaches described in this section, the IW are not expected to cause significant adverse environmental or socio-economic effects as a result of external factors, accidents, or malfunctions.

7.3.7.1 Effects of the External Events

As Section 7.1.6 stated, the FMC and the IW's abilities to withstand floods, earthquakes, and forest fires are important considerations in the assessment. These external factors present risks to the project that could result in adverse environmental or socio-economic outcomes. The following paragraphs describe risks associated with each of these types of events.

Floods

Important flood risks at the FMC are associated with the three main surface water diversions that convey clean water around the site: the RCD, the FCD, and the VCD. Failure of any of these diversions during flood events may lead to contamination of clean water by mine wastes, and possibly to release of contaminated water. The following appendices provide information related to evaluation of flood related risks at the FMC:

- Appendix 5D, C&M Risk Assessment Report, characterizes flood risks for facilities at the FMC.
- Appendix 5I, Down Valley Interim Hydraulic Upgrades Design, describes the current flood routing capacities for the RCD and the RCTA, and proposed upgrades to improve flood routing capacity.
- Appendix 6B, Hydraulic Characterization of Existing Facilities, describes the current hydraulic performance of flood routing facilities.
- Appendix 6C, Stability of Major Existing Facilities, describes the flood routing capacity for key facilities.
- Appendix 6F, Hydrology Baseline Report, provides flow estimates for floods of various return periods.

The RCD conveys fresh water around the RCTA. Hydraulic failure of the RCD could route water into the RCTA, resulting in risks for the ID. The RCD was designed and constructed to convey 140 m^3/sec, slightly more than the 120.2 m^3/sec estimate of the 1-in-500-year flood event (Appendix 6C). However, the current condition of the RCD is such that vegetative growth and other channel maintenance related issues have decreased this flow capacity (Appendix 5N). The RCD's existing configuration does not provide adequate capacity to convey the 1-in-50-year flood flow of 72.8 m^3/s before the flow overtops the overflow weir (Appendix 6C). The existing ID spillway capacity of 32 m^3/s is not sufficient to safely pass a moderate or major flood event without overtopping and potentially failing the ID, and releasing tailings to the downstream environment (Appendix 6C).

The annual operational risk assessment identified several flood-related risks for the RCD and RCTA (Appendix 5D). Table 7-43 lists these risks, alongside corresponding mitigation actions. Most importantly, the proposed DVIHU will increase capacity of both the RCD and the ID Spillway to 1-in-500-year peak flow, and will effectively manage flood risks for the RCTA during the IW.

The FCD conveys fresh water around the Faro Pit into the NFRC. Hydraulic failure of the FCD would route water into the Faro Pit, resulting in increased requirements for treatment of contaminated water. While the flood return period capacity of the existing FCD is unknown, it has performed suitably during the post-operational period. For geotechnical reasons, the FCD must be reconstructed at a new location during the FMRP. During the IW, the FCD's failure is unlikely to result in measureable environmental effects because the Faro Pit has enough capacity to store several months of Faro Creek inflows following a flood event. This would provide enough time for the FCD to be repaired before environmental effects took place. The annual risk assessment described in Appendix 5D identified flood risks associated with the FCD, as well as the following risk management measures:

- Ongoing monitoring and maintenance to maintain diversion capacity
- Management of Faro Pit water levels to maintain sufficient storage capacity for floods and failure events
- Retention of sufficient supplies to construct a piped diversion for Faro Creek on short notice after a failure event

The VCD conveys fresh water around the Vangorda Pit. For most of its components, their failures would result in water being routed into the Vangorda Pit. This would increase the requirements for water treatment, and possibly cause contaminated water to be released into Vangorda Creek. The existing VCD was designed and constructed to convey flows up to 10 m^3/s, the peak flow for a 1-in-100-year event. Over the last 10 years, the VCD has experienced floods, slope failures, and ice buildup that have compromised the diversion and resulted in significant maintenance requirements. Appendix 6B summarizes the existing condition of the VCD as follows:

- Existing flume structures require ongoing maintenance and repair to limit plugging of the diversion, erosion of roadway, and resulting discharge to Vangorda Pit
- Drop structures at roadways require ongoing maintenance to limit the risk of plugging and overtopping
- The VCD does not have capacity to convey peak flow in excess of 10 m^3/sec, which is the 1-in-100-year design peak flow event.
- Bank Slopes associated with the half-round CSP culvert component of the VCD are at risk of instability and slumping.
- Ice damage impacts the instability of the diversion structures.
- Pit wall instability threatens the VCD.

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TABLE 7-43
Flood Risks – Rose Creek Diversion and Rose Creek Tailings Area
Faro Mine Interim Works

Risk	Risk Rating [a]	Risk Mitigation
A Probable Maximum Flood event exceeds the capacity of the ID spillway, leading to release of tailings and water to environment.	Moderately High	DVIHU will provide capacity for the ID to convey 1-in-500-year flood events. This provides suitable management for risk during IW, since the likelihood of larger floods is very small during a period of 10 years or less. Further upgrades to be completed as part of FMRP.
A 1-in-500-year to 1-in-1,000-year flood event exceeds the capacity of the ID spillway, leading to the breach of the ID, the release of contaminated water, and 10-20% of the total volume of tailings being released to the CVD Pond. The CVD Pond spillway releases contaminated water to the environment, but the tailings are contained in the CVD Pond.	Moderately High	DVIHU will provide capacity for the ID to convey 1-in-500-year flood events. This provides suitable management for risk during IW, since the likelihood of larger floods is very small during a period of 10 years or less. Further upgrades to be completed as part of FMRP. The CVD Pond Spillway has the capacity to convey approximately 300 m^3/sec, sufficient for the estimated flow during a 1-in-1,000-year event. The magnitude and duration of effects would be reduced because tailings would likely remain contained within the CVD Pond.
A flood event causes a breach of RCD dike, leading to a breach of the ID and the release of tailings and water.	Moderately High	DVIHU will reduce likelihood of a RCD dike breach, and provide additional capacity for ID to convey flood flows. This provides suitable management for risk during IW, since likelihood of larger floods is very small during a period of 10 years or less. Further upgrades to be completed as part of FMRP.
The catastrophic structural failure of the RCD during a 1-in-50 to 1-in-100-year event, causing the breach of the dike and the uncontrolled flow of RCD into the ID Pond for 1 month. The ID Pond spillway conveys majority of flow into CVD, where it short-circuits the pond and leads to the discharge of undiluted ID Pond overflow into the environment (elevated zinc/suspended solids).	Moderately High	DVIHU will reduce likelihood of a RCD dike breach. This provides suitable management for risk during IW, since the likelihood of larger floods is very small during a period of 10 years or less. Further upgrades to be completed as part of FMRP.
A flood event in the range of 1-in-50 to 1-in-100 year event overtops the RCD dike or fuse plug (no major structural failure), and leads to the flow of water into the ID Pond, with continued pumping capacity, out through ID Pond spillway/CVD and into receiving environment for 1 to 7 days. Mechanisms of debris flow, icing, and slope failure were also considered but have lower likelihoods.	Moderate	DVIHU will reduce the likelihood of RCD dike overtopping. This provides suitable management for risk during IW, since the likelihood of larger floods is very small during a period of 10 years or less. Further upgrades to be completed as part of FMRP. Ongoing maintenance of the diversion and pumping system, and effective management of water levels in the ID Pond will also reduce the likelihood and magnitude of contaminant releases.

[a] Refer to Appendix 5G for explanations about risk ratings.

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The annual operational risk assessment identified several flood-related risks for the VCD (Appendix 6C). Table 7-44 lists these risks, alongside associated mitigation actions. The risk assessment did not identify specific flood-related risks for the VCD with ratings higher than Moderate. However, considering the VCD's limited hydraulic capacity and deteriorating condition, along with its limited storage capacity and very adverse water quality in Vangorda Pit, the combined risks for the VCD may warrant upgrading the facility before the FMRP is implemented. Design information to support evaluation of any upgrade is not currently available and will be addressed in future assessment and regulatory processes if needed.

The annual operational risk assessment and the specific risk assessment for the IW identified risks that flooding may overwhelm the capacity of water management systems for the Grum Dump, especially the pumping system at V-15, and the capacity of Moose Pond (Appendix 5D; Appendix 6K). Upgrades for the V-15 pumping system are planned to provide additional capacity during freshet and flood conditions.

Earthquakes

Risks associated with seismic events are an important consideration for waste- and water-retaining structures at the FMC, including the ID, Secondary Dam, CVD, LCD, and RCD dike. Each dams retains contaminated mine waste or water that would affect local aquatic ecosystems if the facilities failed. The RCD dike effectively separates clean water from the Rose Creek tailings. Appendix 6C - Stability of Major Existing Facilities describes the current status of FMC facilities, related to their expected seismic performances. Appendix 5D -Site Operations Risk Assessment characterizes seismic risks for facilities at the FMC.

Seismic analyses in Appendix 6C concluded that the ID, Secondary Dam and CVD would be stable for 1-in-500-year seismic events. These conditions effectively manage risks for the IW period, because the likelihood of seismic events larger than 1-in-500-year events is very small for the 10-year duration.

Appendix 5D identified Moderately High risks for RCD dike and LCD failures during seismic events. These risk ratings are related to the current lack of information about, or analyses of, the seismic stability of these facilities. Field investigations have been conducted and analyses are under way to develop a better understanding of seismic stability of the RCD dike. Both facilities need to undergo further seismic condition analyses. This need will be addressed by implementing recommendations that arise from the proposed 2014 Dam Safety Review, which will take place in accordance with the Dam Safety Guidelines (CDA, 2007), and ongoing annual dam safety inspections as described in Appendix 5B, Environmental Monitoring, Surveillance, and Reporting Plan. In the meantime, risks associated with seismic events at the LCD will be reduced by maintaining a low water level therein, at least 2 to 3 m below the spillway invert.

Forest Fires

Appendix 5D identified a Low risk associated with loss of access at the FMC for a period up to 14 days, resulting from forest fire. The assessment assumed that pumping and water treatment activities at the FMC would be curtailed during the forest fire event. Discontinuing water treatment presents no measurable risk to the environment because the pits have enough capacity to store contaminated water. Discontinuing pumping from SISs (e.g., S-Wells SIS) could lead to contaminant releases to the aquatic environment for short periods of time. The water quality and aquatic effects assessment considered events more severe than those associated with potential forest fire events and concluded that effects would not be significant.

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TABLE 7-44
Flood Risks – Vangorda Creek Diversion
Faro Mine Interim Works

Risk	Risk Rating [a]	Risk Mitigation
A flood event greater than the capacity of the VCD allows water to flow into Vangorda Pit, which overflows, causing the release of contaminated water to Vangorda Creek.	Moderate	The VCD has capacity to convey peak flow from a 1-in-100-year event. Water level management in the Vangorda Pit provides capacity to store water if the VCD fails or is overtopped. At the average maintained water level (1,185 masl) there are approximately 4.8 Mm^3 of capacity to the final spill elevation of 1,130 masl. This provides 5.6 days of storage capacity at a peak 1-in-100-year flow of 10 m^3/sec.
A flood event greater than the capacity of the VCD allows water to flow into the Vangorda Pit, without overflowing.	Moderate	The VCD has capacity to convey peak flow from a 1-in-100-year event. Water level management in the Vangorda Pit provides capacity to store water if the VCD fails or is overtopped. At the average maintained water level (1,185 masl), there are approximately 4.8 Mm^3 of capacity to the final spill elevation of 1,130 masl. This provides 5.6 days of storage capacity at a peak 1-in-100-year flow of 10 m^3/sec.
An ice formation and flood event that causes damage to VCD flume.	Moderate	Ongoing monitoring and maintenance of the VCD, and effectively managing water levels in the Vangorda Pit, will also reduce the likelihood and magnitude of contaminant releases.

[a] See Appendix 5G for an explanation about risk ratings.

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7.3.7.2 Effects of Malfunctions and Accidents

Appendix 5D and the evaluation of specific risks for the IW considered effects that could arise from a variety of potential failure modes and events:

- Engineering failures (e.g., structural failure of building)
- Human error (e.g., operator error, inspector error, mischief, or vandalism)
- Prediction errors (e.g., uncertainty in geochemical predictions, or underestimates of flood events)

As Appendix 5D described, the 2013 annual operational risk assessment did not identify any high environmental risks at the FMC. This outcome illustrates the success of ongoing risk management evaluations and responses at the FMC, where actions have been taken to reduce environmental risks. The risk assessment identified three environmental risks with moderately high ratings, indicating that mitigation plans should be developed and implemented. The following paragraphs describe scenarios with moderately high environmental risks, along with responses that will be implemented in the coming year.

- **A piping failure of the ID leads to release of contaminated water through the CVD Pond.** The status of the ID is addressed through ongoing monitoring programs, rendering the event unlikely.
- **Wind erosion from tailings causes contamination of surrounding land, affecting ecosystem health.** Revised protocols for undertaking dust control measures are needed to minimize wind erosion. These protocols have been developed as part of the IWPP and will be part of licence applications.
- **Contaminated water migrates below the CVD Pond, resulting in the escape of contaminated water to the environment.** The AMP includes monitoring and thresholds that will guide the timely design and implementation of groundwater collection systems. Existing pumping wells could be used for the immediate collection of affected water. A collection system is already being designed, and extensive aquifer testing has taken place to support that design.

The evaluation of specific risks for the IW identified several environmental risks that could arise during site investigation or DVIHU activities. Appendix 5E (Spill Contingency Plan) and Appendix 5A (Environmental Management Plan) address risks arising from transporting, transferring, and handling fuels or other hazardous materials. The Environmental Management Plan (Appendix 5A) addresses risks of contamination of clean water during drilling or aquifer testing activities. It also describes measures for preventing cross-contamination within aquifers during drilling, or preventing the release of contaminated water to surface water during drilling or aquifer testing. Risks associated with operational failures of pumping, piping, and water treatment systems will be addressed by Failure Modes Effects Analysis undertaken for specific pumping, conveyance, and treatment facilities, to identify appropriate mitigation strategies and critical spare parts lists. These Failure Modes Effects Analyses have been conducted for some facilities and will continue as part of ongoing operations.

The 2013 operational risk assessment identified two High human health and safety risks for the FMC. According the YG and AANDC risk management practices, appropriate mitigation responses must be developed and implemented immediately. The risks and responses that will be implemented in the coming year are described herein.

- **Faro pit wall failure occurs while personnel and equipment are working on the FCD.** This is a new risk identified in 2013, reflecting concern about heavy equipment operation along the FCD near the pit wall, and potential implications on physical stability. Stability under these circumstances will be further evaluated, and appropriate responses will be developed within the calendar year.
- **Worker breaks through the ice or falls into water, resulting in injury or death.** Operational procedures and training have been implemented for working on ice or water. However, working on ice/water is inherently hazardous and some risk remains.

Appendix 5D identified numerous moderately high human health and safety risks. Several of these are related to unauthorized access to onsite facilities by members of the public. Ongoing improvements to site and building security will reduce the likelihood of such events. The Mill Building is no longer used for water treatment, which

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eliminates the need for site staff to access it on a daily basis and provides opportunities for more effective access control. Some additional moderately high risks are associated with use of the Mill Building. Reduced use of that facility will also reduce these risks. Finally, a new risk identifies potential worker health and safety effects associated with the daily operation of the proposed interim water treatment facility, in an area that may have high lead concentrations. Further investigation will identify the scope of the risk, and remedial measures may be required to address this risk.

The evaluation of specific risks for the IW identified several human health and safety risks that could arise during site investigation or DVIHU activities. These are primarily risks to worker safety and will be addressed via appropriate worker health and safety protocols.

Appendix 5D identified several cost risks for the FMC. While these risk events may cause additional costs for co-proponents, they are not expected to cause significant environmental or socio-economic effects.

7.3.7.3 Significance of Effects of Extreme Events

Based on the results of risk assessments, extreme events including floods, earthquakes, forest fires, and malfunctions and accidents are not expected to cause significant adverse environmental or socio-economic effects during the IW.

The facilities and operations at the FMC are sufficiently robust to effectively manage risks associated with floods, earthquakes, and forest fires during the IW period. Therefore, these events are not expected to cause significant adverse environmental or socio-economic effects. The proposed DVIHU will address higher risks associated with flood conveyance in the RCTA. Ongoing monitoring, maintenance, pit water management, and emergency preparedness planning will reduce risks associated with floods, earthquakes, and forest fires.

Appropriate actions will be taken to reduce and manage risks arising from malfunctions and accidents. Therefore, these events are not expected to cause significant adverse effects. The annual systematic operational risk assessment provides an effective tool to identify and track risks, and to develop appropriate responses.

7.3.8 Overall Significance of Effects

This section summarizes the major potential effects evaluated in the assessment for the IW, and describes the significance of those effects.

For air quality, the major potential effects arise from dust releases from the FMC, including metal-laden dust from mine wastes (e.g., tailings). The assessment evaluated the significance of the potential effects by comparing predicted concentrations of TSP, PM_{10}, $PM_{2.5}$ and metals against provincial and territorial air quality criteria (Appendix 7A).

For surface water quality, the major potential effects arise from contaminants of concern being released to receiving water. These releases could take place via controlled surface discharges (e.g., treated effluent from the Faro and Vangorda Water Treatment Systems), uncontrolled surface discharges (e.g., untreated runoff and seepage), and groundwater. The assessment evaluated the potential effects of sulphate, cadmium, cobalt, iron, lead, manganese, and zinc. These contaminants have exceeded water quality guidelines for the protection of aquatic life at surface water stations located around, and downstream from, the FMC. To evaluate the significance of potential effects, predicted contaminant concentrations for normal and adverse conditions were compared with water quality guidelines and aquatic toxicity thresholds (Appendix 7C).

For fish and fish habitat, the major potential effects arise from surface water contamination. The significance of these potential effects was addressed in conjunction with the effects on surface water quality. Predicted concentrations of contaminants of concern were compared with water quality criteria and aquatic toxicity thresholds (Appendix 7C).

For wildlife and wildlife habitat, the major potential effects arise from the permanent or temporary destruction or alteration of habitat, metals uptake through feeding or exposure, entrapment or drowning in site facilities, vehicle collisions or equipment-related trauma, or sensory disturbance (i.e., visual, olfactory, or auditory). To adequately describe these potential effects, which could apply to a wide variety of species, the assessment evaluated effects

of IW activities on six wildlife indicators: (1) moose, (2) thinhorn sheep, (3) grizzly bear, (4) avian nesting habitats, (5) waterfowl, and (6) small mammals. The evaluation compared the expected effects of the IW with ecological objectives for habitat loss, mortality, local site use, and metals uptake.

For economy and employment, the major potential effects arise from the increased employment and spending associated with the site investigations in 2014 and DVIHU construction in 2016. The assessment characterized the potential changes in business development, economic diversification, employment and income levels, and education and training.

For infrastructure and services, the major potential effects arise from the potential influx of workers for certain IW activities. The assessment characterized potential effects on roads and traffic, housing, health services, emergency services, and community infrastructure.

For land use and access, the IW may result in increased access to currently undisturbed areas and changes in access to the area by local users, resulting from changes in access management at the FMC. The assessment characterized potential effects on traditional land use, hunting and fishing, recreation, tourism, and forestry.

For community stability and well-being, major potential effects may arise from the potential influx of workers for certain IW activities. The assessment characterized potential effects on demographics, social cohesion and cultural well-being.

No major potential effect were identified for culture and heritage, or human health and safety. In addition, extreme events including floods, earthquakes, forest fires, and malfunctions and accidents are not expected to cause significant adverse environmental or socio-economic effects during the IW.

As Section 7.2.3 mentioned, the evaluation of the effects' significance considers the following factors:

- Direction
- Magnitude
- Likelihood
- Duration
- Geographic extent
- Probability/frequency
- Reversibility
- Socio-economic context

Table 7-45 summarizes the significance of the proposed IW's potential effects on the VCs for the above factors. The factors considered vary with the VC depending on its nature and measures used to rate significance. An overall significance rating for each VC is identified based on the evaluation. Because none of the ratings of overall significance are high, none of the potential effects exceed the threshold for significance defined in Section 7.2.3. Therefore, the co-proponents have concluded the IW will not cause significant adverse environmental or socio-economic effects.

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TABLE 7-45
Summary of Significance of Effects
Faro Mine Interim Works

Valued Component		Direction	Magnitude	Duration	Likelihood	Geographic Extent	Probability/ Frequency	Reversibility	Socio-economic Context	Overall Significance
Air Quality	Tailings	-	L			L	M	M		M
	DVIHU	-	M			L	H	L		M
	Roads	-	L			L	L	L		L
Surface Water Quality	Sulphate, Cd, Co, Pb, Mn	-	L-M			L		L		L
	Zn Normal	-	M			M		L		M
	Zn Adverse	-	M			M		M		M
Fish and Fish Habitat		-	M			M		M		M
Wildlife and Wildlife Habitat	Moose	-	L-M			L		L-M		L
	Thinhorn Sheep	-	L			L		L-M		L
	Grizzly Bear	-	L-M			L		L-M		L
	Avian Nesting Habitat	-	L-M			L		M		L
	Waterfowl	-	L-M			L-M		L-M		L
	Small Mammals	-	L-M			M-H		L-M		L
Economy and Employment	Business Development	+	M			LSA/RSA	M		M	M+
	Economic Diversification	+	M			LSA/RSA	M		M	M+
	Employment Opportunities and Income	+	M			LSA/RSA	M		M	M+
	Education and Training	+	M			LSA/RSA	M		M	M+
Infrastructure and Services	Roads and traffic	N	L			LSA	L		H	L
	Housing	N	L			LSA	L		H	L
	Health Services	N	L			LSA	L		H	L
	Emergency Services	N	L			LSA	L		H	L
	Community infrastructure	N	L			LSA	L		H	L

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TABLE 7-45
Summary of Significance of Effects
Faro Mine Interim Works

Valued Component		Direction	Magnitude	Duration	Likelihood	Geographic Extent	Probability/ Frequency	Reversibility	Socio-economic Context	Overall Significance
Community Stability and Well-being	Community demographics	N	L			LSA	L		M	L
	Community Well-being	N/+	L			LSA/RSA	L		M	L
	Social Cohesion	N	L			LSA	L		M	L
Land Use and Access	Traditional Use	N	L			LSA	L		N/A	L
	Harvest	N	L			LSA	L		N/A	L
	Recreation	N	L			LSA	L		N/A	L
	Tourism	N	L			LSA	L		N/A	L
Culture and Heritage	Traditional Culture and Use	-/N	L			LSA	L		H	L
	Heritage Resources	-	L			LSA	L		L	L
	Culture	-/N	L			LSA	L		H	L
Human Health and Safety										L

Notes:
+ =
Cd = cadmium
Co = cobalt
H = high
L = low
LSA = local study area
M = manganese
M+ =
Mn =
-/N =
N = north
N/A = not applicable
Pb = lead
RSA = regional study area
Zn = zinc

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SECTION 8

Signature Page

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SECTION 9

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SECTION 10

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Please note: This section is currently under development. A complete Works Cited will accompany the Final Interim Works Project Proposal.

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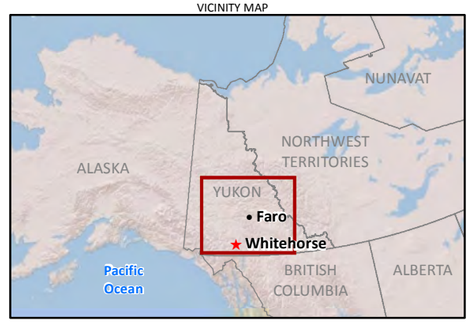
Figures



VICINITY MAP



LEGEND

- Faro Mine Complex
- Province Boundary

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FIGURE 3-1
Faro Mine Complex Location
Faro Mine Interim Works

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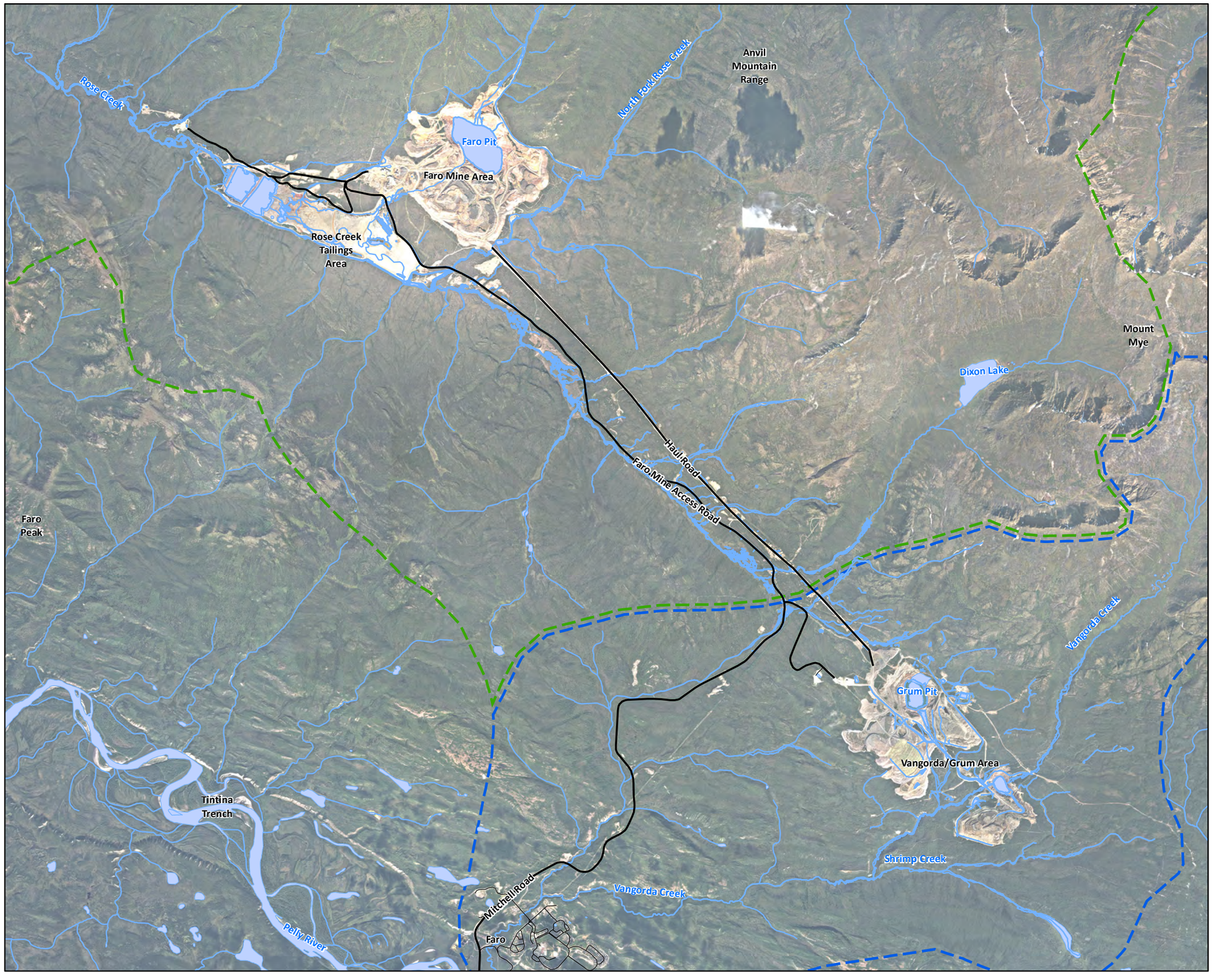

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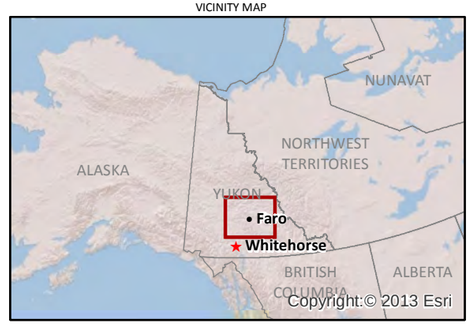

LEGEND

- Rose Creek Watershed
- Vangorda Creek Watershed

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FIGURE 3-2
Faro Mine Complex Overview
Faro Mine Interim Works

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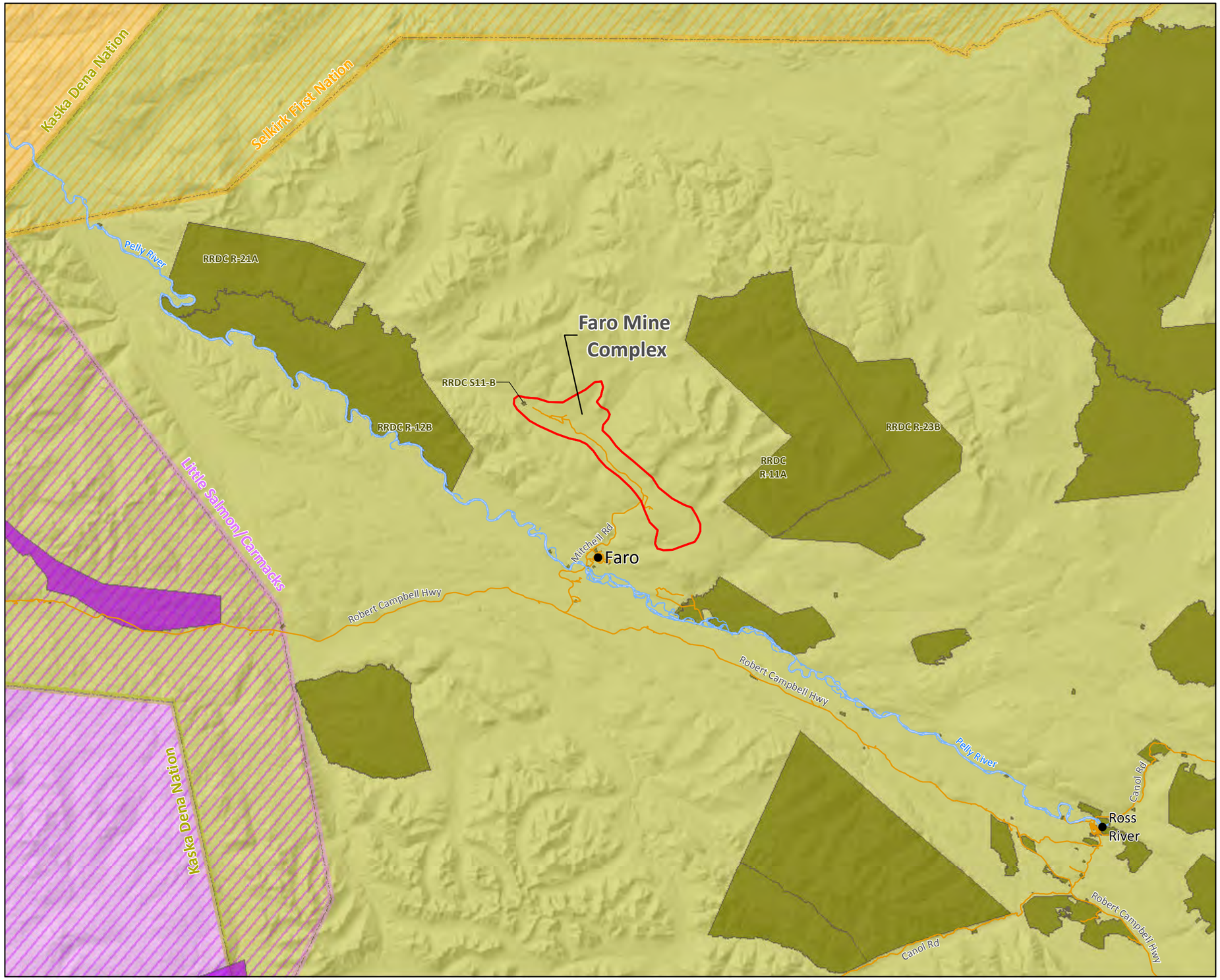

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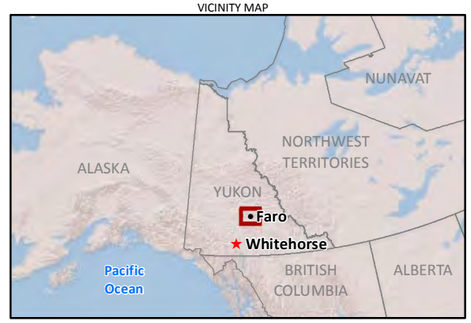

LEGEND

- Faro Mine Complex
- Ross River Dena Council Interim Protected Lands
- Little Salmon/Carmacks First Nation Interim Protected Lands

First Nation Traditional Territories

- Kaska
- Selkirk
- Little Salmon/Carmacks

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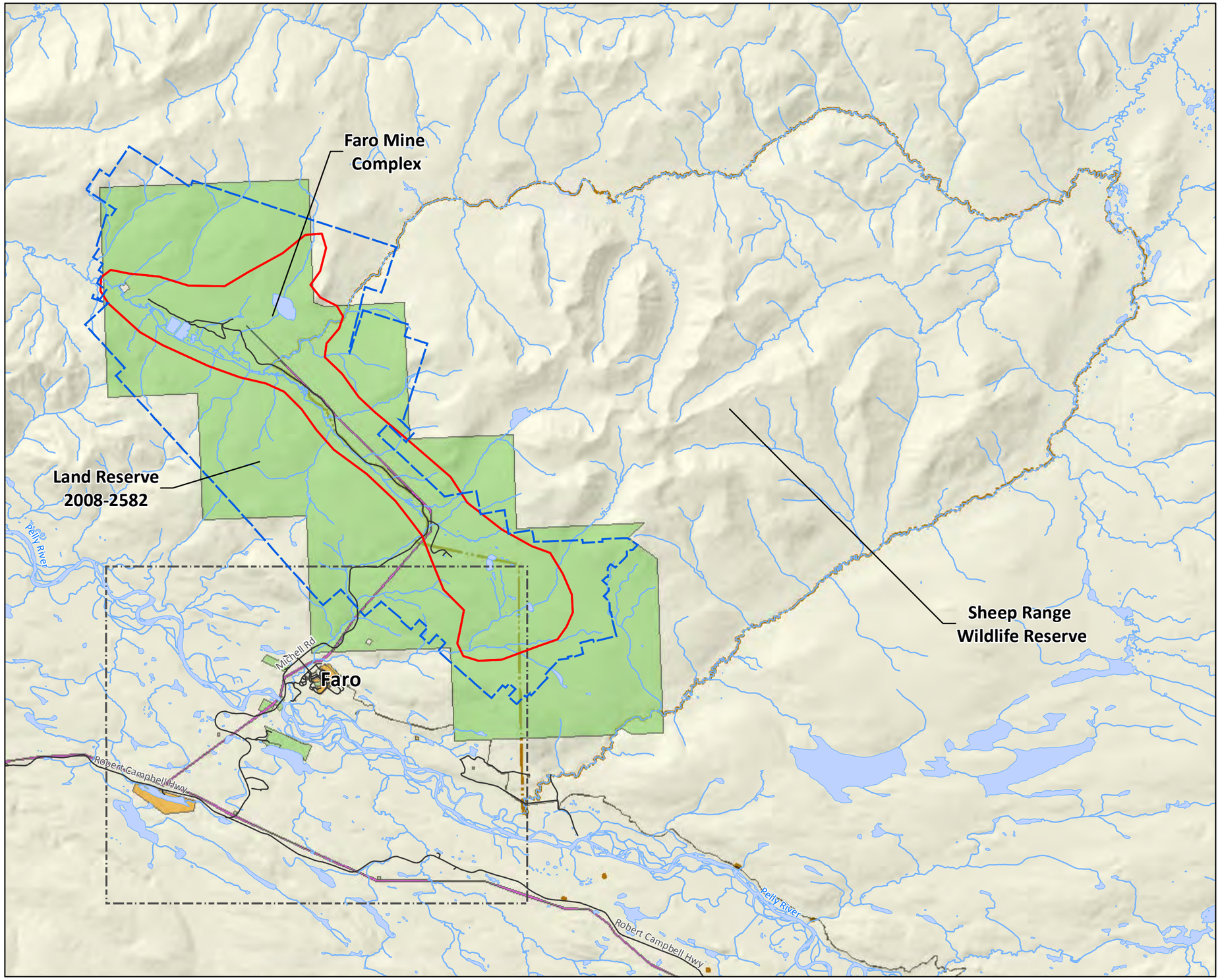
FIGURE 3-3
First Nation Interim Protected Lands
Faro Mine Interim Works



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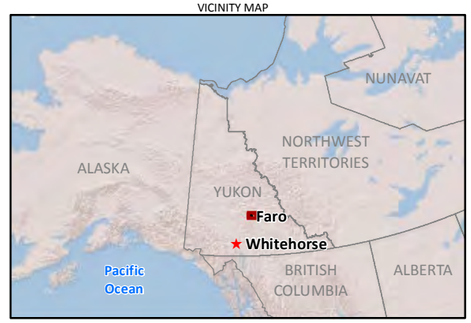

LEGEND

- Faro Mine Complex
- OIC 2008/168
- Faro Municipal Boundary

Land Tenure

- Wildlife Reserve
- Easement
- Lease
- Reservation

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FIGURE 3-4
Land Tenure
Faro Mine Interim Works

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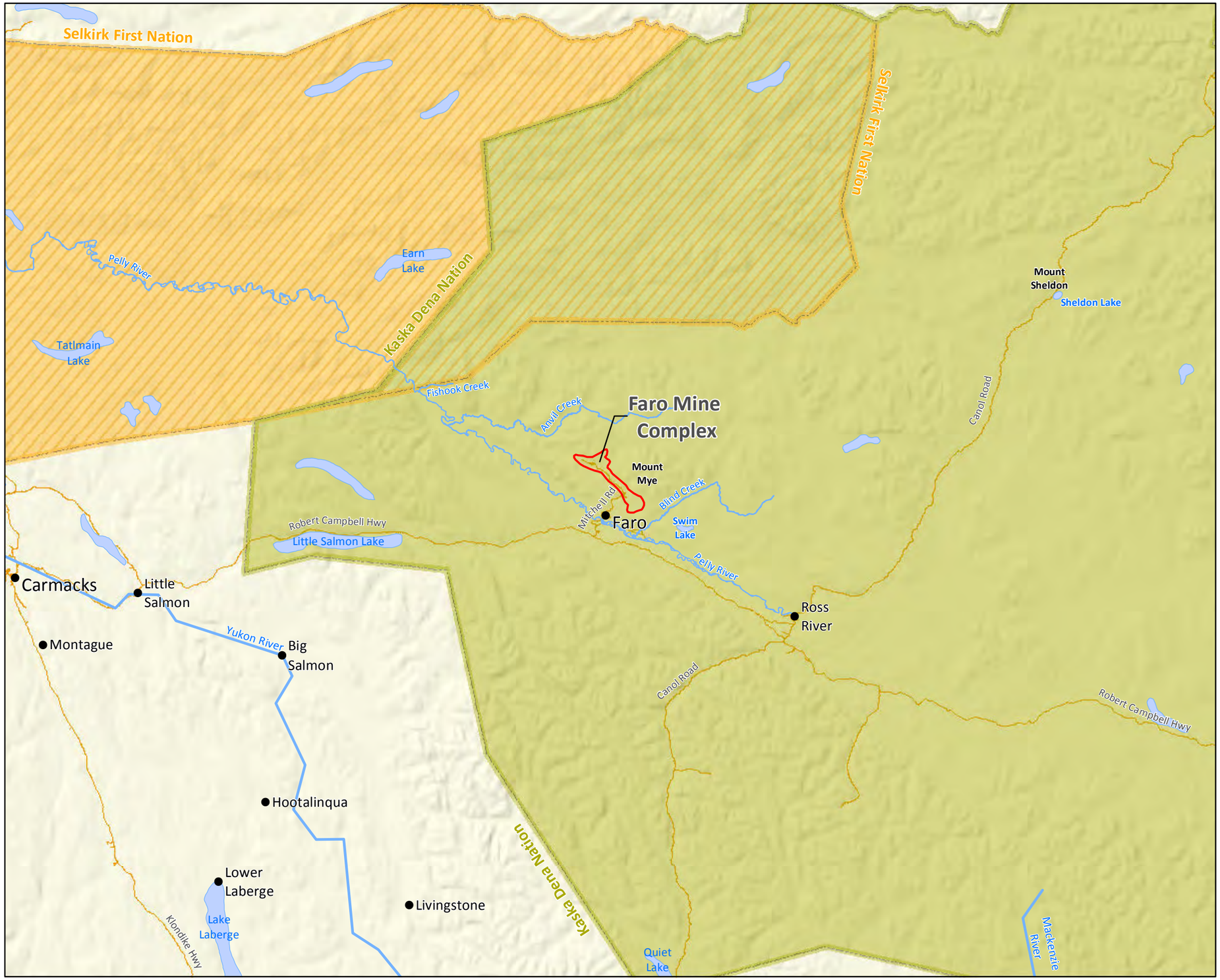

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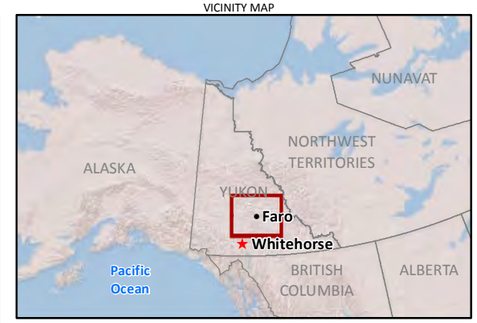

LEGEND

Faro Mine Complex

First Nation Traditional Territories

Kaska

Selkirk

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FIGURE 3-5

Seasonal Round Areas of Use by Ross River Dena

Faro Mine Interim Works

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VICINITY MAP



LEGEND

Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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Metres

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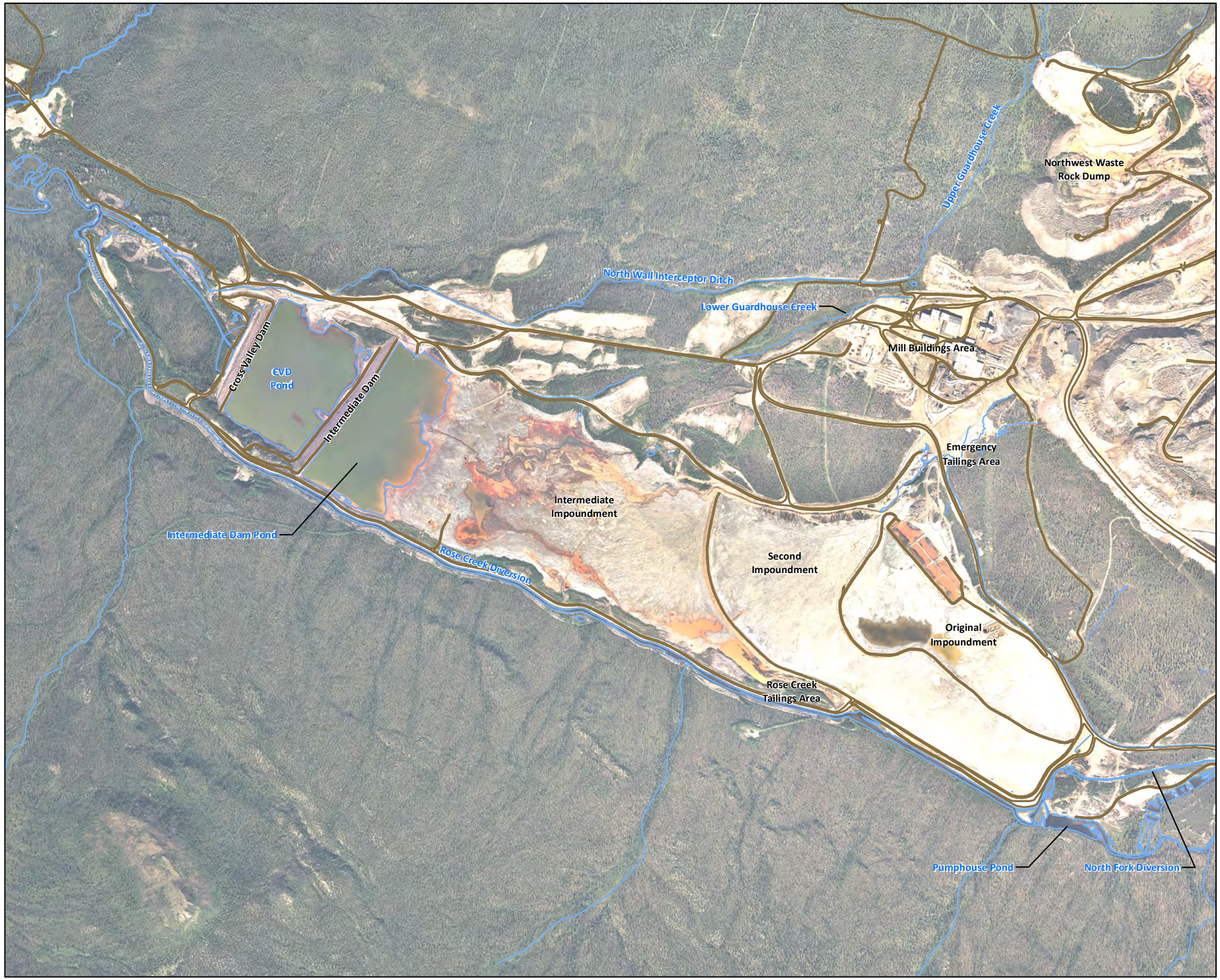
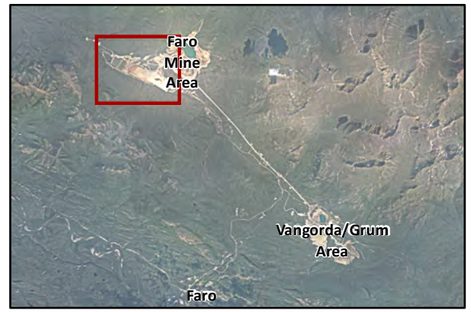
CRITIGEN

FIGURE 3-6
Faro Mine Area
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 200 400 600 800

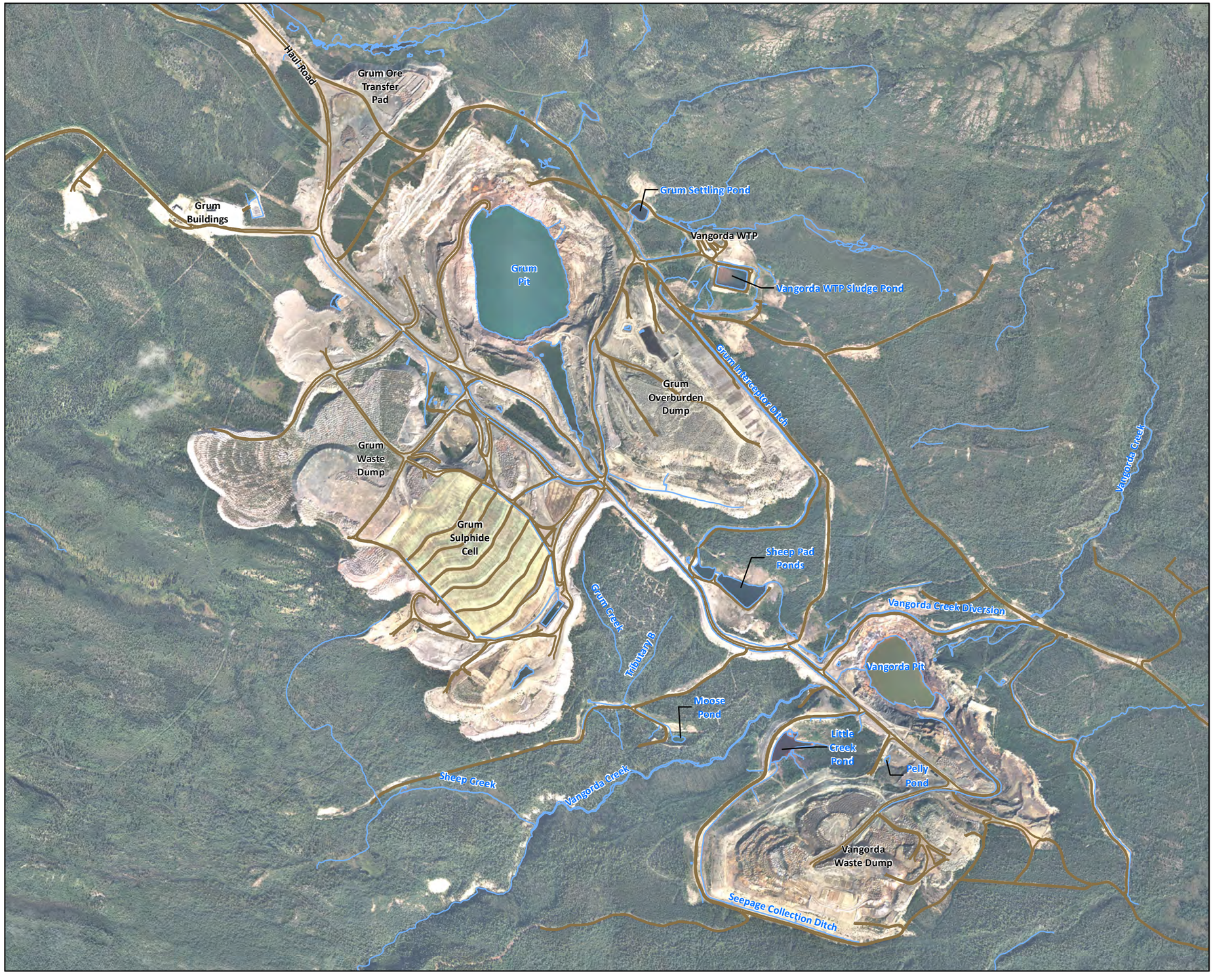
Metres

Created by: CRITIGEN

FIGURE 3-7

Rose Creek Tailings Area

Faro Mine Interim Works



VICINITY MAP



LEGEND

Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 200 400 600 800
Metres

Created by: CRITIGEN

FIGURE 3-8
Vangorda/Grum Area
Faro Mine Interim Works

Activity Name	Start	Finish
ONGOING FIELD INVESTIGATIONS	Sept-13	Oct-15
FMRP DESIGN	Apr-13	Aug-16
Research, Analysis and Model Development	Apr-13	Dec-15
Develop FMRP Design Definition and Concepts	Aug-14	Jan-15
Prepare Initial FMRP 30% Engineering Designs	Feb-15	Jun-15
Refine 30% Designs to Address Environmental and Socio-economic effects	Jul-15	Aug-16
PREPARE PROJECT PROPOSAL	Apr-13	Apr-17
Environmental & SE Baseline	Jul-13	Sep-15
Environmental & SE Effects Assessment	Apr-14	Jun-16
Prepare Project Proposal and Supporting Documents	Nov-14	Apr-17
CONSULTATION & ENGAGEMENT	Apr-14	May-17
SUBMIT PROJECT PROPOSAL	May-17	

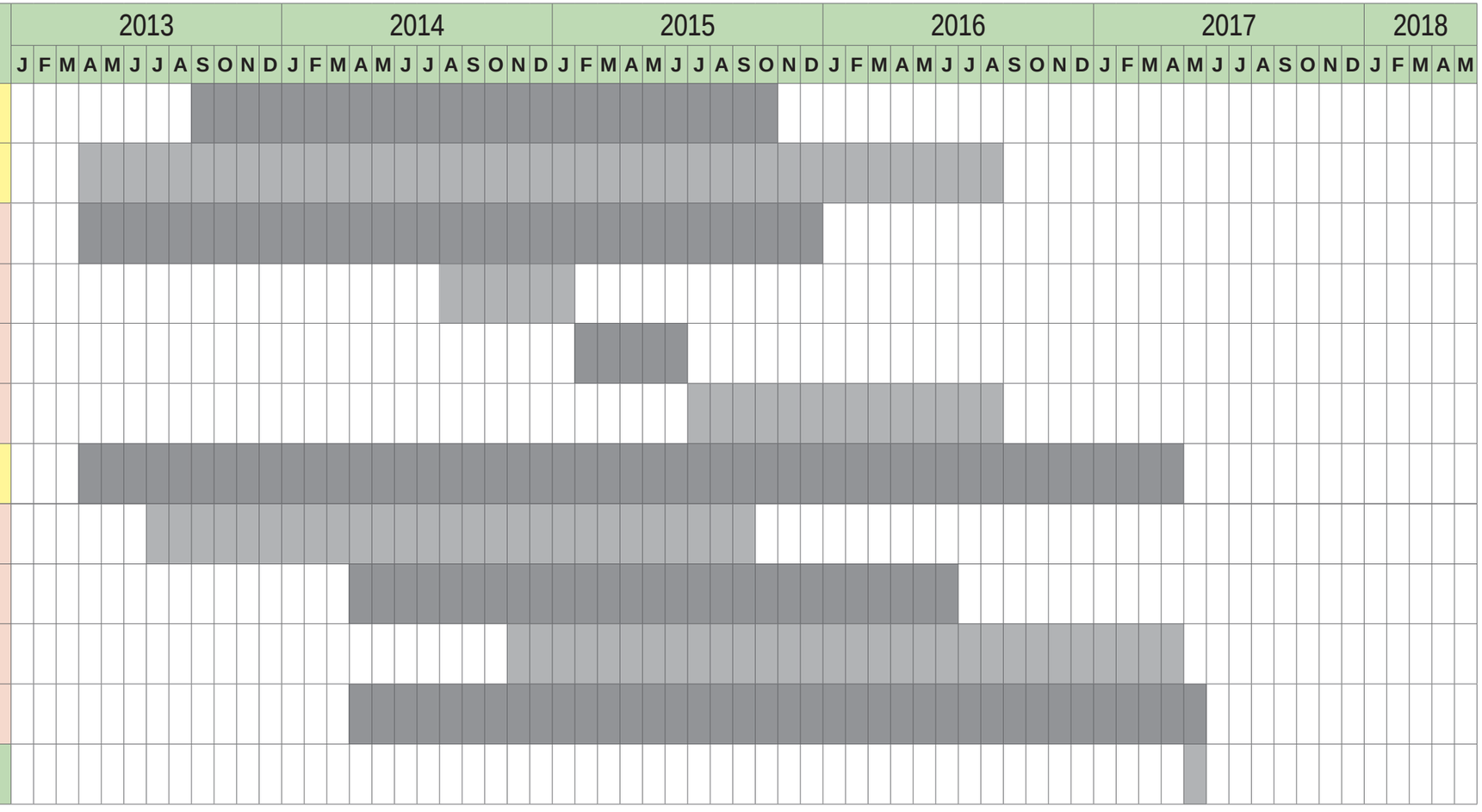
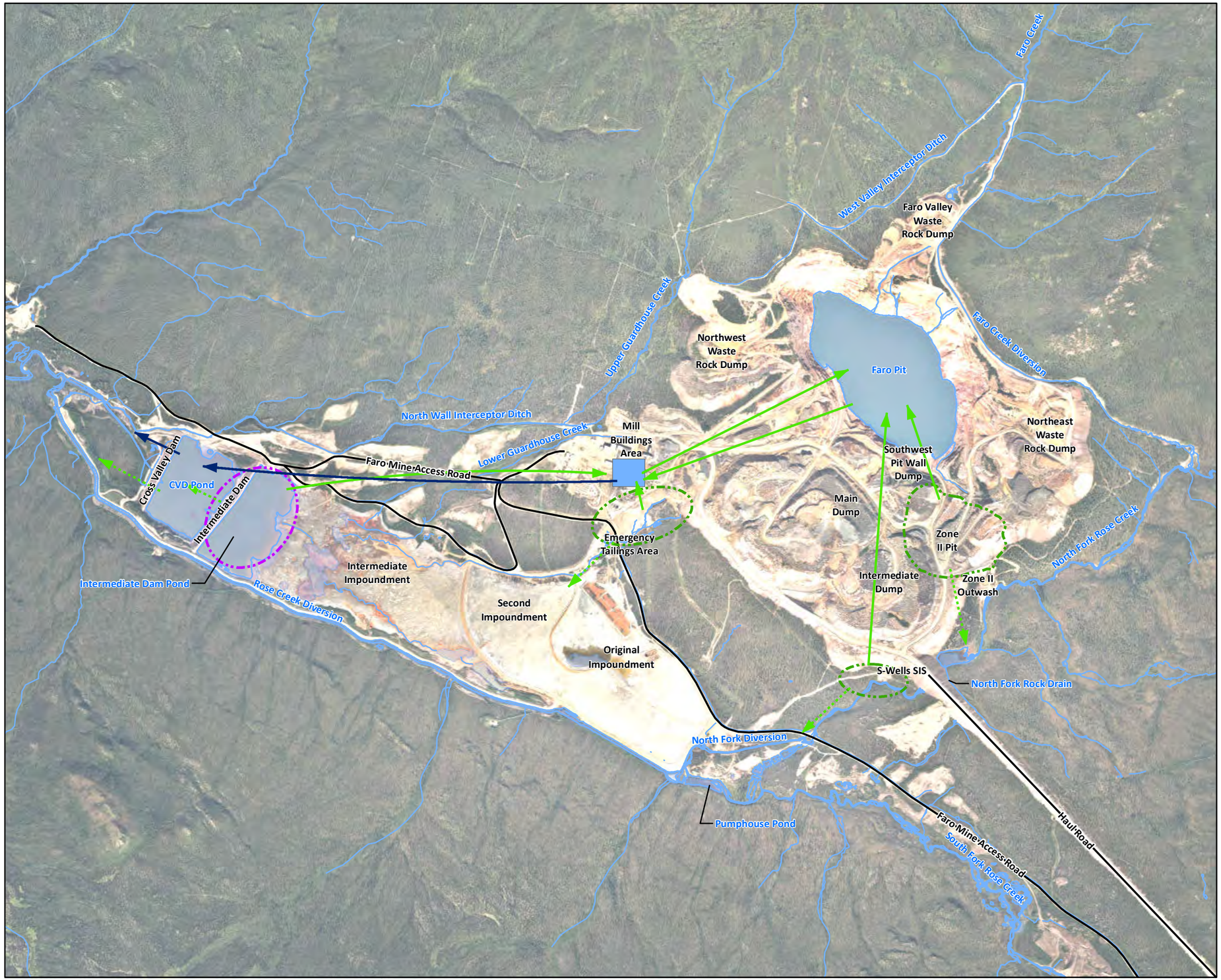


FIGURE 3-9
FMRP Project Proposal Schedule
Faro Mine Interim Works



VICINITY MAP



LEGEND

- Water to Pit or Treatment
- Seepage Bypassing Current Collection
- Treated Water Discharge
- Installed Groundwater or Surface Water Collection System
- Installed Surface Water Collection
- Interim Water Treatment System

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. ETA - Emergency Tailings Area
3. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
4. Orthophotography prepared by Critigen Canada Corp.

N

0 250 500 750 1,000

Metres

Created by: CRITIGEN

FIGURE 5-1

Faro Mine Area including Rose Creek Tailings Area

Faro Mine Interim Works

CH2MHILL

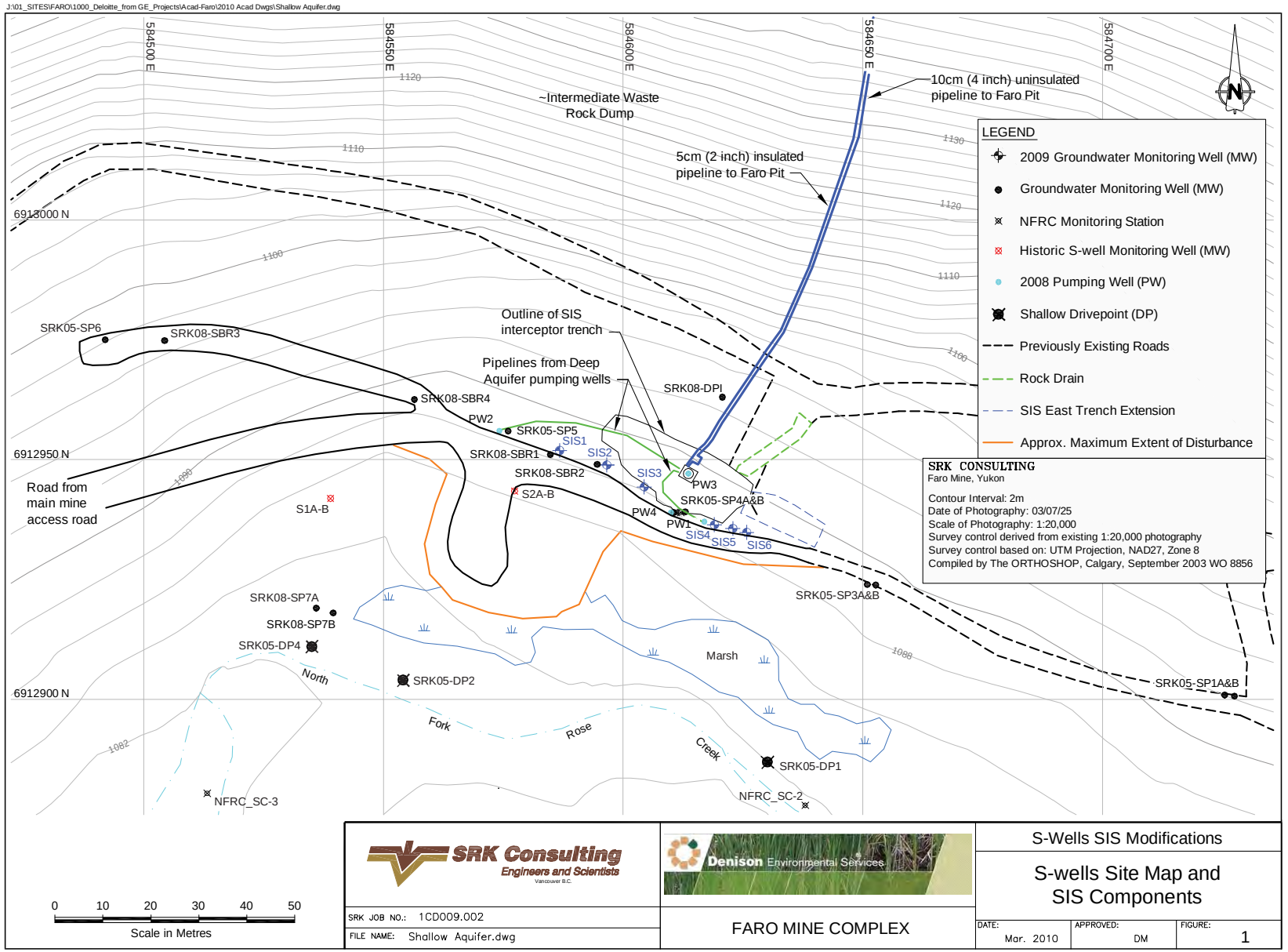
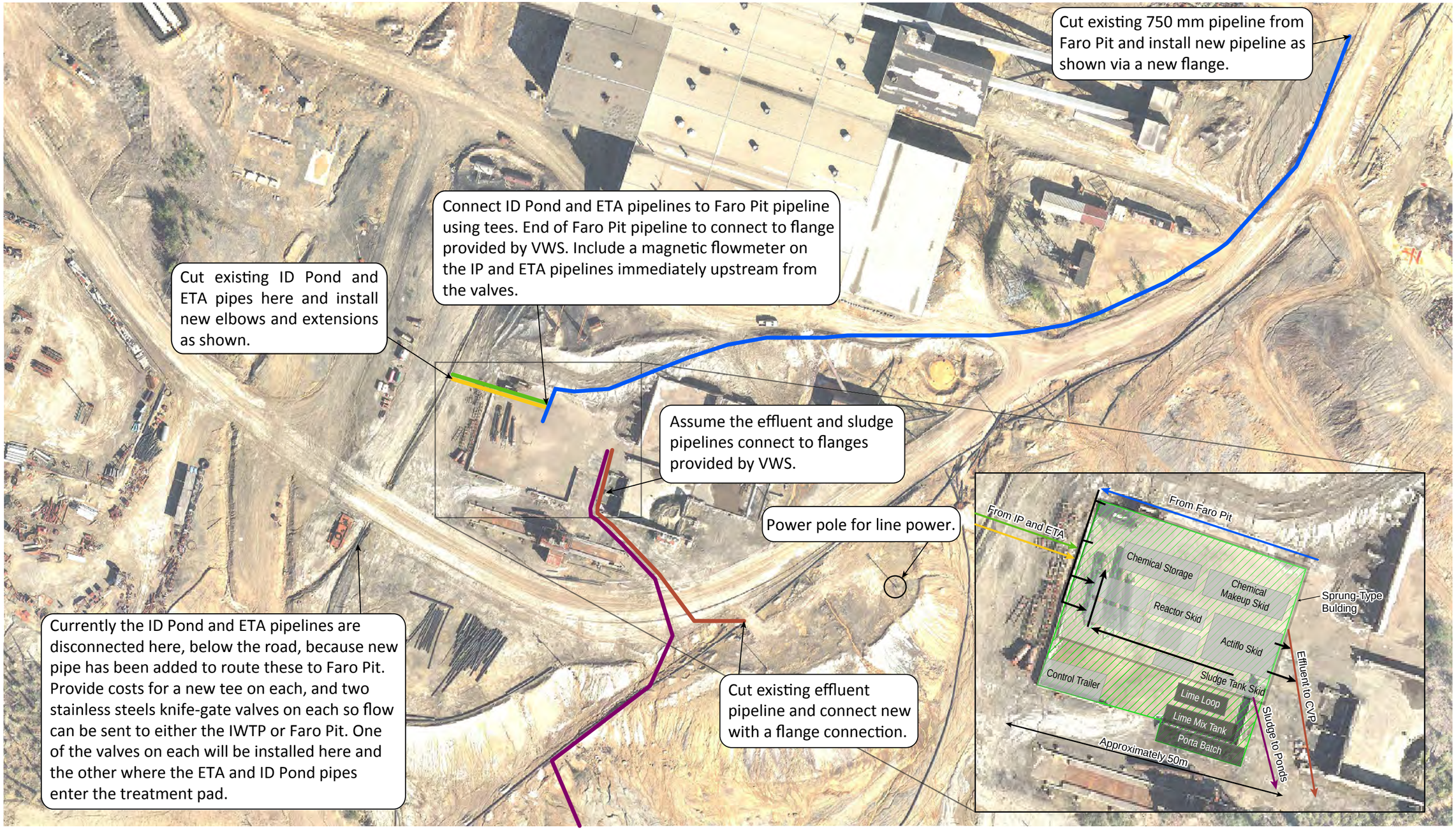


FIGURE 5-2
S-Wells SIS Layout
Faro Mine Interim Works

Source: SRK Consulting Engineers and Scientists (SRK). 2010. 2009. Prepared for Denison Environmental Services. March.



LEGEND

- 750 mm Faro Pit at 350 m
- 350 mm ID Pond at 36 m
- 240 mm ETA at 36 m 500 mm
- Effluent at 100 m 200 mm
- Sludge at 240 m
- Package 1

North

0 100 200

Approximate scale in feet

Note: Assume all are SDR 17 HDPE

Source: CH2M HILL 2014 – CH2M HILL Canada Limited (CH2M HILL). 2014.

FIGURE 5-3
Layout of Interim Water Treatment System
Faro Mine Interim Works

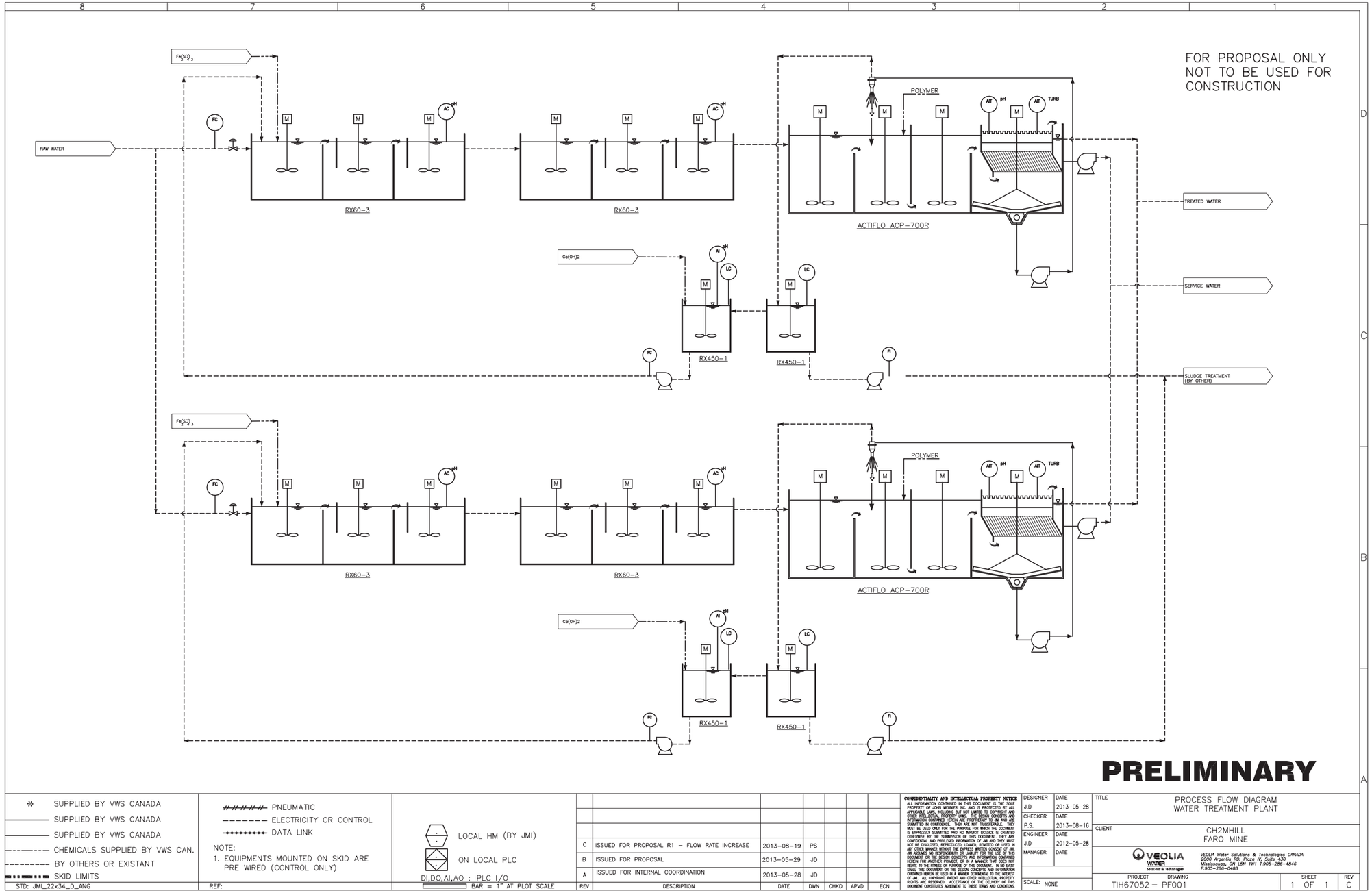
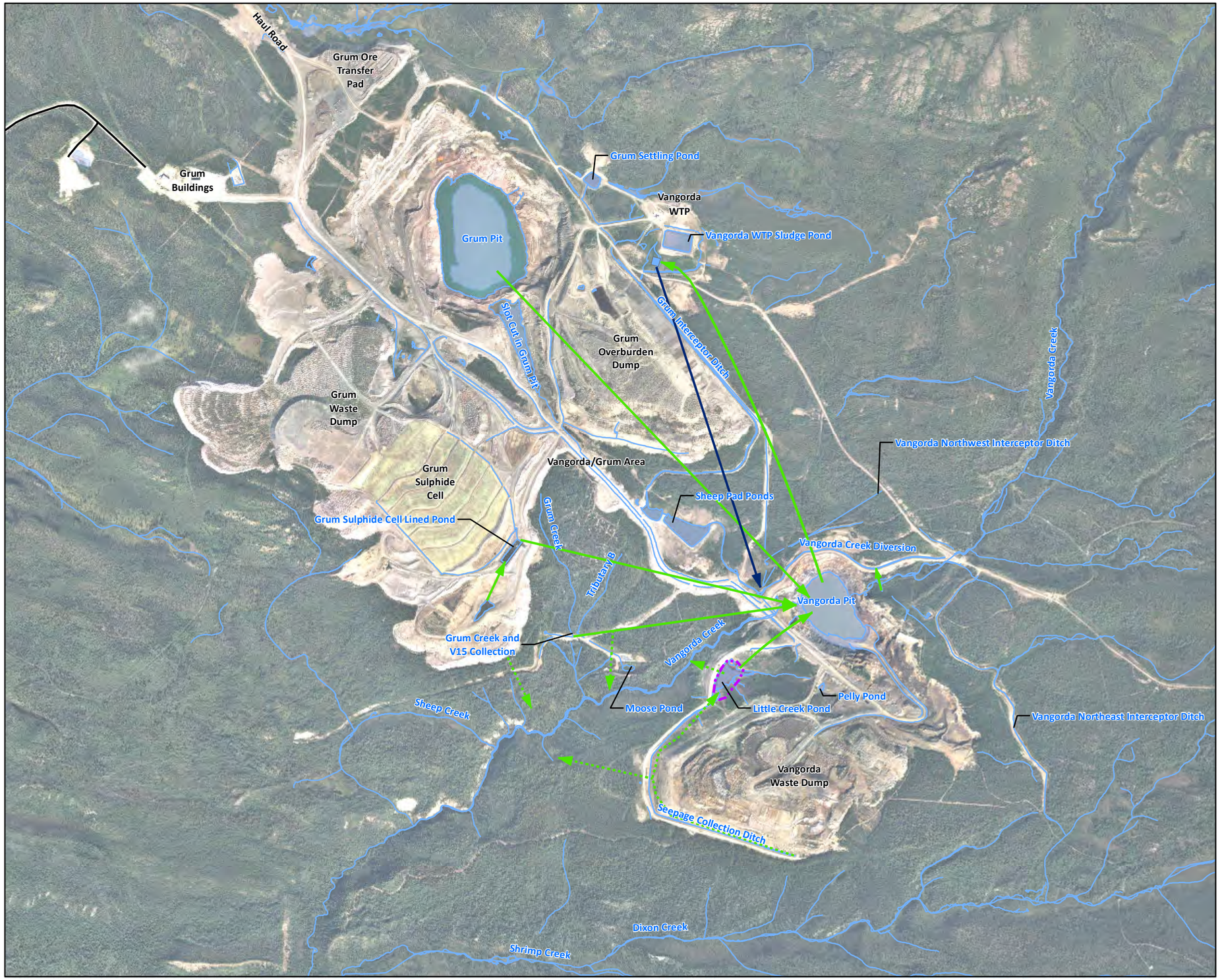


FIGURE 5-4
Process Flow Diagram of Interim Water Treatment System
Faro Mine Interim Works

Source: CH2M HILL Canada Limited (CH2M HILL). 2013.
Prepared for Government of Yukon. October 4.



VICINITY MAP



LEGEND

- Water to Pit or Treatment
- Seepage Bypassing Current Collection
- Treated Water Discharge (via Grum Interceptor Ditch and Sheep Pad Ponds)
- Installed Surface Water Collection
- Water Treatment Plant

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Faro = Town of Faro

N

0 250 500 750 1,000
Metres

Created by: CRITIGEN

FIGURE 5-5
Vangorda/Grum Mine Area
Faro Mine Interim Works

CH2MHILL

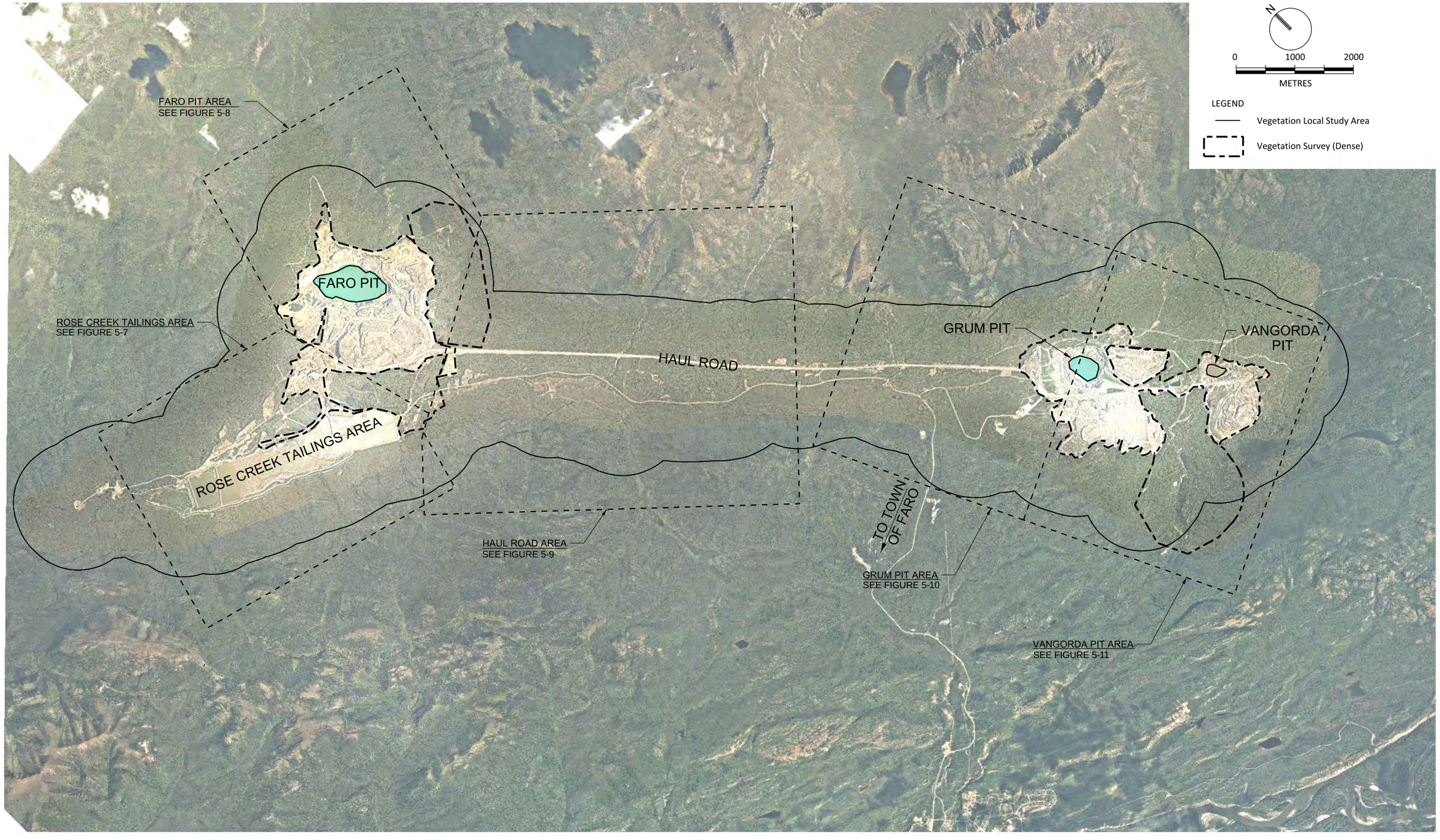
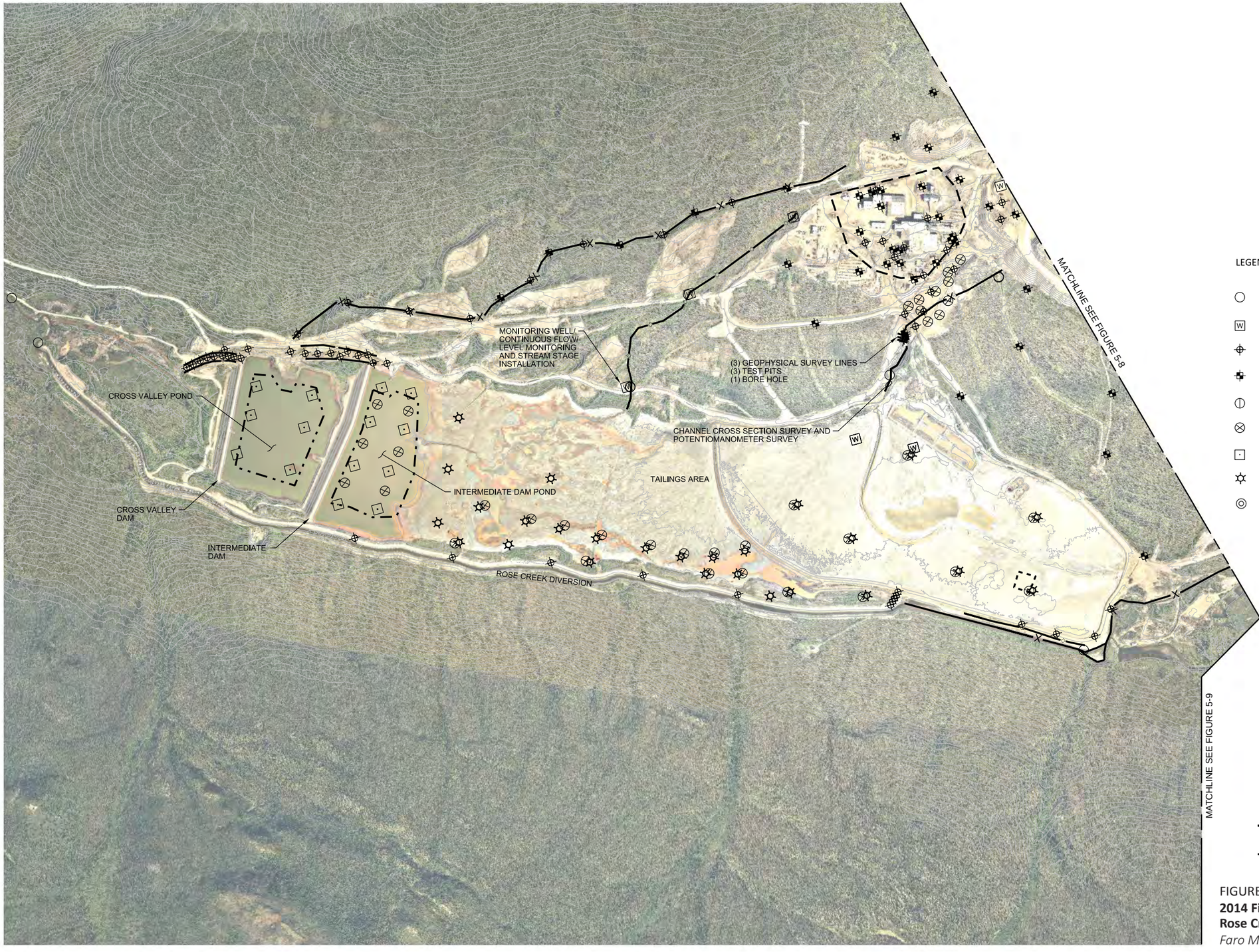


FIGURE 5-6
Figure Kep Map
Faro Mine Interim Works



N

0 300 600

METRES

TOPOGRAPHY IS BASED ON OCT. 2001 LIDAR AND AERIAL PHOTO DATED AUG. 2012
HORIZONTAL DATUM: NAD83 CSRS
VERTICAL DATUM: CGVD28 (HTv2.0)

Note:

Locations are approximate. Final locations will be set in field.

LEGEND

- Continuous Flow/Level Monitoring Location
- Monitoring Well/Piezometer Location
- Borehole Location
- Test Pit Location
- New Stream Stage Installation Location
- Cone Penetrometer Location
- Vibrocore Sediment Sample Location
- Direct-Push Drilling Location
- Surface Soil Sample Location
- Bathymetric Survey With Sub-Bottom Geophysics
- Field Reconnaissance / Utility Locate
- Instrumented Cover Trail
- Geophysical Survey
- Channel Cross-Section Survey And Potentiomanometer Survey

FIGURE 5-7
2014 Field Sampling Plan – Rose Creek Tailings Area
Faro Mine Interim Works

CH2MHILL®

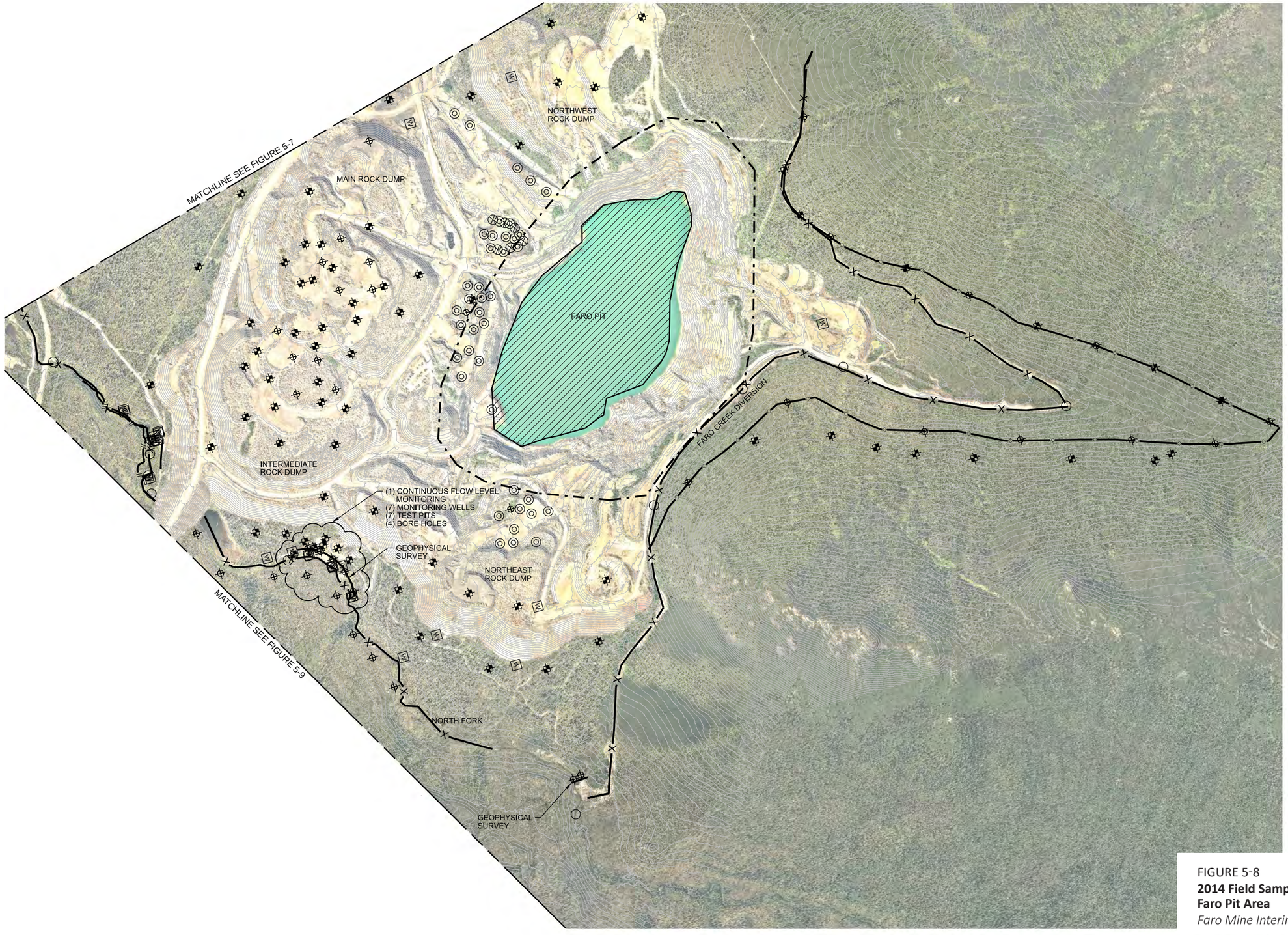
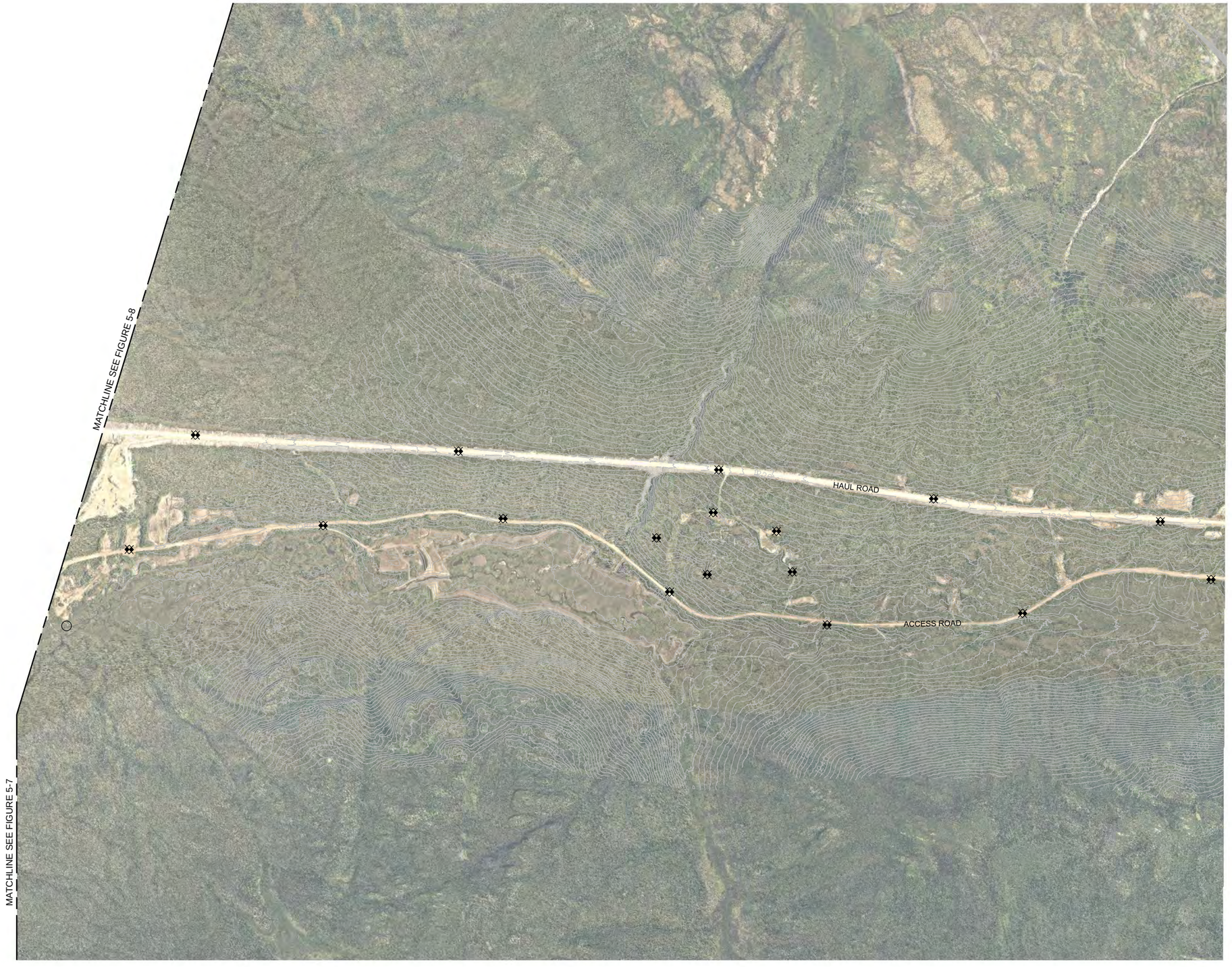


FIGURE 5-8
2014 Field Sampling Plan – Faro Pit Area
Faro Mine Interim Works



N

0 200 400 600 800

METRES

TOPOGRAPHY IS BASED ON OCT. 2011 LIDAR AND AERIAL PHOTO DATED AUG. 2012
HORIZONTAL DATUM: NAD83 CSRS
VERTICAL DATUM: CGVD28 (HTv2.0)

Note:

Locations are approximate. Final locations will be set in the field.

LEGEND

- Test Pit Location
- Continuous Flow/Level Monitoring Location

FIGURE 5-9
2014 Field Sampling Plan – Haul Road Area
Faro Mine Interim Works

CH2MHILL®



N

0 300 600

METRES

TOPOGRAPHY IS BASED ON OCT. 2001 LIDAR AND AERIAL PHOTO DATED AUG. 2012
HORIZONTAL DATUM: NAD83 CSRS
VERTICAL DATUM: CGVD28 (HTv2.0)

Note:

Locations are approximate. Final locations will be set in field.

LEGEND

- Test Pit Location
- Monitoring Well/Piezometer Location
- Borehole Location
- New Stream Stage Installation Location
- Bathymetric Survey / Pit Lake Profiling / Seasonal Sampling
- Field Reconnaissance / Utility Locate
- Geological Reconnaissance

FIGURE 5-10
2014 Field Sampling Plan – Grum Pit Area
Faro Mine Interim Works

CH2MHILL®



N

0 300 600

METRES

TOPOGRAPHY IS BASED ON OCT. 2001 LIDAR AND AERIAL PHOTO DATED AUG. 2012
HORIZONTAL DATUM: NAD83 CSRS
VERTICAL DATUM: CGVD28 (HTv2.0)

Note:

Locations are approximate. Final locations will be set in field.

LEGEND

- Continuous Flow/Level Monitoring Location
- Monitoring Well/Piezometer Location
- Borehole Location
- New Stream Stage Installation Location
- Test Pit Location
- Bathymetric Survey / Pit Lake Profiling / Seasonal Sampling
- Geological Reconnaissance / Stability Evaluation
- Potentiomanometer Survey
- Geophysical Survey
- Channel Cross-Section Survey And Potentiomanometer Survey

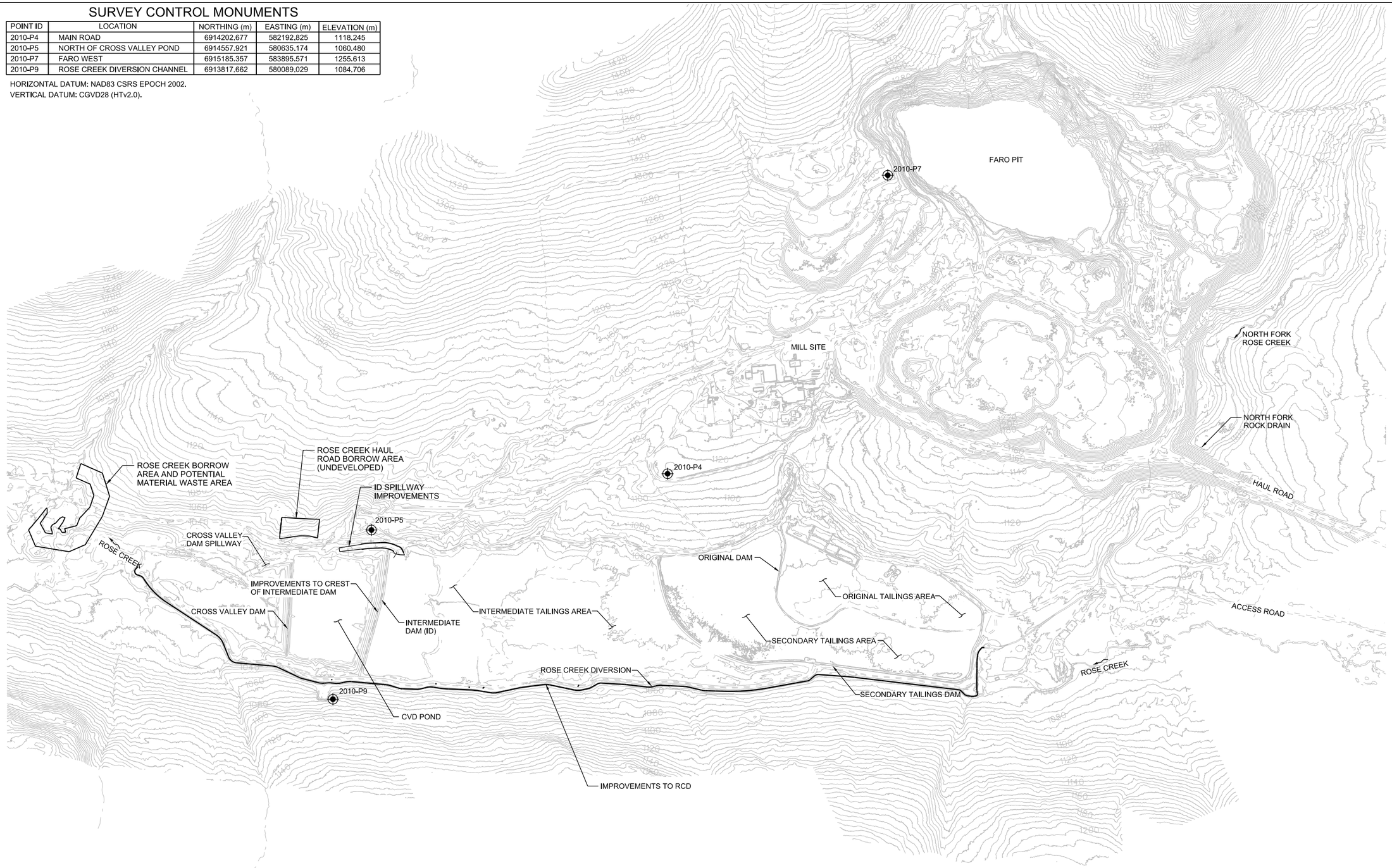
FIGURE 5-11
2014 Field Sampling – Vangorda Pit Area
Faro Mine Interim Works

CH2MHILL®

SURVEY CONTROL MONUMENTS

POINT ID	LOCATION	NORTHING (m)	EASTING (m)	ELEVATION (m)
2010-P4	MAIN ROAD	6914202.677	582192.825	1118.245
2010-P5	NORTH OF CROSS VALLEY POND	6914557.921	580635.174	1060.480
2010-P7	FARO WEST	6915185.357	583895.571	1255.613
2010-P9	ROSE CREEK DIVERSION CHANNEL	6913817.662	580089.029	1084.706

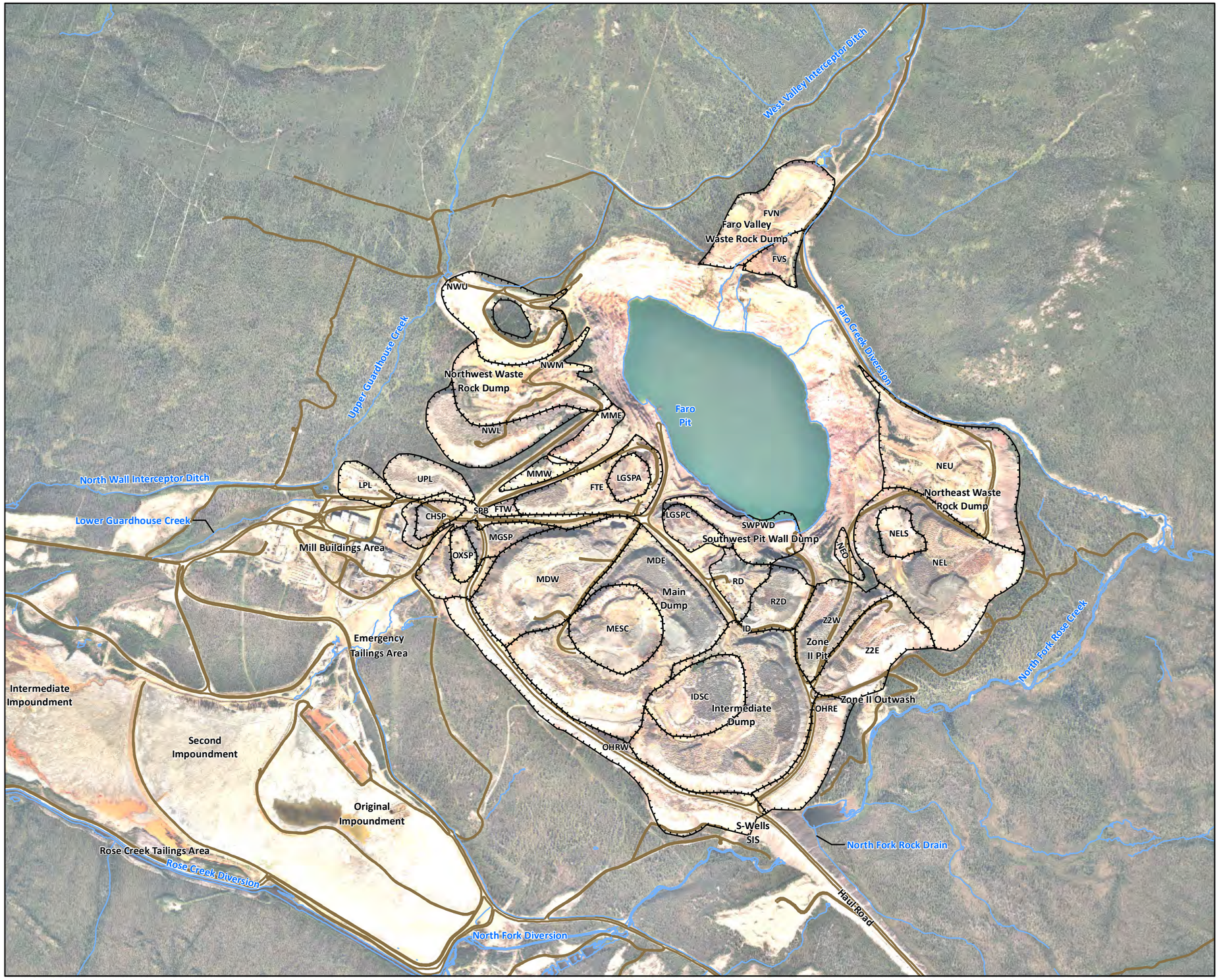
HORIZONTAL DATUM: NAD83 CSRS EPOCH 2002.
VERTICAL DATUM: CGVD28 (HTv2.0).



PLAN
SCALE: 1:20,000
CONTOUR INTERVAL 5m

FIGURE 5-12
Down Valley Interim Hydraulic Upgrade Project
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Waste Dump

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Rose Creek Tailings Area is also called Down Valley Tailings Area, and is where the Rose Creek Alluvial Aquifer is located.
4. Waste Dump Definitions:

CHSP - Crusher Stockpile
FTE - Fuel Tank East
FTW - Fuel Tank West
FVN - Faro Valley North
FVS - Faro Valley South
ID - Intermediate Dump
IDSC - Intermediate Dump Sulphide Cell
LGSPA - Low Grade Stockpile A
LGSPC - Low Grade Stockpile C
LPL - Lower Parking Lot
MDE - Main Dump East
MDW - Main Dump West
MESC - Main Dump Sulphide Cell
MGSP - Medium Grade Stockpile
MME - Mt. Mungly East
MMW - Mt. Mungly West
NEL - Northeast Lower
NELS - Northeast Lower Sulphide Cell
NEO - Northeast Outer
NEU - Northeast Upper
NWL - Northwest Lower
NWM - Northwest Middle
NWU - Northwest Upper
OHRE - Outer Haul Road East
OHRW - Outer Haul Road West
OXSP - Oxide Fines Stockpile
RD - Ranch Dump
RZD - Ramp Zone Dump
SPB - Stock Piles Base
SWPWD - Southwest Pit Wall Dump
UPL - Upper Parking Lot
Z2E - Zone II East
Z2W - Zone II West

N

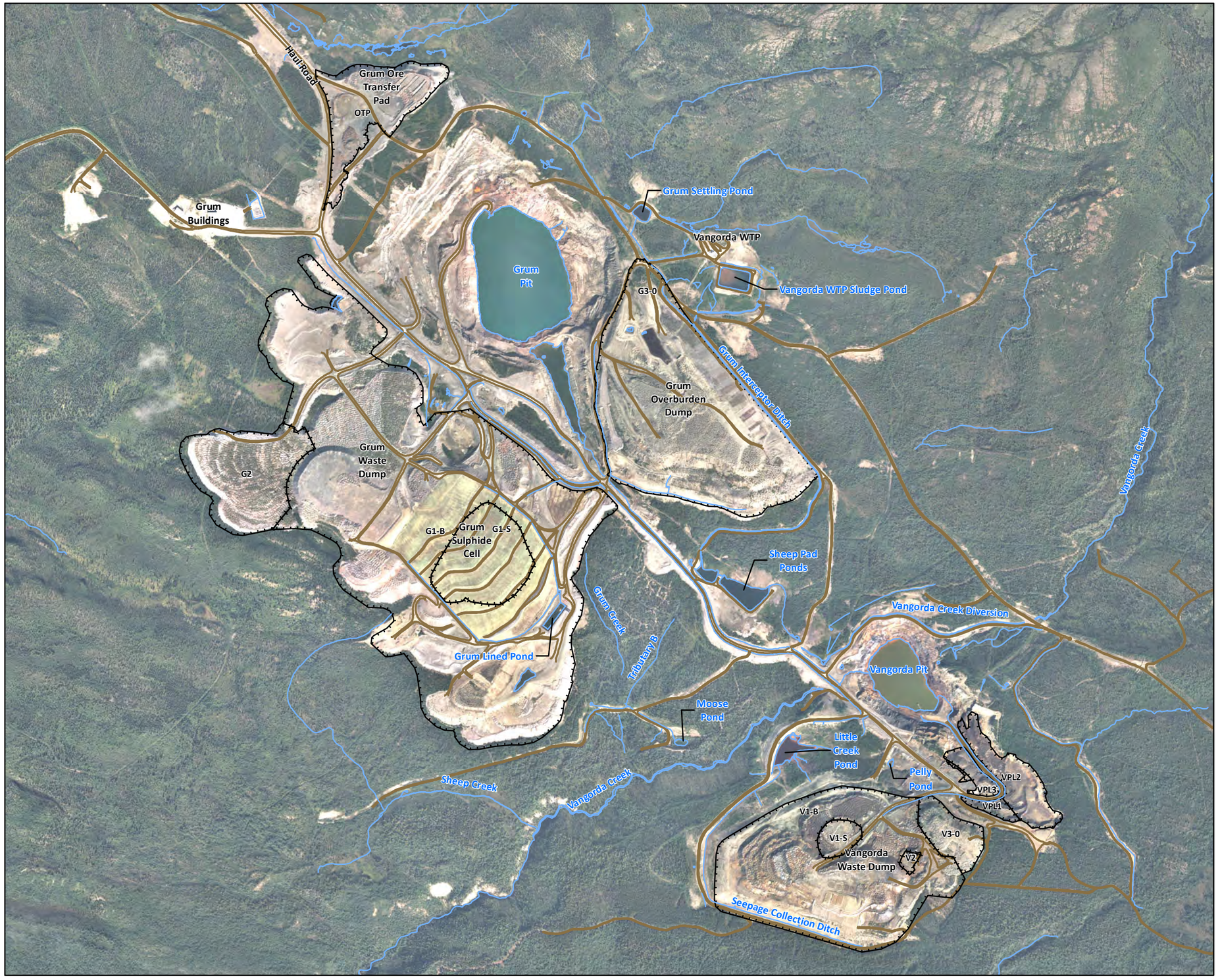
0 250 500 750 1,000

Metres

Created by:
CRITIGEN

FIGURE 6-1
Faro Waste Dump Footprints
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Waste Dump

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Waste Rock Definition:
   - G1-B - Grum Main Dump
   - G1-S - Grum Main Sulphide Cell
   - G2 - Grum Southwest Dump
   - G3-0 - Grum Overburden Dump
   - OTP - Ore Transfer Pad
   - V1-B - Vangorda Main Dump
   - V1-S - Vangorda Main Sulphide Cell
   - V2 - Vangorda Baritic Fines Dump
   - V3-0 - Vangorda Overburden Dump
   - VPL1 - Dump Southeast of Ramp
   - VPL2 - Dump inside Hairpin
   - VPL3 - Oxide Fines Dump

N

0 250 500 750 1,000

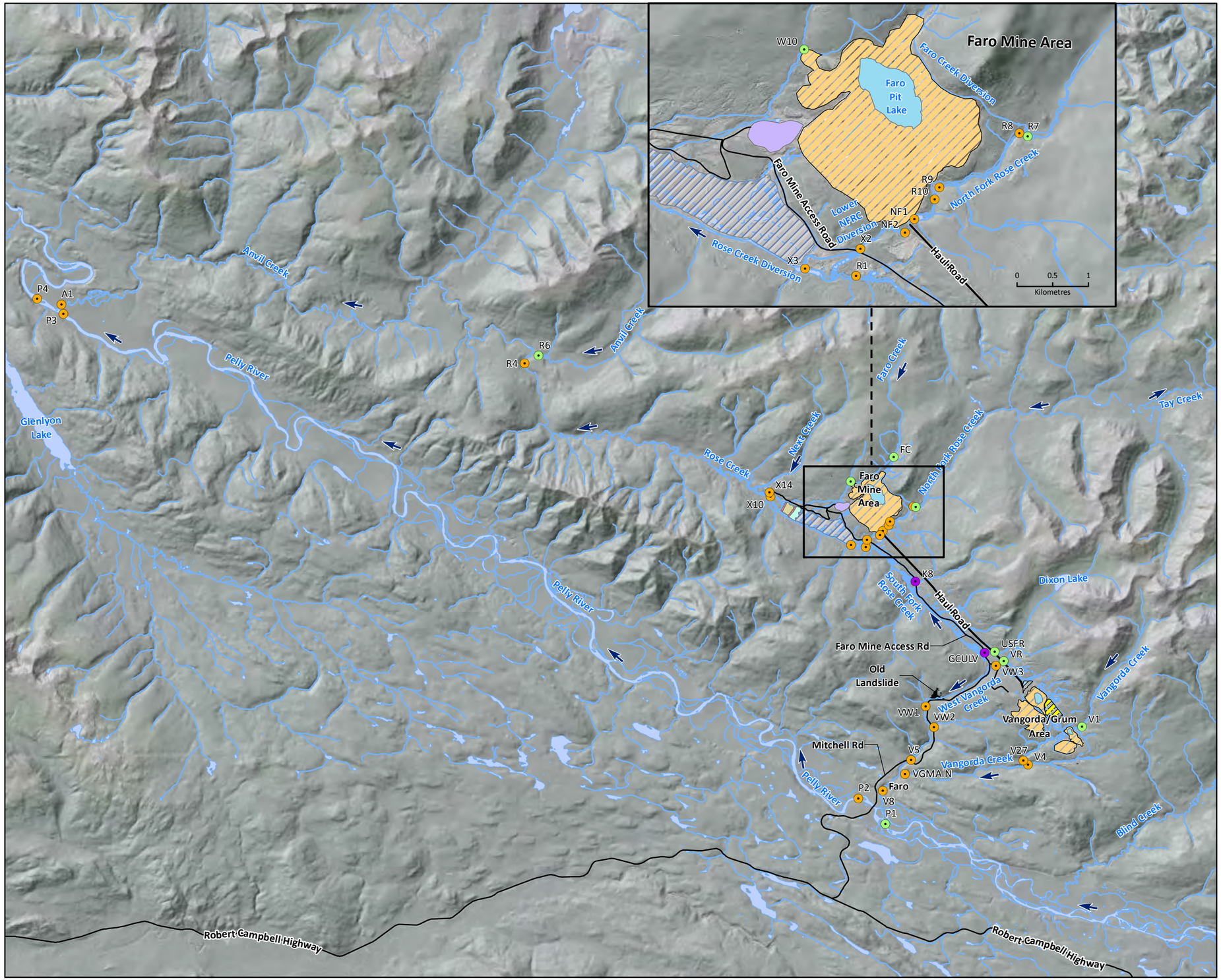
Metres

Created by: CRITIGEN

FIGURE 6-2

Vangorda/Grum Area Waste Dump Footprints

Faro Mine Interim Works



VICINITY MAP



LEGEND

Water Monitoring Station:

- Mine-Exposed
- Reference
- Historical First Nations Drinking Water Location

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

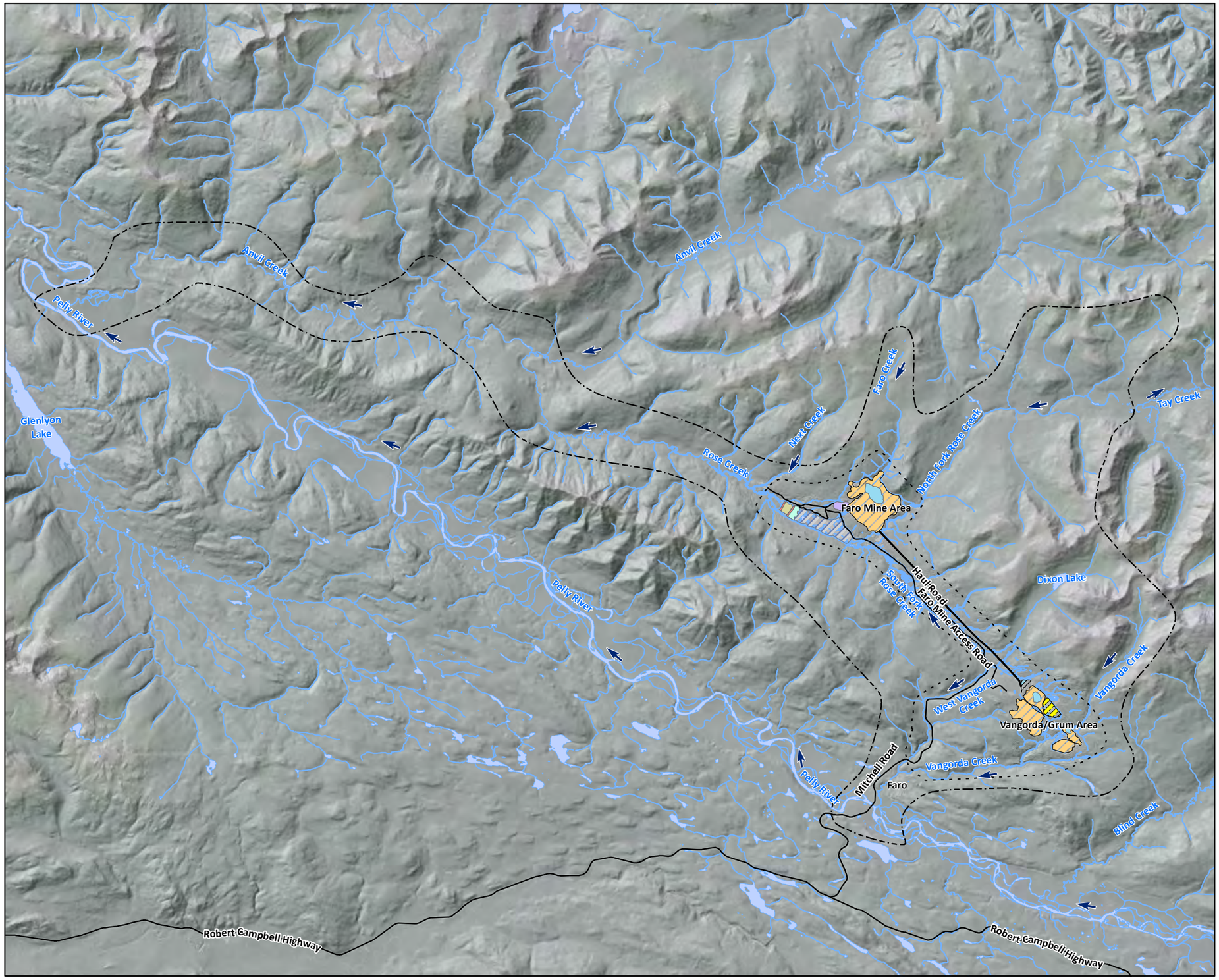
1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

N

0 5 10
Kilometres

Created by:
CRITIGEN

FIGURE 6-3
Locations of Reference and Mine-Exposed Water Monitoring Stations
Faro Mine Interim Works



VICINITY MAP



LEGEND

- Aquatic Local Study Area
- Aquatic Regional Study Area

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

N

0 5 10

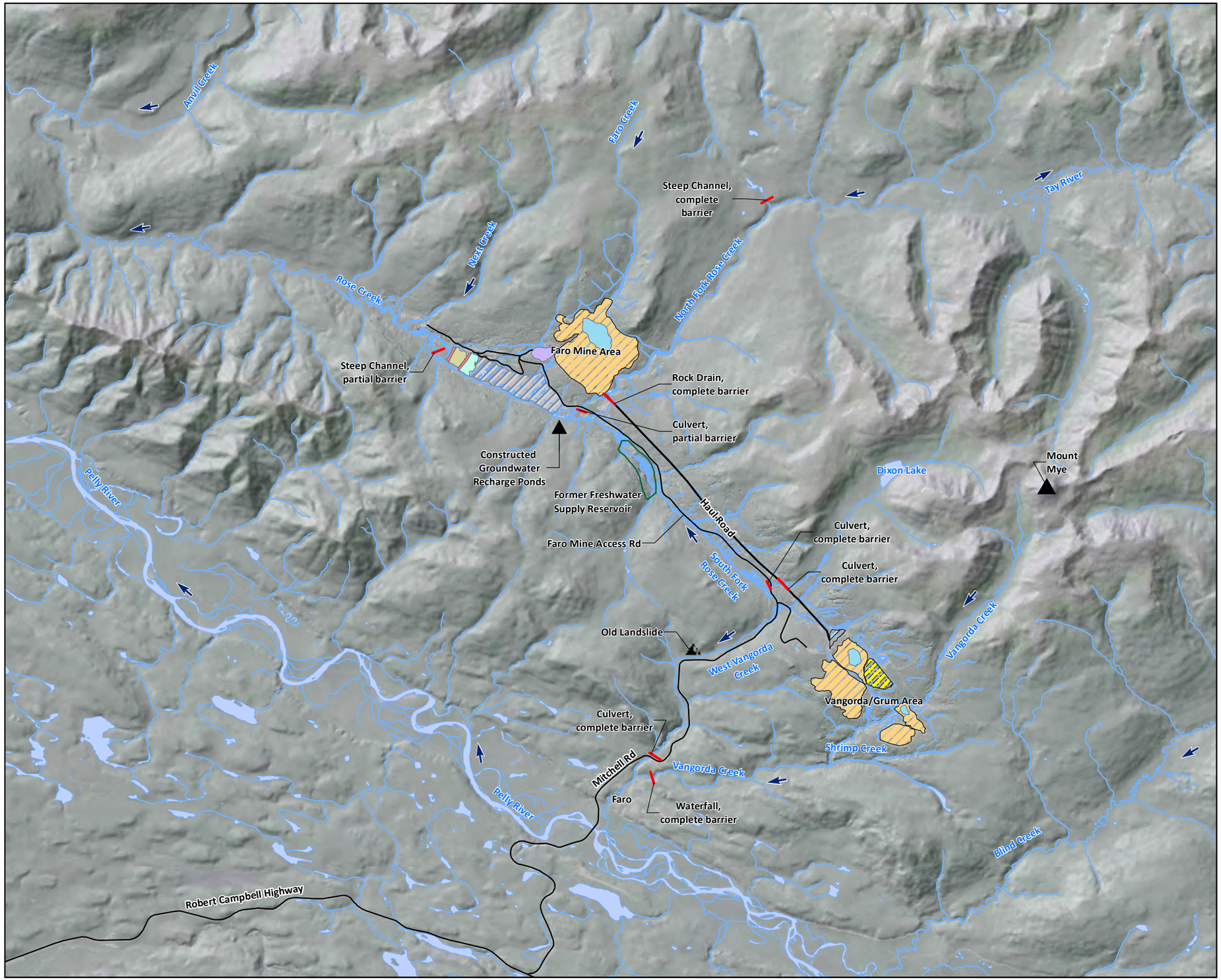
Kilometres

Created by: CRITIGEN

FIGURE 6-4

Aquatic Regional and Local Assessment Study Area

Faro Mine Interim Works



VICINITY MAP



LEGEND

- Mountains
- Barrier to Fish Migration
- Direction of Flow

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

N

0 2.5 5

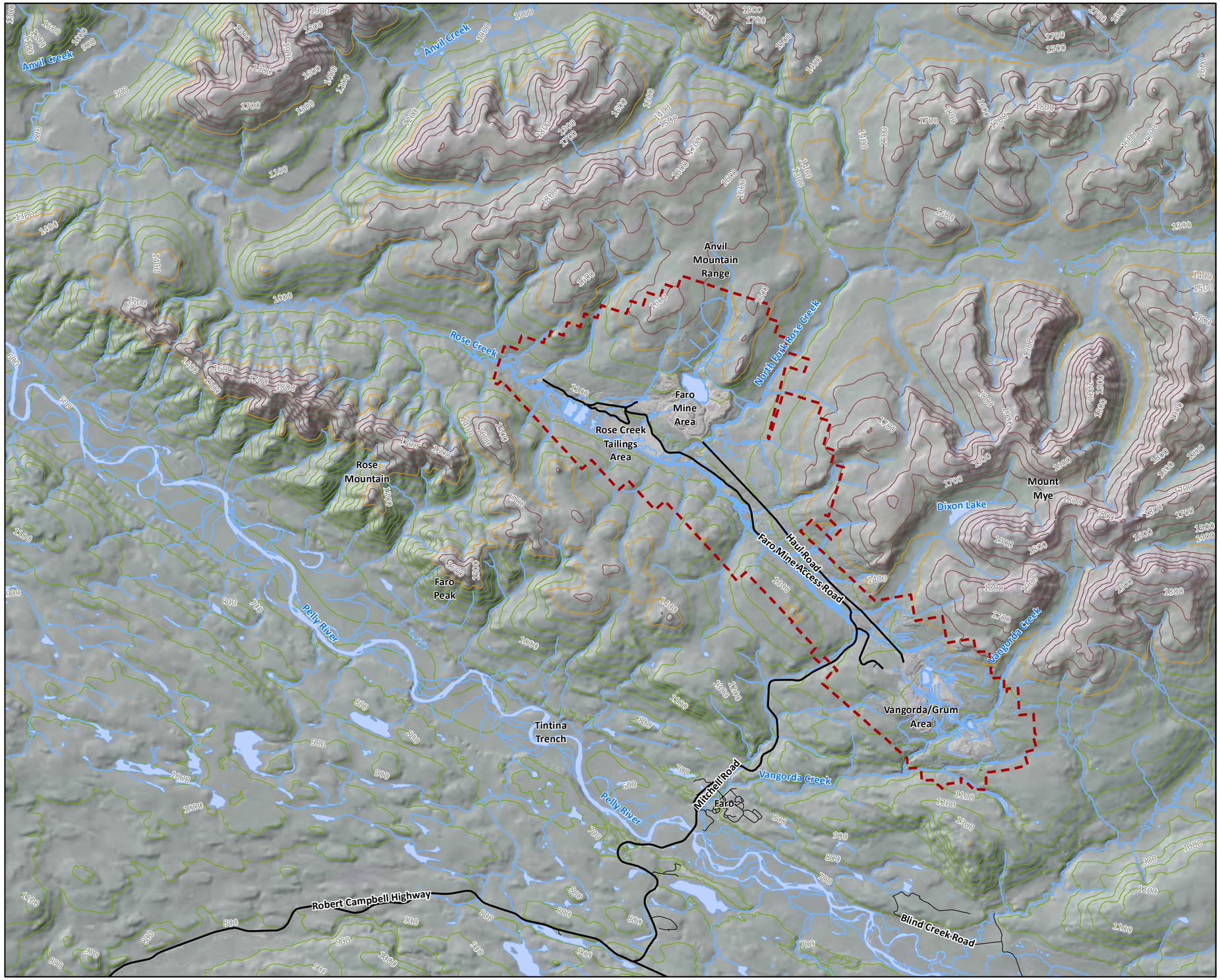
Kilometres

Created by: CRITIGEN

FIGURE 6-5

Habitat Features of Rose and Vangorda Creeks

Faro Mine Interim Works



VICINITY MAP



Legend

- Impacted Area

Ecosystem Zones

- Boreal Zone (<1450 m asl)
- Supalpine Zone (1450 m - 1550 m asl)
- Alpine Zone (>1550 m asl)

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

N

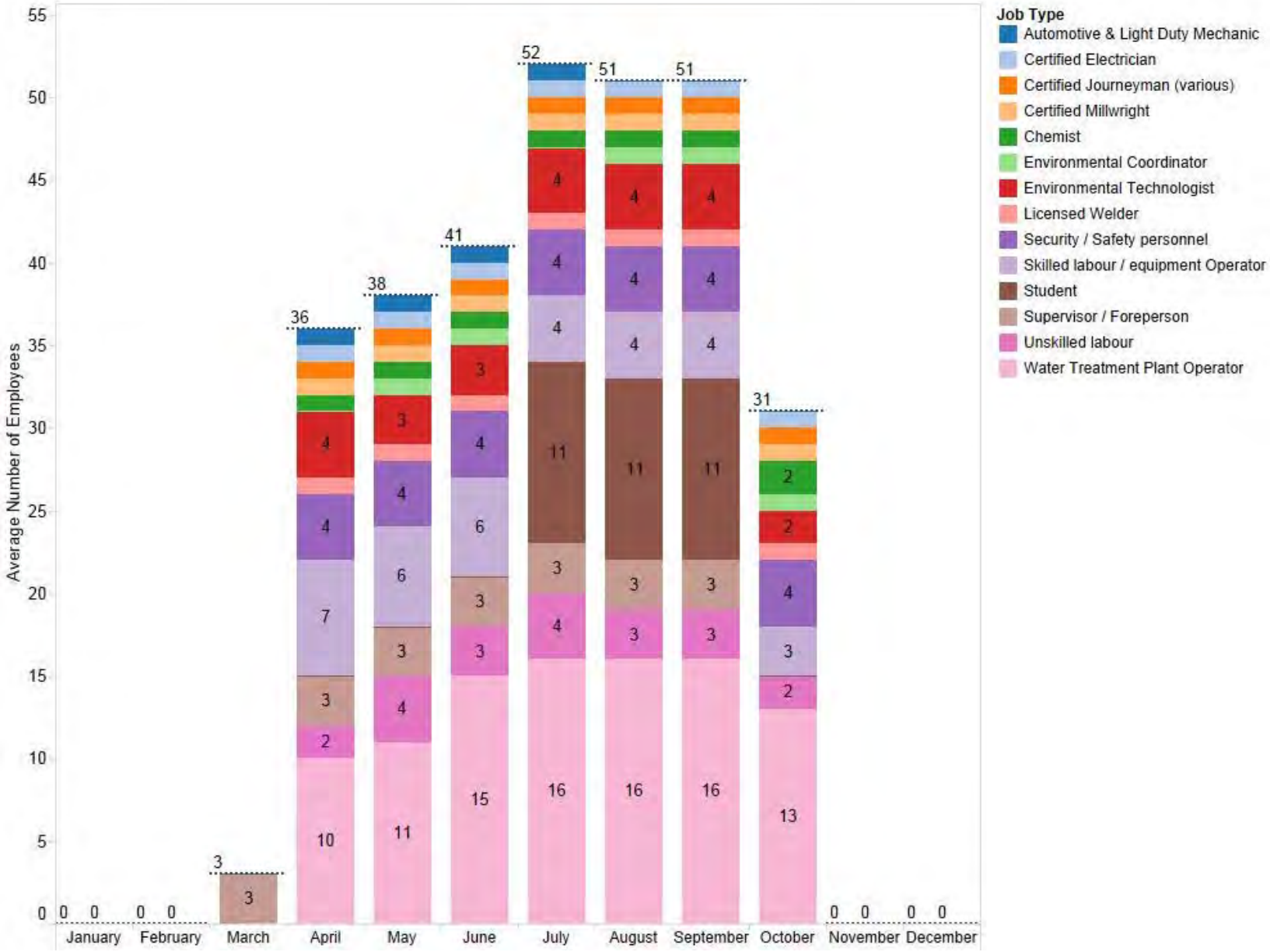
0 1,250 2,500 3,750 5,000

Metres

Created by: CRITIGEN

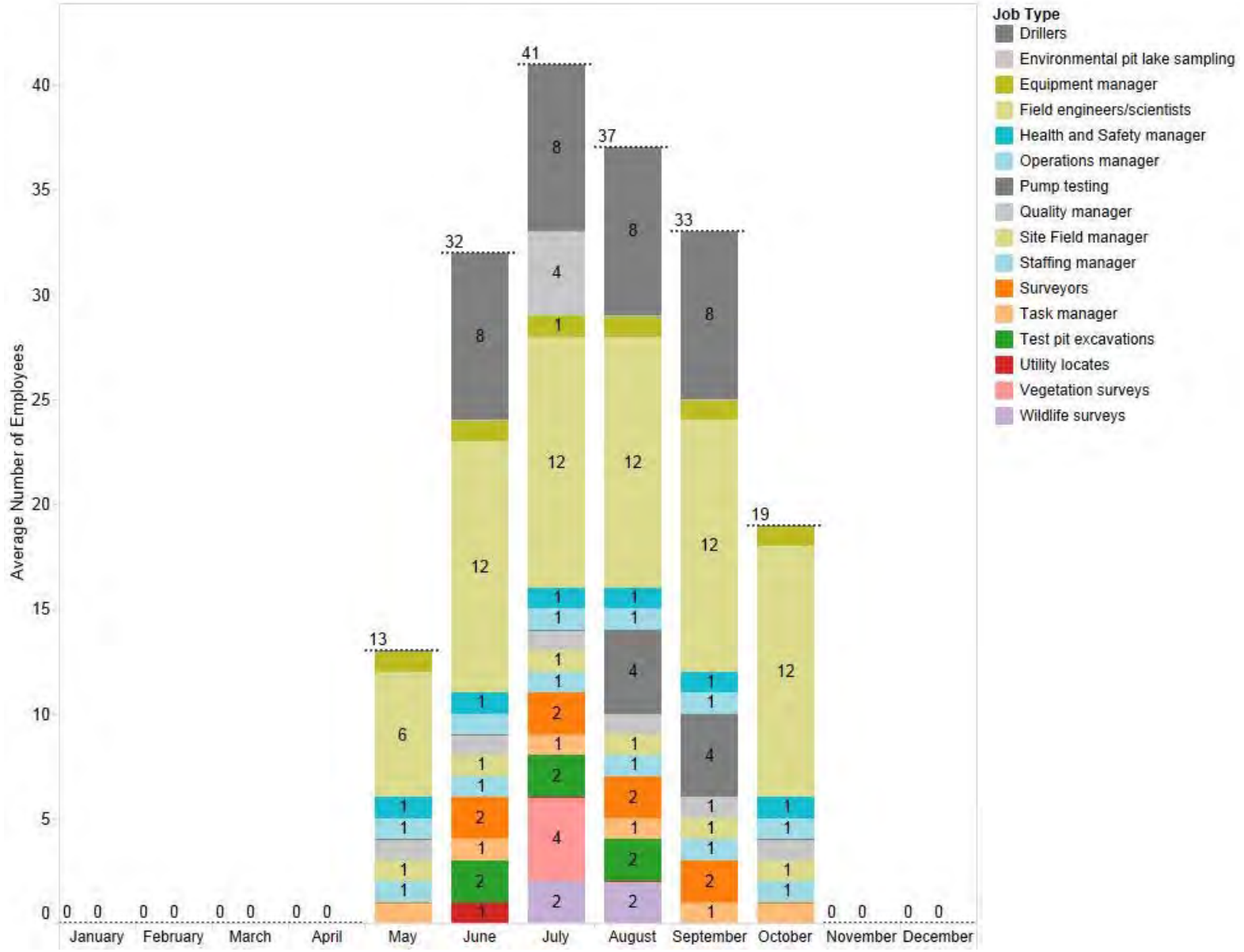
FIGURE 6-6
General Physiography
Faro Mine Interim Works

FIGURE 7-1
Faro Interim Works 2014 Site Operations
Average Number of Employees by Month and Job Type
Faro Mine Interim Works



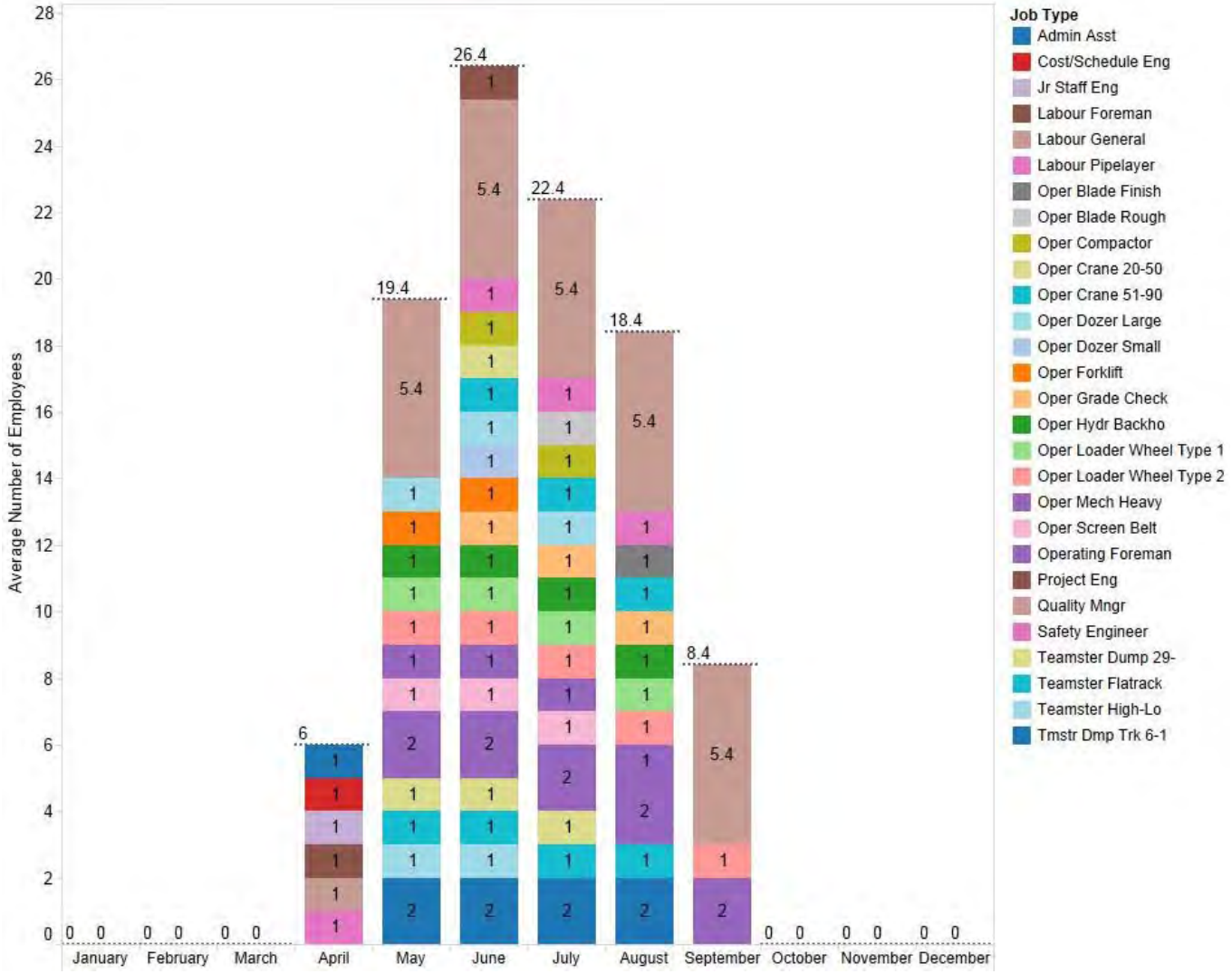
Source: CH2M HILL, 2013c

FIGURE 7-2
Faro Interim Works 2014 Site Investigations
Average Number of Employees by Month and Job Type
Faro Mine Interim Works



Source: CH2M HILL, 2013b

FIGURE 7-3
Faro Interim Works 2016 Down Valley Interim Hydraulic Upgrades
Average Number of Employees by Month and Job Type
Faro Mine Interim Works



Source: CH2M HILL, 2013d

Notes:

Admin Asst=Administrative Assistant
Cost/Schedule Eng=Cost/Schedule Engineer
Jr Staff Eng=Junior Staff Engineer
Oper=Operator
Oper Hydr Backho=Operator Hydraulic Backhoe
Oper Mech Heavy=Operator Mechanical Heavy
Project Eng=Project Engineer
Quality Mgr=Quality Manager
Tmstr Dmp Trk 6-1=Teamster Dump Truck 6-1

Appendix 3A
Supporting Documentation of Engagement Activities

Attachment 3A-1
Faro Mine: Arriving at a Closure Plan Presentation, January 2008



Faro Mine Closure

Arriving at a Closure Plan


Mill buildings


Faro Pit and Waste Rock


Tailings Impoundment


Vangorda Plateau

January 2008

Faro Mine Closure
Fermeture de la mine Faro



Faro Mine Closure - History

1969 - The Faro Mine officially opened.

1998 - The mine's final owner was placed into receivership and all mining operations stopped.

2003 - The federal and Yukon governments acknowledged that the mine would not reopen. With the Ross River Dena Council (on behalf of the Kaska Nation) and Selkirk First Nation, they began working together to develop a closure and remediation plan for the Faro Mine Complex.



Closure planning over the years

Many different plans have been proposed for addressing the environmental issues at the Faro Mine Complex:

1981 Tailings Abandonment Plan

1988 Curragh Resources Abandonment Submission

1991 Down Valley Tailings Abandonment Plan

1996 Integrated Comprehensive Abandonment Plan (ICAP)



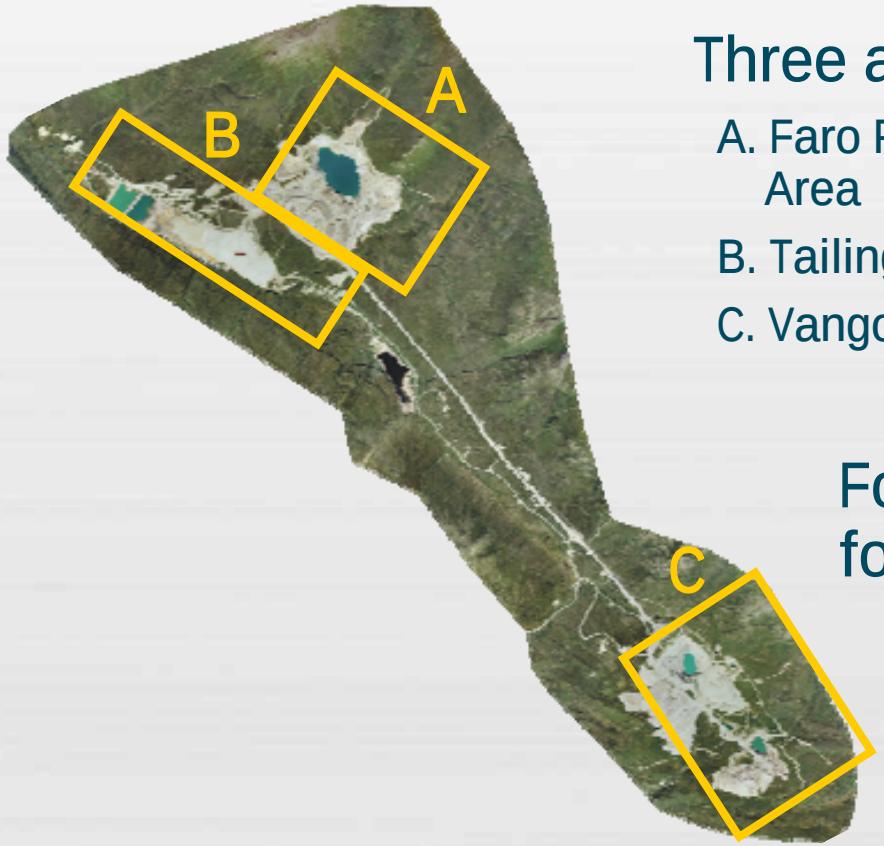
Understanding the issues

To create a complete **final closure and remediation plan**, we gathered and studied information on a wide range of environmental issues.

- From 2002 to 2005 - conducted technical workshops with consultants, governments (federal, territorial, First Nation, municipal), regulatory agencies, and others.
- From 2003 to 2006 - completed over 90 technical studies.

2006 - Example Alternatives

From the studies and the workshop results, we created 12 “example alternatives”.



Three areas

A. Faro Pit and Waste Rock Area

B. Tailings Area

C. Vangorda/Grum Area

Four alternatives for each area

12 total



2007 – Further Narrowing the Options

During 2006 and 2007, the 12 example alternatives were subject to:

- Independent Peer Review
- Community input
- Further technical studies

This allowed us to refine and condense the

12 example alternatives

into

5 closure options

2007 - Closure Options

We now have 5 closure options.



Two areas

A. Faro Mine Area
(this combines the Faro Pit and Waste Rock with the Tailings Area)

B. Vangorda/Grum Area

3 options for the Faro Mine Area

2 options for the Vangorda/Grum Area

5 total



2007 – 5 Closure Options in Two Areas

Combined Faro Mine Area

Move All Tailings	+	Upgrade Faro Creek Diversion and Cover/Revegetate Faro Waste Rock
or		
Cover Tailings with Soil	+	Upgrade Faro Creek Diversion and Cover/Revegetate Faro Waste Rock
or		
Move Some Tailings and Cover Some Tailings with Soil	+	Upgrade Faro Creek Diversion and Cover/Revegetate Faro Waste Rock

= 3 Combined Options

Vangorda/Grum Mine Area

Move Vangorda Waste Rock into Vangorda Pit

or

Cover Vangorda Waste Rock in Place

= 2 Options



Common Elements of the Options (1)

Any overall closure plan for the Faro Mine Complex will include some common things:

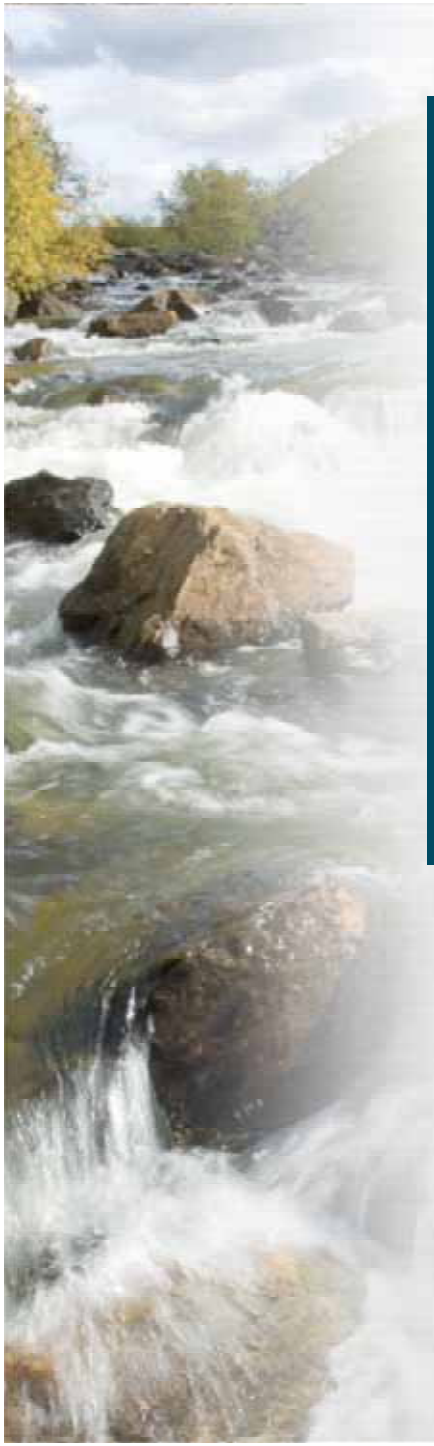
- Resloping and covering waste rock
- Revegetation of soil covers and other areas
- Diversion of clean water around the site
- Long-term collection and treatment of contaminated water
- Long-term management of water treatment sludge
- Long-term storage of water in pits
- Long-term maintenance of remaining site facilities (diversions, covers, water collection systems, water treatment systems, dams, etc.)
- Long-term monitoring of environmental conditions (water, animals, plants, climate, etc.)



Common Elements of the Options (2)

All of the closure options for the Faro Mine Complex are designed to do the following:

- Avoid unacceptable risks to public health and safety
- Avoid unacceptable risks to worker health and safety
- Meet appropriate environmental standards and guidelines, etc.



Combined Faro Mine Area Option 1

Upgrade Faro Creek diversion
Reslope, cover and revegetate Faro waste rock
Move all tailings

Estimated Jobs: 975 person years

Estimated Cost: $590 M

Combined Faro Mine Area Option 1:
Upgrade Faro Creek Diversion / Cover Faro Waste Rock

Closure Approach

What is involved?

- Build new diversion channel for Faro Creek
- Remove North Fork Rock Drain
- Build lined channel for North Fork Rose Creek
- Waste Rock
  - Reslope and cover with soil
  - Possibly move some waste rock to Faro Pit
- Revegetate covered waste rock
- Move tailings from Emergency Tailings Area to Faro Pit or Tailings Area.
- Collect and treat contaminated water from below waste rock, Zone 2 Pit and in Faro Pit (100s of years)
- Maintain covers and channels (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $150M

Estimated employment: 230 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.



Before remediation (Now)



Image for illustration purposes only

After remediation (approximately 40 years time)

Combined Faro Mine Area Option 1:
Move all tailings

Move All Tailings to Faro Pit

What is involved?

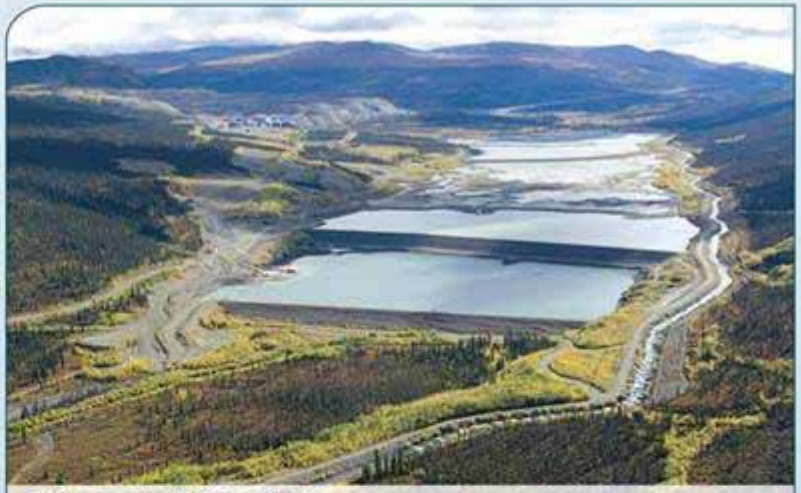
- Mix tailings with lime and water
- Pump tailings to Faro Pit
- Clean up remaining tailings with trucks and loaders
- Collect and treat contaminated water from under tailings (20 years?)
- Cut through dams and revegetate valley
- Construct channel for Rose Creek and put Rose Creek back in the valley when soil and water are clean
- May have to collect and treat contaminated water from mine area in Rose Creek Valley (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $440M

Estimated employment: 745 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.

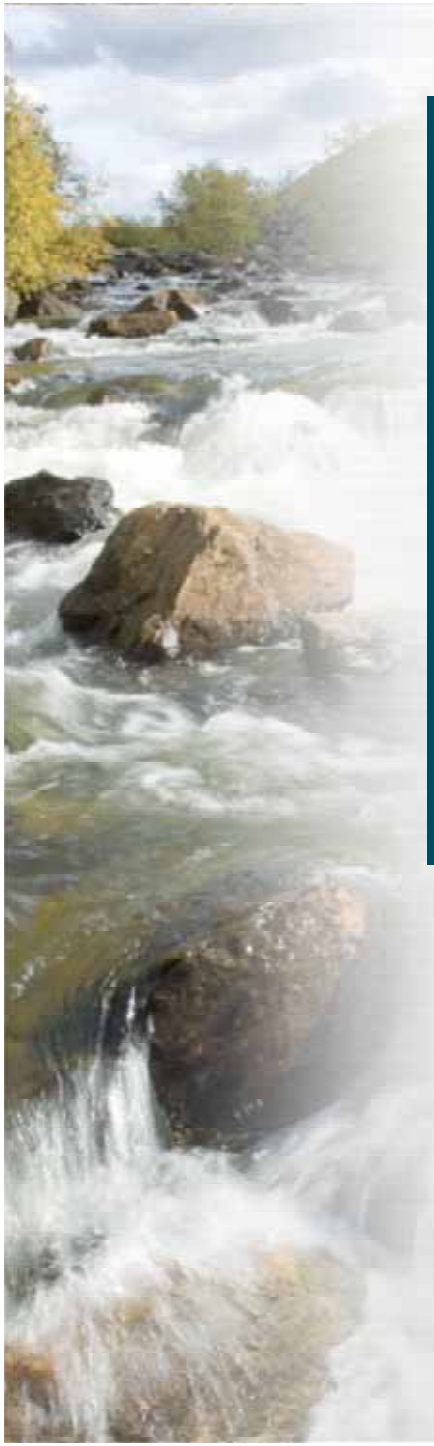


Before remediation (Now)



Image for illustration purposes only.

After remediation (approximately 40 years time)



Combined Faro Mine Area Option 2

Upgrade Faro Creek diversion
Reslope, cover and revegetate Faro waste rock
Cover tailings with soil

Estimated Jobs: 566 person years

Estimated Cost: $410 M

Combined Faro Mine Area Option 2:
Upgrade Faro Creek Diversion / Cover Faro Waste Rock

Closure Approach

What is involved?

- Build new diversion channel for Faro Creek
- Remove North Fork Rock Drain
- Build lined channel for North Fork Rose Creek
- Waste Rock
  - Reslope and cover with soil
  - Possibly move some waste rock to Faro Pit
- Revegetate covered waste rock
- Move tailings from Emergency Tailings Area to Faro Pit or Tailings Area.
- Collect and treat contaminated water from below waste rock, Zone 2 Pit and in Faro Pit (100s of years)
- Maintain covers and channels (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $150M

Estimated employment: 230 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.



Before remediation (Now)



* Image for illustration purposes only.

After remediation (approximately 40 years time)

Combined Faro Mine Area Option 2:
Cover tailings with soil

Cover Tailings with Soil

What is involved?

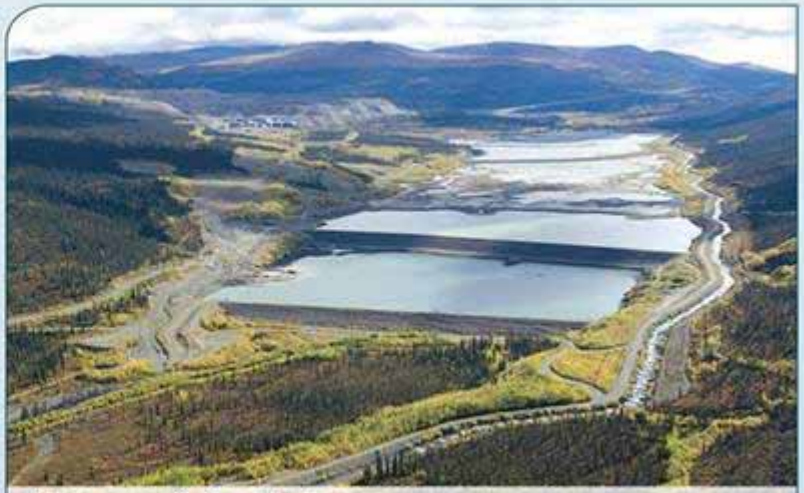
- Remove Cross-Valley Dam or change/upgrade it for emergency water storage
- Stabilize Second Dam
- Regrade tailings and cover with waste rock and soil
- Revegetate covered tailings and other areas
- Build/upgrade diversions, channels and spillways to deal with floods
- Collect and treat contaminated water from valley (100s of years)
- Maintain covers, channels and dams (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $260M

Estimated employment: 336 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.

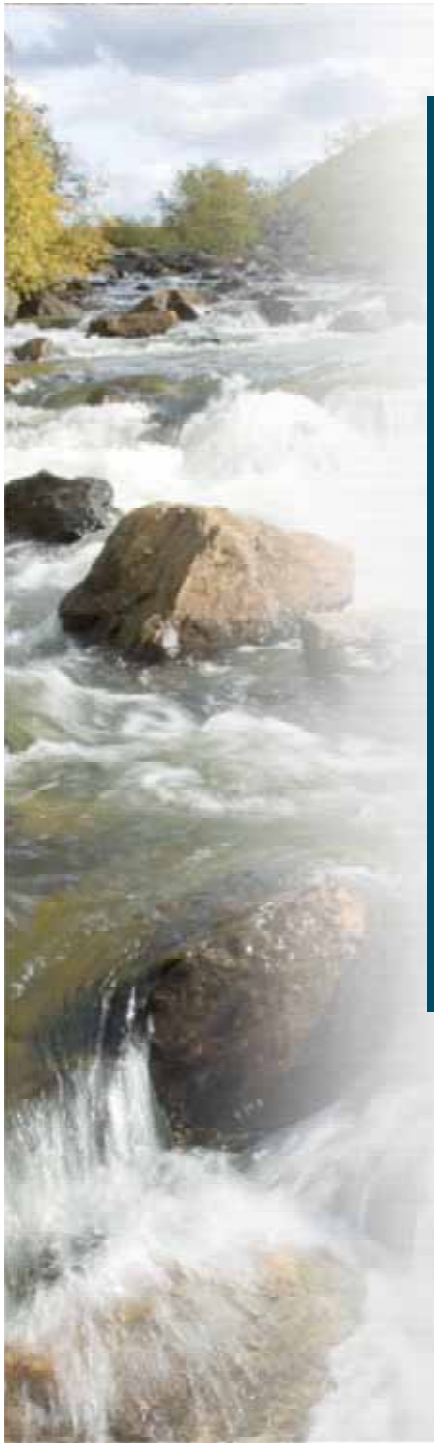


Before remediation (Now)



* Image for illustration purposes only

After remediation (approximately 40 years time)



Combined Faro Mine Area Option 3

Upgrade Faro Creek diversion
Reslope, cover and revegetate Faro waste rock
Move some tailings and cover some tailings with soil

Estimated Jobs: 782 person years

Estimated Cost: $490 M

Combined Faro Mine Area Option 3:
Upgrade Faro Creek Diversion / Cover Faro Waste Rock

Closure Approach

What is involved?

- Build new diversion channel for Faro Creek
- Remove North Fork Rock Drain
- Build lined channel for North Fork Rose Creek
- Waste Rock
  - Reslope and cover with soil
  - Possibly move some waste rock to Faro Pit
- Revegetate covered waste rock
- Move tailings from Emergency Tailings Area to Faro Pit or Tailings Area.
- Collect and treat contaminated water from below waste rock, Zone 2 Pit and in Faro Pit (100s of years)
- Maintain covers and channels (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $150M

Estimated employment: 230 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.



Before remediation (Now)



Image for illustration purposes only.

After remediation (approximately 40 years time)

Combined Faro Mine Area Option 3:
Move some tailings and cover some tailings with soil

Move Some Tailings and Cover Some Tailings

What is involved?

- Remove Cross-Valley Dam or change/upgrade it for emergency water storage
- Stabilize Second Dam
- Mix Intermediate Tailings with lime/water and pump to Faro Pit
- Clean up remaining Intermediate Tailings with trucks and loaders
- Regrade Original and Second Tailings and cover with waste rock and soil
- Revegetate covered tailings and valley area
- Upgrade diversion channel for upper part of Rose Creek
- Construct channel for lower part of Rose Creek and return the creek to the valley when soil and water are clean
- Collect and treat contaminated water (100s of years)
- Maintain covers, channels and dams (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $340M

Estimated employment: 552 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.

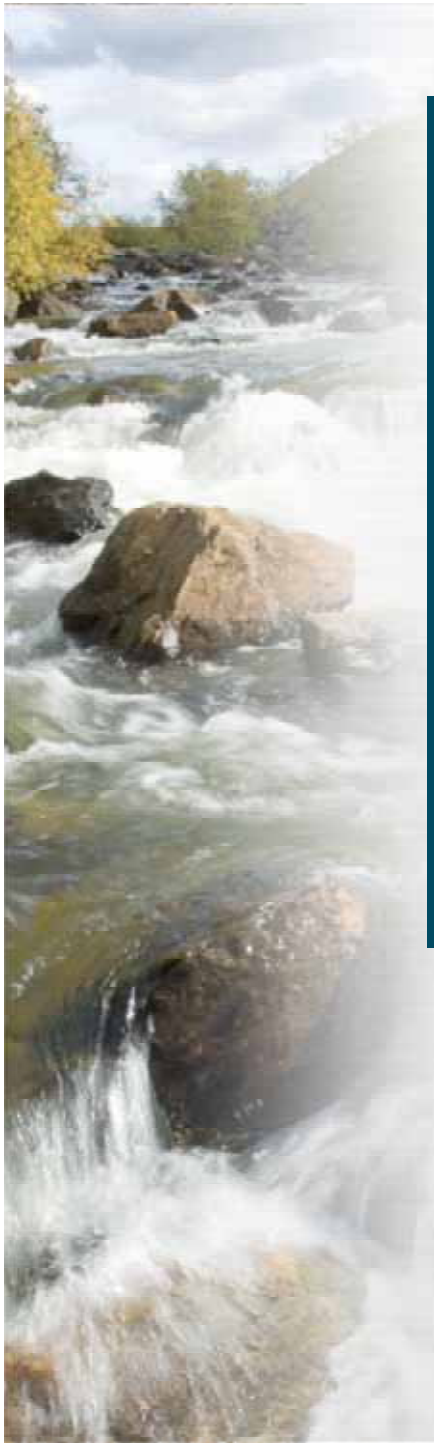


Before remediation (Now)



* Image for illustration purposes only.

After remediation (approximately 40 years time)



Vangorda/Grum Area Option 1

Reslope, cover and revegetate Grum waste rock

Move Vangorda Waste Rock into Vangorda Pit

Estimated Jobs: 225 person years

Estimated Cost: $110 M

Vangorda/Grum Area Option 1

Move Vangorda Waste Rock into Vangorda Pit

What is involved?

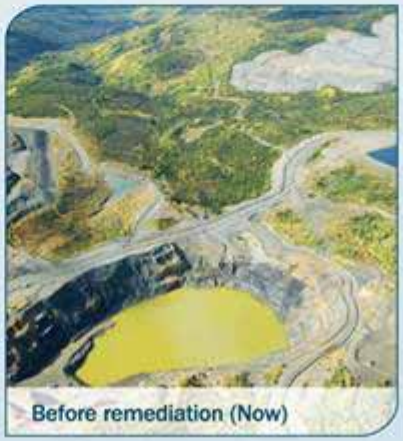
- Mix Vangorda Waste rock with lime and place in Vangorda Pit
- Reslope Grum Waste Rock
- Cover Grum Waste Rock and relocated Vangorda Waste Rock with soil
- Revegetate covered waste rock and other areas
- Build new channel for Vangorda Creek – over filled pit
- Collect and treat contaminated water from Grum Waste Rock and Grum Pit (100s of years)
- Possibly collect and treat contaminated water from Vangorda Pit
- Maintain covers and channels (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $110M

Estimated employment: 225 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.


Before remediation (Now)

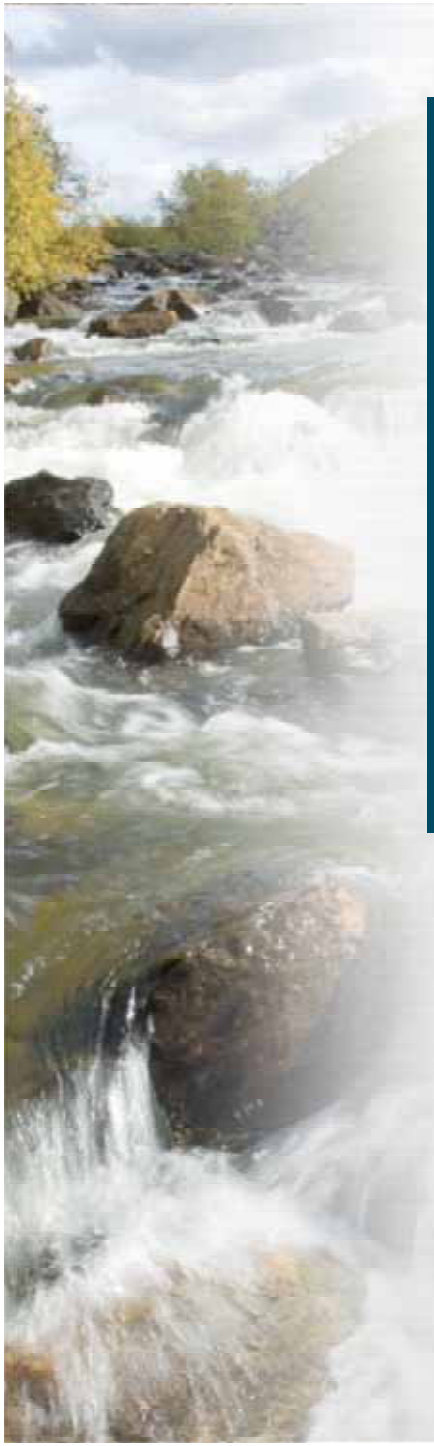

* Image for illustration purposes only.

After remediation (approx. 40 years)


Before remediation (Now)

* Image for illustration purposes only.

After remediation (approximately 40 years time)



Vangorda/Grum Area Option 2

Reslope, cover and revegetate Grum waste rock

Cover Vangorda waste rock in place

Estimated Jobs: 80 person years

Estimated Cost: $80 M

Vangorda/Grum Area Option 2

Cover Vangorda Waste Rock In-Place

What is involved?

- Reslope Vangorda and Grum Waste Rock and cover with soil
- Revegetate covered waste rock and other areas
- Build new diversion channel for Vangorda Creek
- Collect and treat contaminated water from Grum and Vangorda Waste Rock and Grum and Vangorda Pits (100s of years)
- Maintain channels and covers (100s of years)
- Monitor environmental conditions and adapt to changes

Estimated cost to build and maintain: $80M

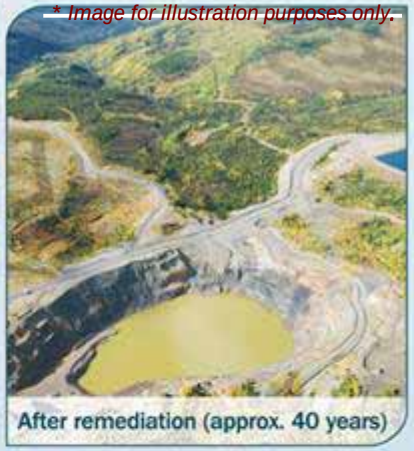
Estimated employment: 80 person years

Each option is designed to meet technical and environmental standards.

An overall closure plan will be created by choosing one option for the Faro Mine Area and one for the Vangorda/Grum Area.



Before remediation (Now)



After remediation (approx. 40 years)

** Image for illustration purposes only.*



Before remediation (Now)

After remediation (approximately 40 years time)

** Image for illustration purposes only.*



So how do we get
from
5 options
to
a closure plan?





Closure Objectives

There are 5 things, or ***objectives***, we want a closure plan to achieve:

1. Protect human health & safety
2. Protect, and to the extent practicable, restore the environment including land, air, water, fish and wildlife
3. Return the mine site to an acceptable state of use that reflects pre-mining land use where practicable
4. Maximize local and Yukon socio-economic benefits
5. Manage long-term site risk in a cost effective manner

Final Closure Plan Options



A **final closure and remediation plan** will be created from:

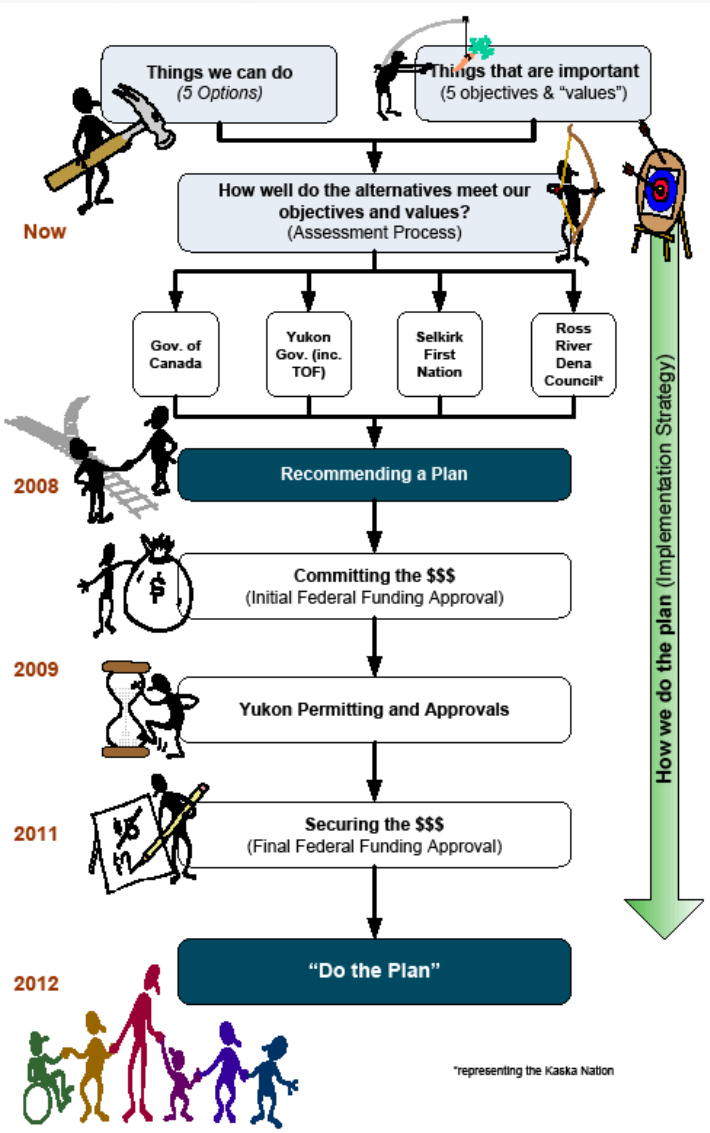
ONE option for the Faro Mine Area

+

ONE option for the Vangorda/Grum Area

and will be designed to meet all of the stated closure objectives.

Next Steps: Roadmap to Remediation



- The communities and governments are now conducting their own assessment processes.
- Information from these processes will be used by the project Oversight Committee to arrive at a **final closure and remediation plan** to recommend to the federal government for initial funding approval.



For more information,
please contact your community office:

Faro Mine Closure
Fermeture de la mine Faro

Whitehorse:
867.633.7966

Ross River:
867.969.2103

Pelly Crossing:
867.537.3144

Town of Faro:
867.994.2728

Yukon Government

Canada

INFO@FAROMINE.CA | WWW.FAROMINE.CA

Attachment 3A-2
Community Meeting with KDC & RRDC - Presentation and Maps, May 26, 2010

Faro Mine Closure
Fermeture de la mine Faro

Faro Project Management Team Update

Kaska Nation Community Meeting
Information Update - May 2010









Faro Closure Update

- Care & Maintenance Update
- First Nation Participation Update
- Assessment and Regulatory Update



Faro Closure – Context Review

- Closure Plan (from consultation & selection of closure plan to YESAA & implementation)
- Transition from Deloitte & Touche to Yukon government
- Currently on site: care & maintenance



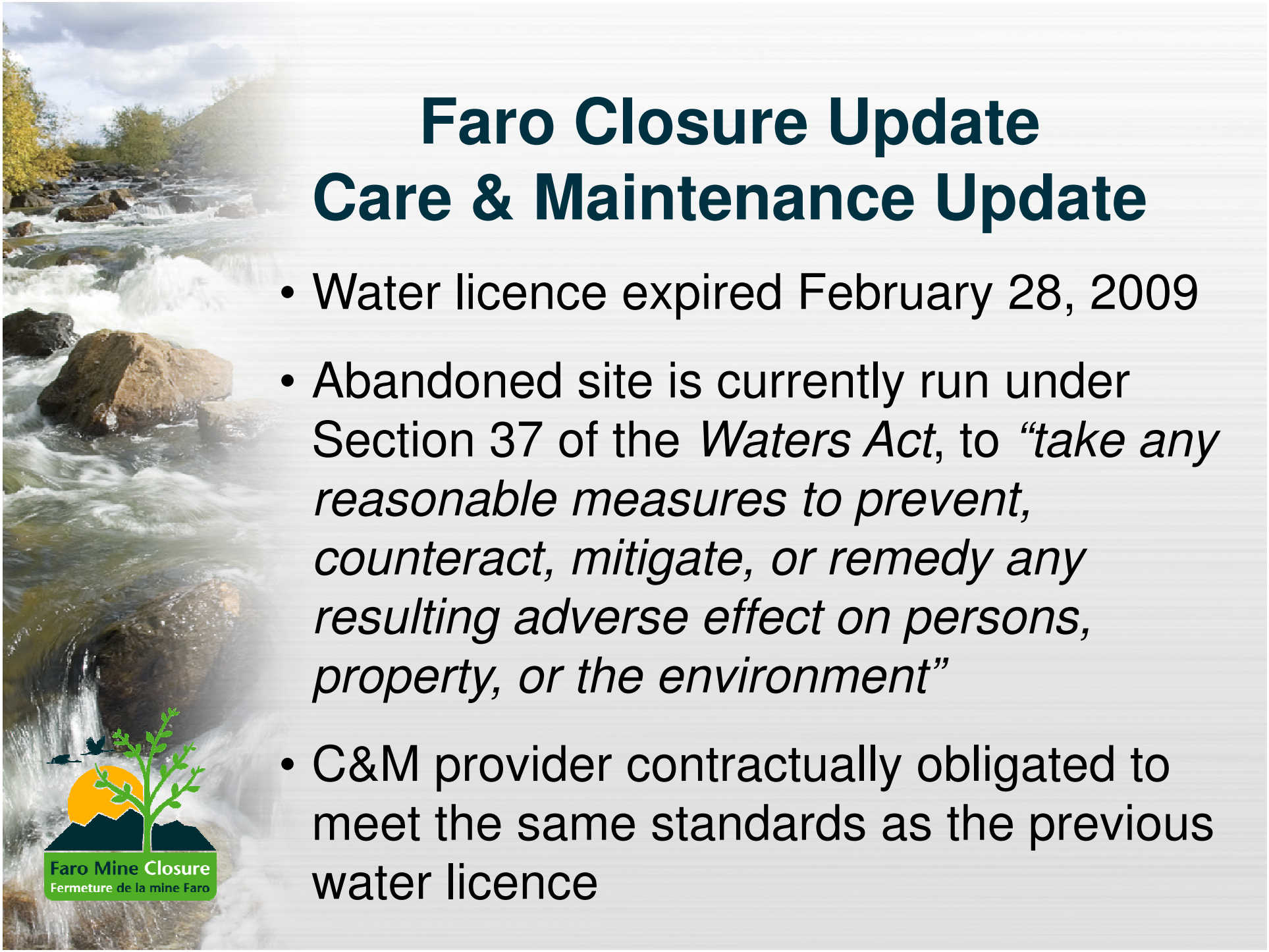
Faro Closure – Closure Planning

- Currently completing the project proposal
- Assessment Process Working Group involved in meetings to provide community input and feedback
- Governments in discussions regarding roles and responsibilities
- Submit project description to YESAA and regulatory processes



Faro Closure Update
Care & Maintenance Update

- Deloitte & Touche discharged from their duties as Interim Receiver as of February 28, 2009
- Denison Environmental Services was the successful bidder
- Contract signed with new care & maintenance contractor as of July 23, 2008



Faro Closure Update
Care & Maintenance Update

- Water licence expired February 28, 2009
- Abandoned site is currently run under Section 37 of the *Waters Act*, to *"take any reasonable measures to prevent, counteract, mitigate, or remedy any resulting adverse effect on persons, property, or the environment"*
- C&M provider contractually obligated to meet the same standards as the previous water licence



Faro Closure Update
Care & Maintenance Update

What's Care and Maintenance?

- Collection & treatment of contaminated water
- Maintenance of dams & diversions
- Protection of environment & human health & safety
- Early reclamation

Faro Closure Update
Care & Maintenance Update

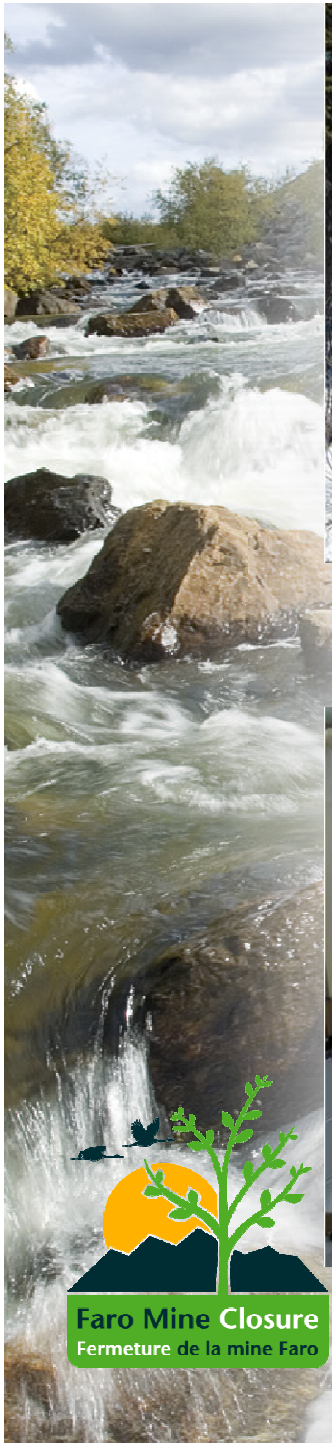
What does C&M look like at the site now?

- Water Treatment





Faro Mine Closure
Fermeture de la mine Faro





- Snow Survey



- Grum Climate Station

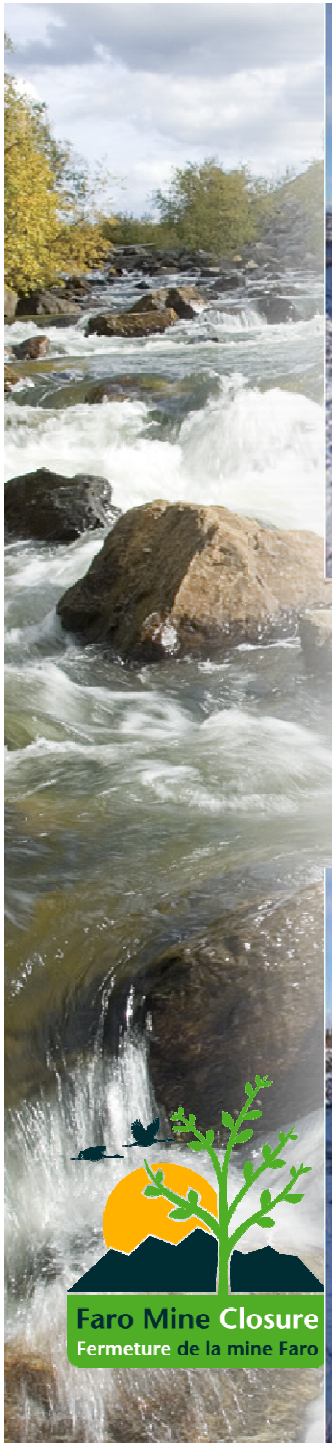


- Sample Analysis In New Lab



- CVP Sample Collection

Faro Mine Closure
Fermeture de la mine Faro







- Removing Sludge from Grum Clarification Pond





Faro Mine Closure
Fermeture de la mine Faro



Faro Closure Update
Care & Maintenance Update

- Early Remediation Projects

  –Grum Sulphide Cell

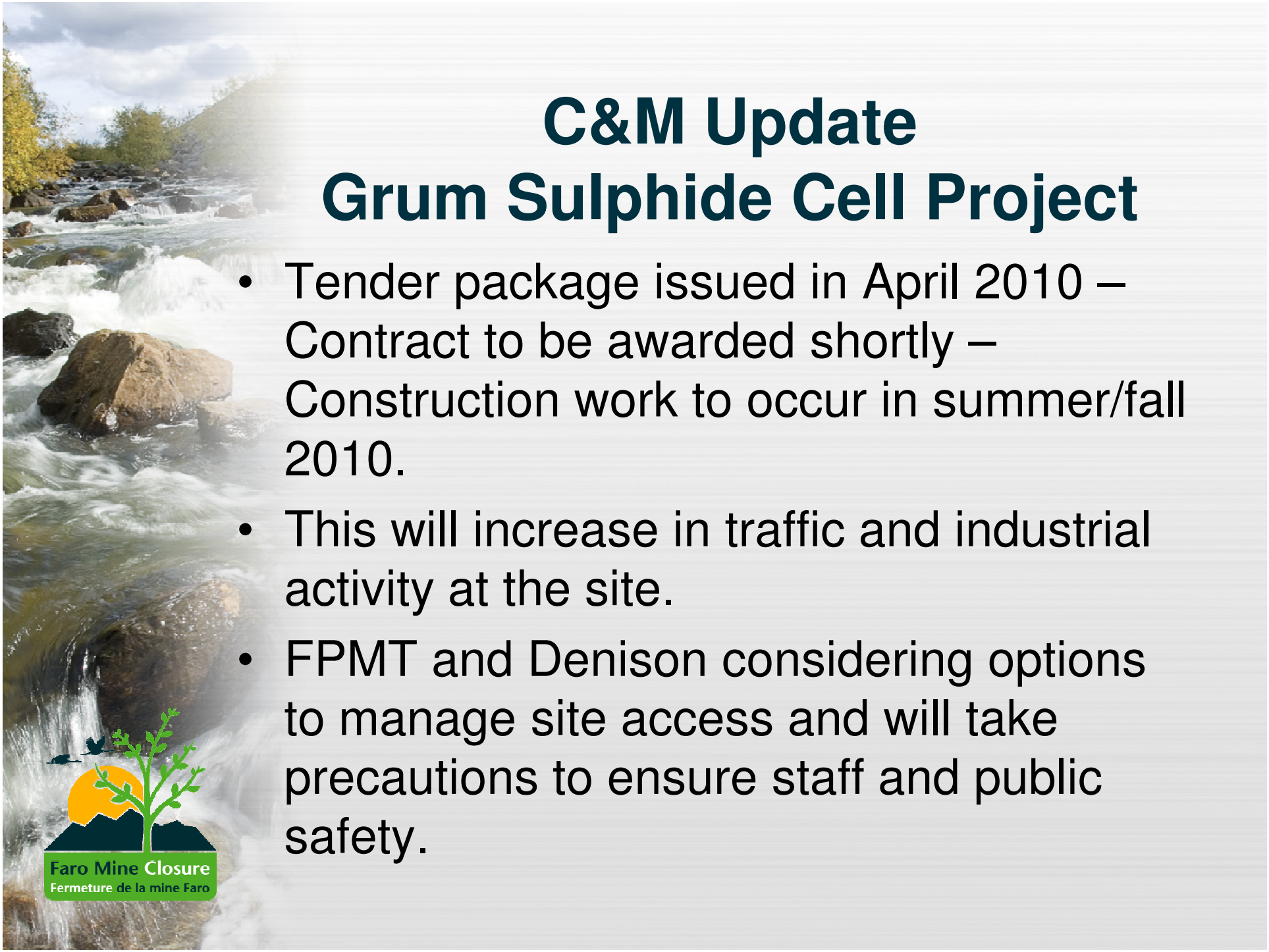
Faro Mine Closure
Fermeture de la mine Faro



C&M Update
Grum Sulphide Cell Project

- Early remediation project at Grum area of site.
- Some waste rock highly sulphidic and contributes to contamination.
- Project is to re-slope waste rock and install a cover to control contaminated seepage and then revegetate area.

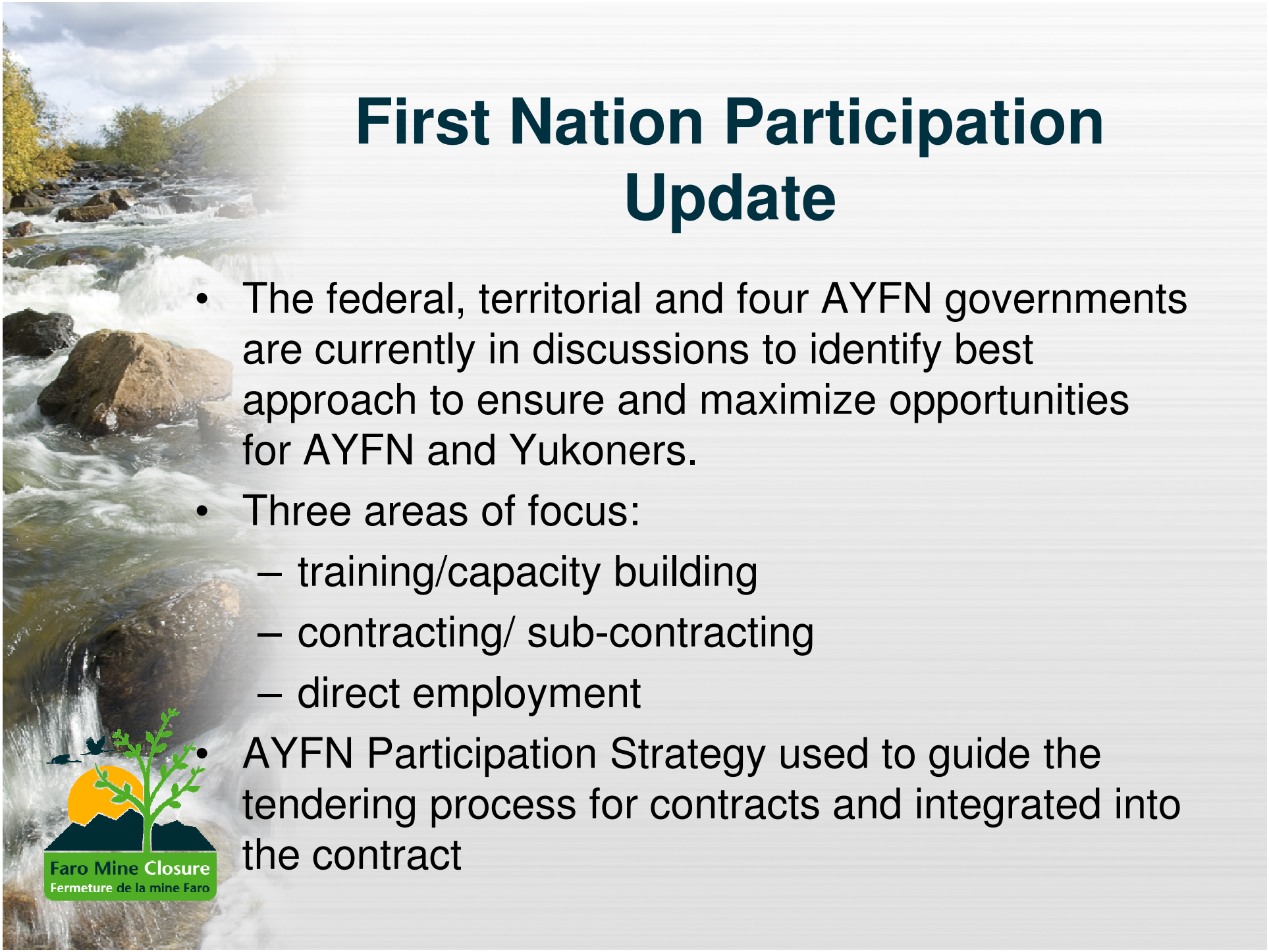
Faro Mine Closure
Fermeture de la mine Faro



C&M Update
Grum Sulphide Cell Project

- Tender package issued in April 2010 – Contract to be awarded shortly – Construction work to occur in summer/fall 2010.
- This will increase in traffic and industrial activity at the site.
- FPMT and Denison considering options to manage site access and will take precautions to ensure staff and public safety.

Faro Mine Closure
Fermeture de la mine Faro



First Nation Participation Update

- The federal, territorial and four AYFN governments are currently in discussions to identify best approach to ensure and maximize opportunities for AYFN and Yukoners.
- Three areas of focus:
  - training/capacity building
  - contracting/ sub-contracting
  - direct employment
- AYFN Participation Strategy used to guide the tendering process for contracts and integrated into the contract

Faro Mine Closure
Fermeture de la mine Faro



First Nation Participation C&M Update

- Faro Project Management Team, AYFN & Denison developed AYFN participation plan within the C&M contract.
- Employment and Training opportunities are being communicated through community coordinators.
- Currently meeting with community coordinators to plan for this coming year.

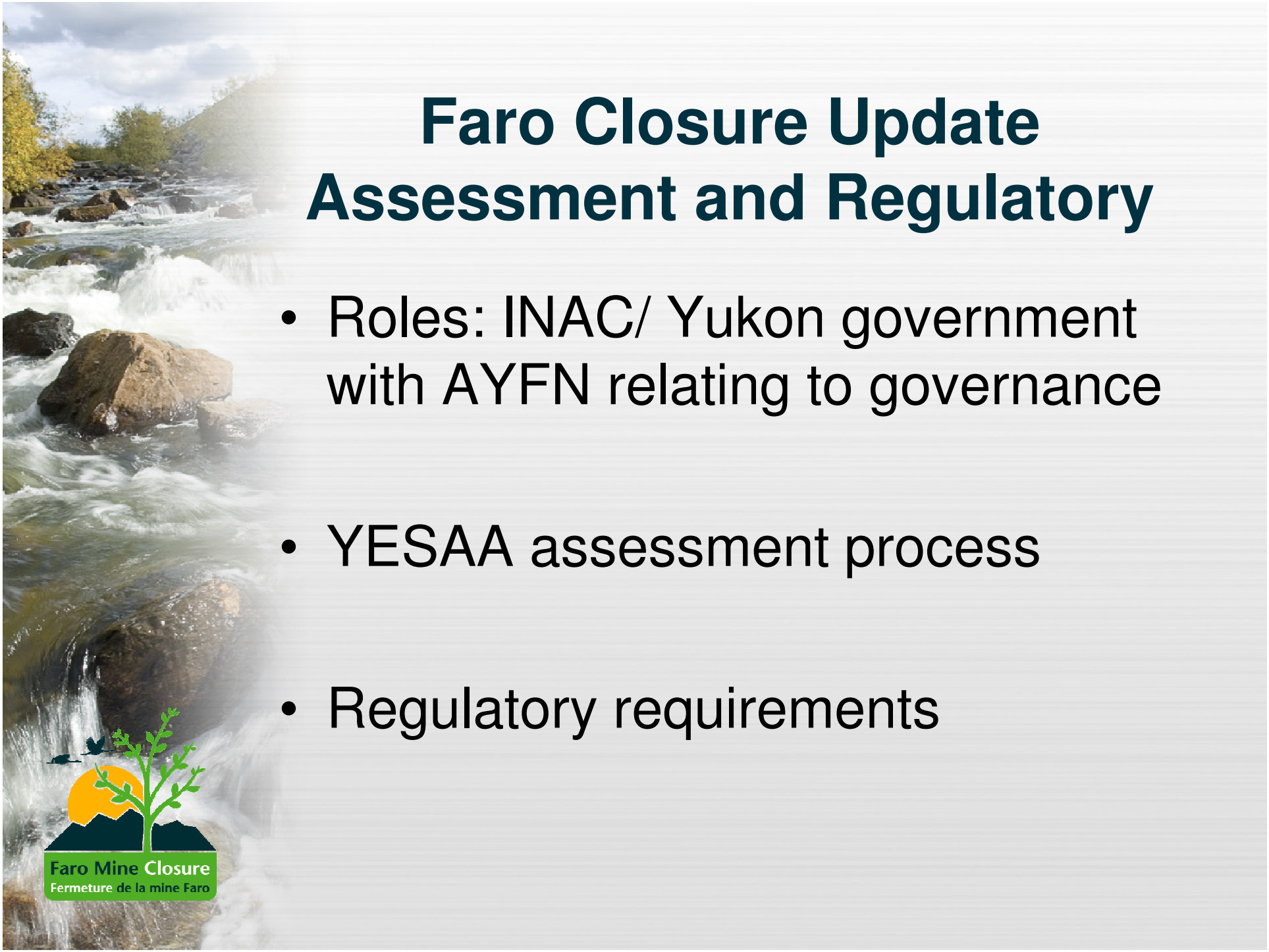
Faro Mine Closure
Fermeture de la mine Faro



First Nation Participation Early Remediation Update

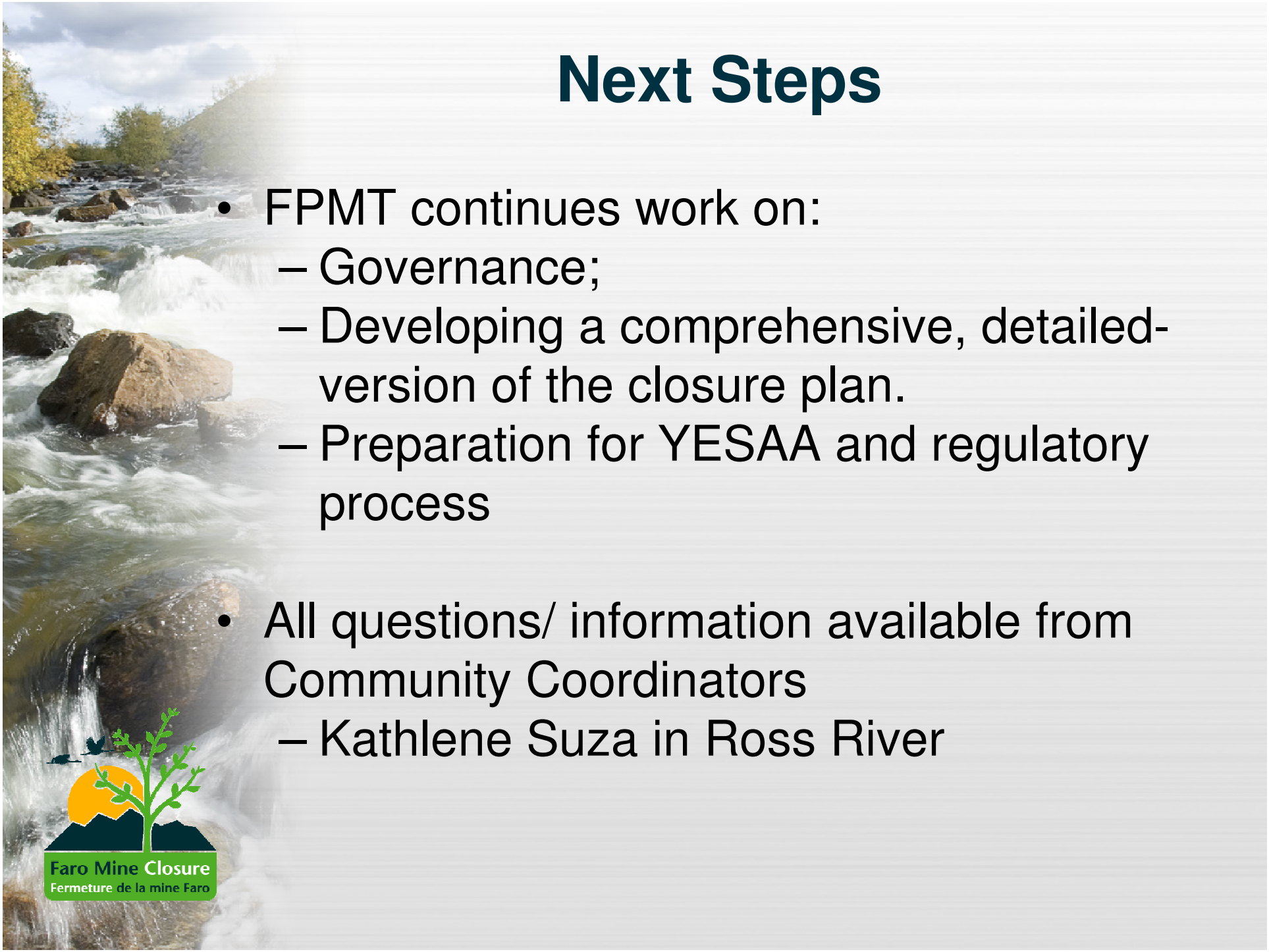
- Continued implementation of the AYFN Participation Strategy for early remediation project contracts such as Grum Sulphide Cell.
- Guides how contractors develop AYFN participation plans within their contracts to provide opportunities to AYFN communities.
- Employment and Training opportunities are being communicated through community coordinators.

Faro Mine Closure
Fermeture de la mine Faro



Faro Closure Update Assessment and Regulatory

- Roles: INAC/ Yukon government with AYFN relating to governance
- YESAA assessment process
- Regulatory requirements



Next Steps

- FPMT continues work on:
  - Governance;
  - Developing a comprehensive, detailed-version of the closure plan.
  - Preparation for YESAA and regulatory process

- All questions/ information available from Community Coordinators
  - Kathlene Suza in Ross River

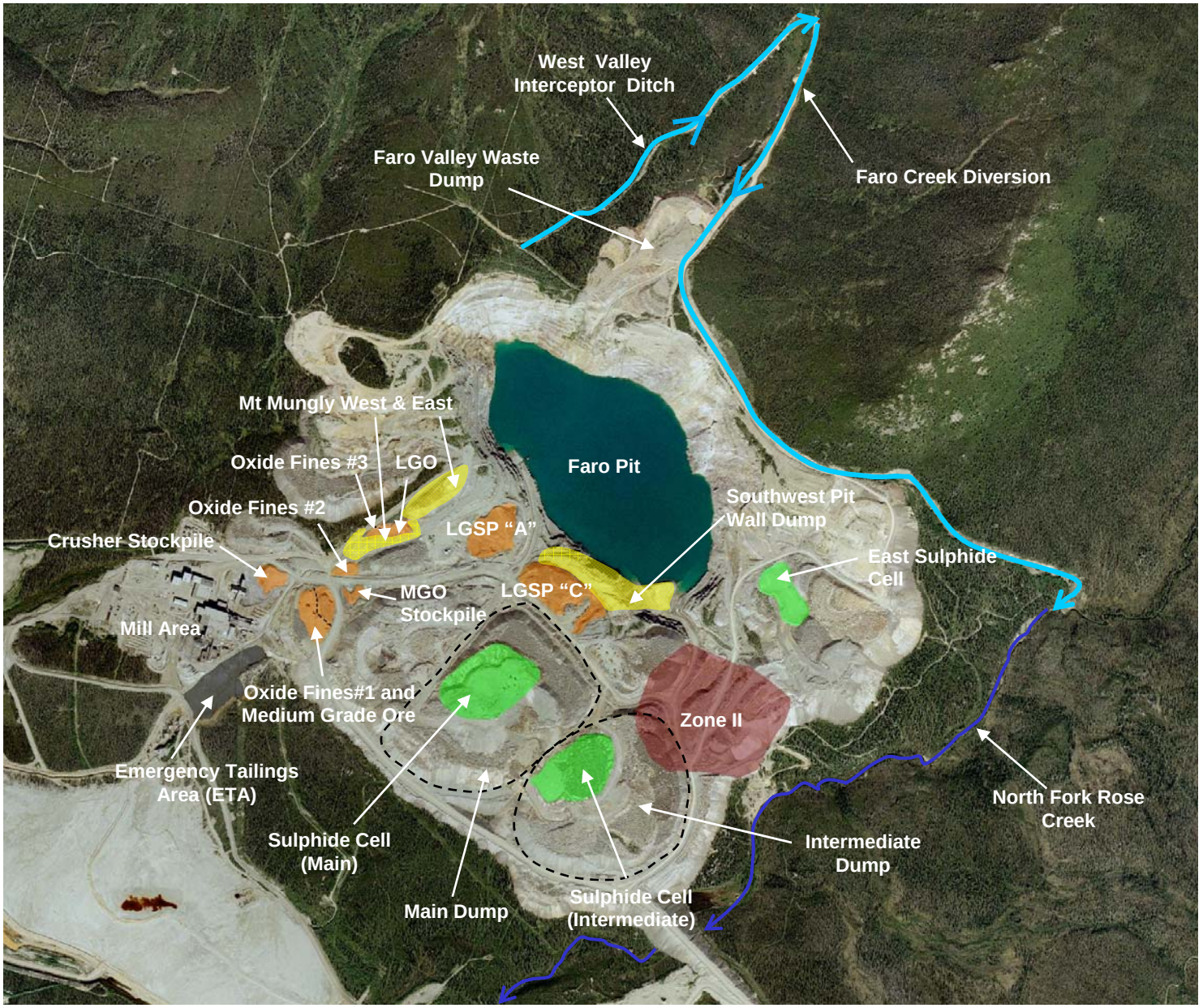
Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex – Update

Questions?



Faro Mine Closure
Fermeture de la mine Faro



LEGEND

LGO - Low Grade Ore
LGSP – Low Grade Stockpile
MGO – Medium Grade Ore

SRK Consulting
Engineers and Scientists
VANCOUVER

Faro Mine Closure
Fermeture de la mine Faro

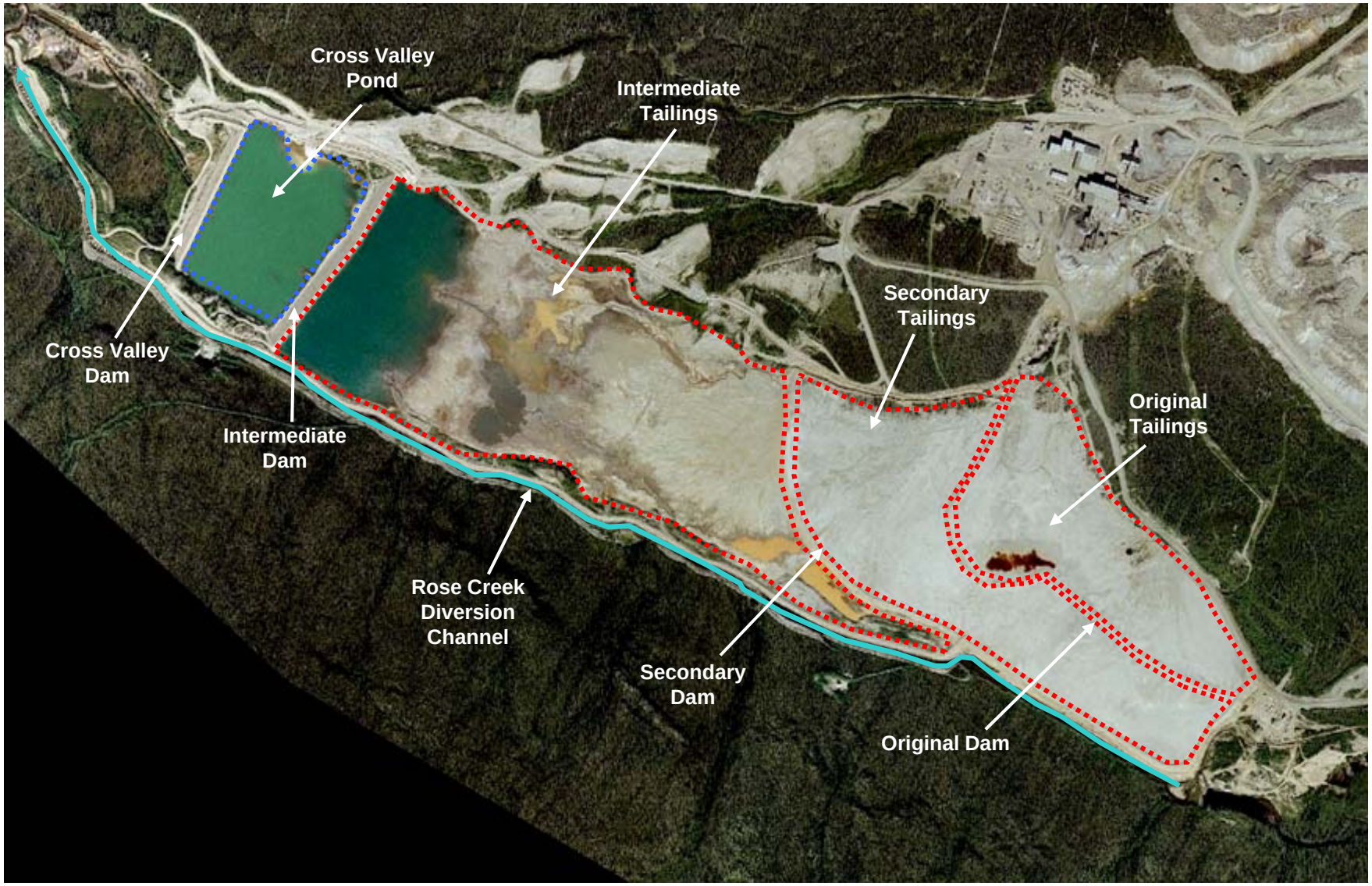
Job No: 1CY001.026
Filename: Figures_4.1-6_Faro Mine_20091127.ppt

Faro Mine Complex
Final Closure and Remediation Plan

Project Description (Draft 4)

Faro Mine Area (100)
Site Plan
(Current Conditions)

Date:	Approved:	Figure:
December 2009		**4.1**



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Engineers and Scientists
VANCOUVER

Faro Mine Closure
Fermeture de la mine Faro

Project Description (Draft 4)

Tailings Area (200)
Current conditions

Job No: 1CY001.026
Filename: Figures_5.1-5_Tailings_20091127.ppt

Faro Mine Complex
Final Closure and Remediation Plan

Date: December 2009
Approved:
Figure: **5.1**



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Engineers and Scientists
VANCOUVER

Faro Mine Closure
Fermeture de la mine Faro

Project Description (Draft 4)

Vangorda/Grum Area (300)
Current Conditions

Job No: 1CY001.026

Filename: Figures_6.1-4_Vangorda-Grum_20091127.ppt

Faro Mine Complex
Final Closure and Remediation Plan

Date: December 2009

Approved:

Figure: **6.1**

583000 E
584000 E
585000 E
586000 E
6916000 N
6915000 N
6914000 N
6913000 N

N

200 0 400 600 1200 feet
100 0 200 400 600 Metres

Construct West Valley Extension (102.2)

Regrade and Cover (106.1)

Consolidate with relocated LGO, Crusher SP, Oxide Fines(#1, 2, 3), and Medium Grade Ore Stockpile, Cover (Very low Infiltration, synthetic, or soil equivalent) and Revegetate (104.4)

Haul 681,000m³ of Waste to Tailings Pond for Trafficable Layer (202.1/2)

Faro Valley Dump

Construct Faro Creek Diversion (east valley) (102.1)

Regrade LGSP "A", Cover (Very low Infiltration, synthetic, or soil equivalent) and Revegetate (104.3)

Existing Faro Creek Diversion Channel to be decommissioned and revegetated

FARO PIT

Relocate Crusher SP, Oxide Fines(#1, 2, 3), LGO, and Medium Grade Ore to LGSP "C". Regrade and cover remaining area with rudimentary cover and revegetate (104.1/2).

Construct Safety Berm Around Faro Pit (101.2)

Regrade, Cover (Low Infiltration) and Revegetate (106.3/1/2/3)

LGO

Oxide Fines #3

Mt. Mungly (east)

Mt. Mungly (west)

Cover, Revegetate East Sulphide Cell Waste (106.2/1)

Regrade, Reslope, Cover and Revegetate Main and Intermediate Sulphide Cells (106.2/2)

Decontaminate and Demolish Buildings (108.2)

LGSP "A"

Oxide Fines #2

Southwest Pit Wall Dump

LGSP "C"

East Sulphide Cell

Crusher Stockpile

Medium Grade Ore Stockpile

Install Groundwater Wells, Piping, Heat Tracing for Zone II Pit Water Management (103.1)

Install Cutoff Wall to Capture Clean Flow of North Fork into Raised Channel (107.1B)

ETA Tailings

Oxide Fines #1 and Medium Grade Ore

Main Sulphide Cell

Zone II

Construct Sediment Basins and Run-off Control Ditches on Covers (106.4)

Relocate Contaminated Soil from Mill Site Area and Cover (Synthetic/Soil) (108.3/4)

Remove Tailings to Rose Creek Tailings Facility (105.1)

Intermediate Sulphide Cell

Construct Low Permeability Channel to Isolate North Fork from Groundwater (107.1)

Relocate Outwash Material to Intermediate Dump (107.2)

Install ETA Collection System. Pump to Faro Pit, if applicable (105.2)

Install Zone II outwash groundwater interception wells and trench. Pump to Faro Pit, if applicable (107.3).

Construct Sediment Basins and Run-off Control Ditches on Covers (106.4)

Regrade and Reslope Waste Rock Dumps (106.1B)

Place Cover on remaining Waste Rock and Revegetate (106.3/4/5)

Install S-wells Groundwater Collection System (107.5)

Haul Road - Remove Culverts, Scarify, Revegetate (108.1)

Develop and Decommission Faro Borrow Sources (108.5)

WTP

Sludge Pond

Construct Polishing Pond (205.2)

Construct New Water Treatment Plant and Sludge Pond (Final disposal in pit). Install Pipeline and Power Heat Supply Tracing System (101.1/3)

Legend

Construct Safety Berm Around Faro Pit (101.2)	Closure Activity (work item number, See Tables in Appendix B)
LGSP	Low Grade Ore Stock Pile
	Rudimentary Cover (vegetative soil cover) (1m of Loose Till)
	Low Infiltration Cover (1m of compacted Till overlain by 1.0m lightly compacted Till)
	Very Low Infiltration Cover (Minimum 2.5m compacted Till overlain by 1.0m loose Till)
	Waste Rock Slope Pulled-Back
	Collection Sump
	Sediment Collection Basins
	Groundwater Pumping Well
	Water Treatment Plant
	Change in Channel
	Sediment Collection Ditch
	Pipeline
	Resloped Dump Toe
	Safety Berm around Faro Pit

SRK Consulting
Engineers and Scientists
Vancouver B.C.

SRK JOB NO.: 1CY001.026
FILE NAME: 1CY001_026-20_Rev_A.dwg

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex
Final Closure and Remediation Plan

Project Description (Draft 4)

Faro Mine Area (100) Closure Activities

DATE:	APPROVED:	FIGURE:
December 2009	PMH	4.7

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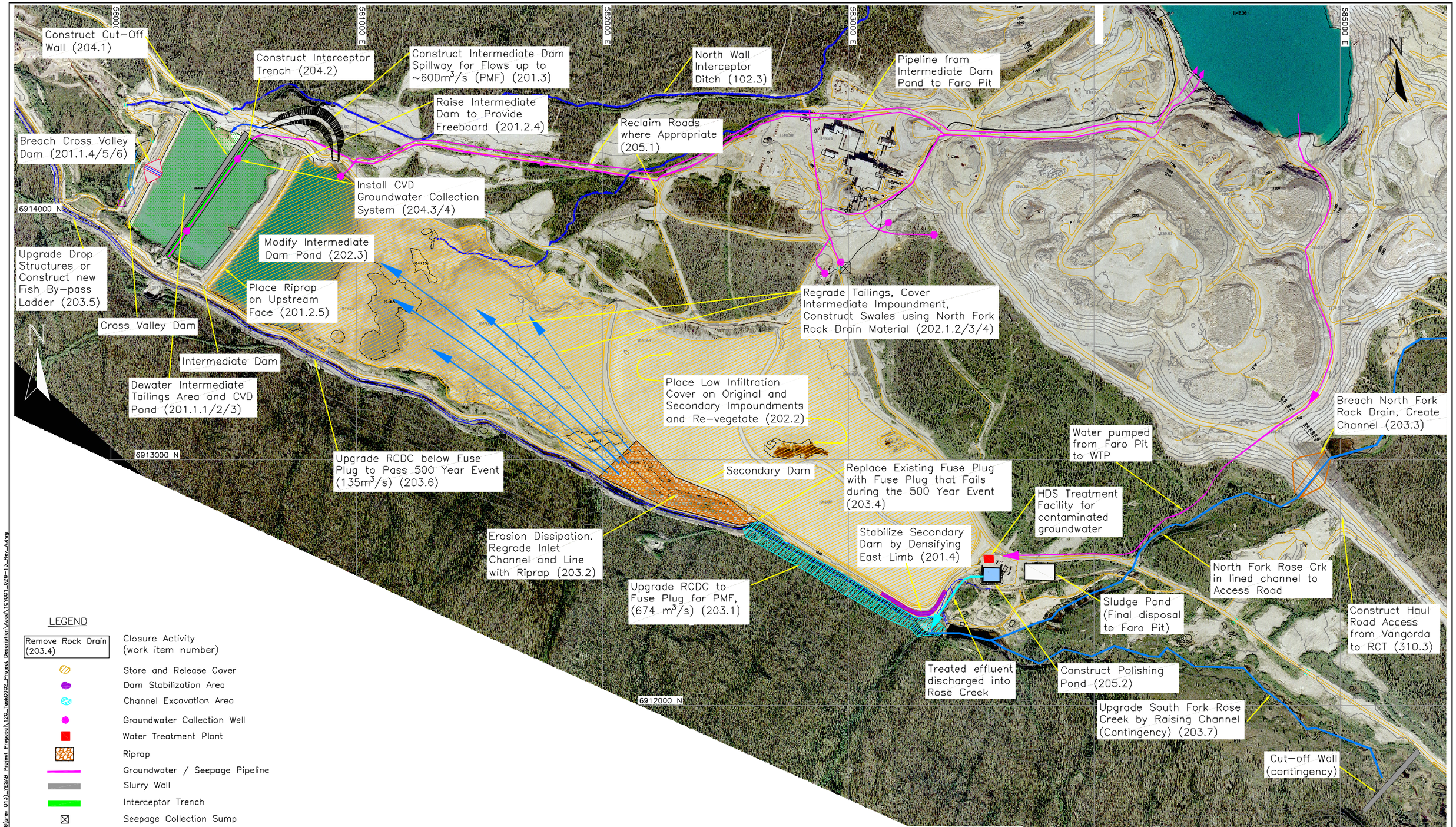

LEGEND

Remove Rock Drain (203.4)	Closure Activity (work item number)
	Store and Release Cover
	Dam Stabilization Area
	Channel Excavation Area
	Groundwater Collection Well
	Water Treatment Plant
	Riprap
	Groundwater / Seepage Pipeline
	Slurry Wall
	Interceptor Trench
	Seepage Collection Sump

REFERENCE

Klohn Crippen Berger report titled "Intermediate Dam Spillway – PMF Flood Handling", dated April 2008 with job number M09237A06.

200 0 400 600 1200 feet

100 0 200 400 600 Metres

Faro Mine, Yukon

Contour Interval: 10m
Survey control derived from existing 1:20000 photography
Survey control based on: UTM Projection, NAD27
Compiled by The ORTHOSHOP, Calgary, September 2003
WO 8856

SRK Consulting Engineers and Scientists Vancouver B.C.

SRK JOB NO.: 1CY001.026
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Faro Mine Closure Fermeture de la mine Faro

Faro Mine Complex
Final Closure and Remediation Plan

Project Description (Draft 4)

Tailings Area (200)
Closure Activities

DATE:	APPROVED:	FIGURE:
December 200	PMH	5.6

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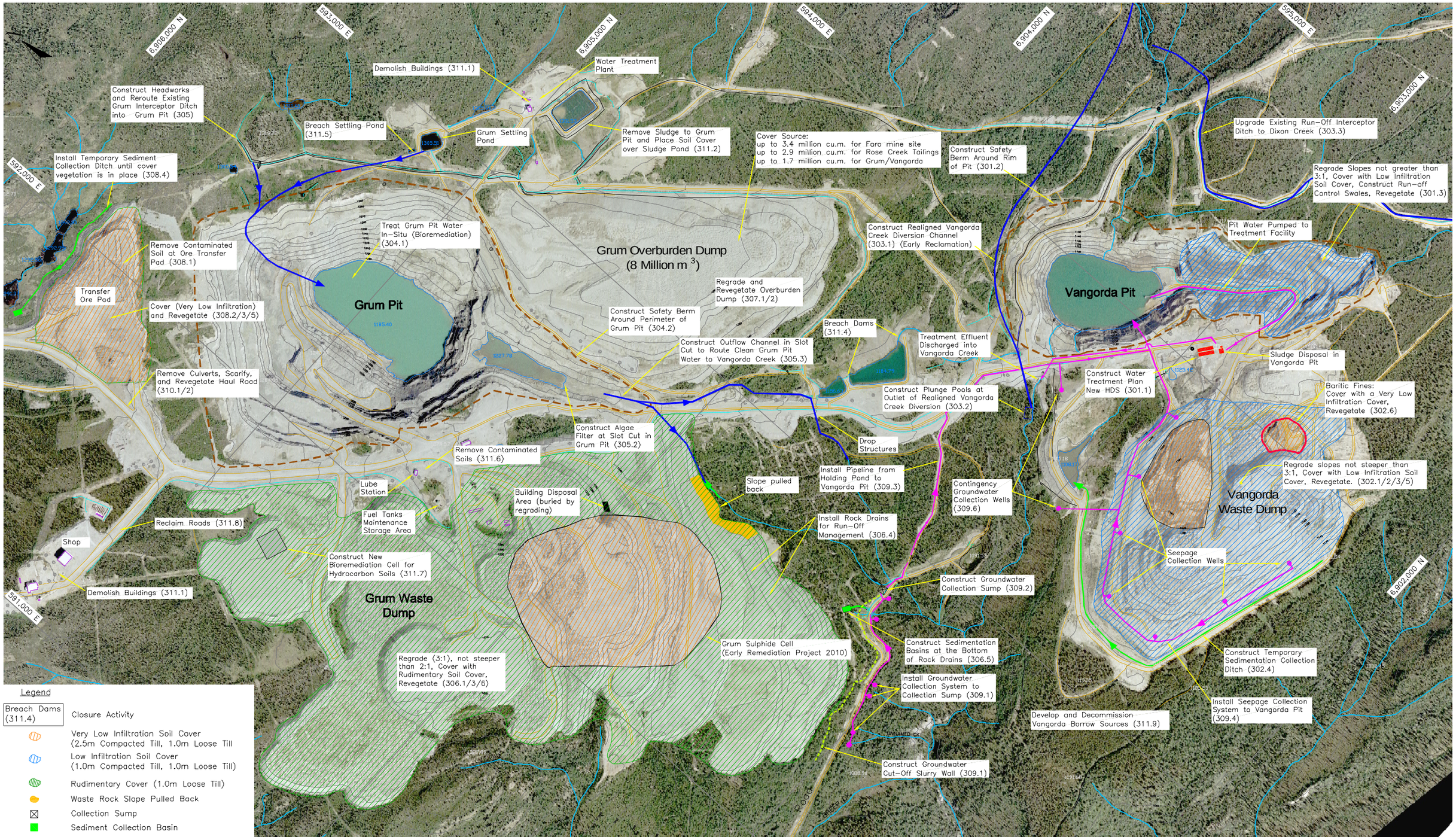

Note: 3:1 resloping is defined as 3H:1V.

Contour Interval: 10m
Date of Photography: 03/07/25
Scale of Photography: 1:20000
Survey control derived from existing 1:20000 photography
Survey control based on: UTM Projection, NAD27
Compiled by The ORTHOSHOP, Calgary, September 2003
WO 8856

0 100 200 300 400 500 m

SRK Consulting
Engineers and Scientists
Vancouver B.C.

SRK JOB NO.: 1CY001.026
FILE NAME: 1CY001_026-14_Rev_A.dwg

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex
Final Closure and Remediation Plan

Project Description (Draft 4)

Vangorda/Grum Area (300)
Closure Activities

DATE:	APPROVED:	FIGURE:
December 2009	PMH	6.5

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Attachment 3A-3
C&M Community Meeting with LFN / Watson Lake - Poster and Presentation, November 29, 2011

Faro Mine Remediation Project

CARE AND MAINTENANCE COMMUNITY MEETING



EVERYONE IS WELCOME TO ATTEND A FARO MINE CARE AND MAINTENANCE MEETING

Date: Tuesday, November 29, 2011

Time: 1pm

Location: Watson Lake Community Center, Watson Lake

The presentation will cover activities that occurred during the fall season at the Faro Mine Complex.

This is an opportunity for you to discuss care & maintenance activities with representatives from Denison Environmental Services.

Refreshments will be provided.

CONTACT

Jon Bronson
Project Manager
Denison Environmental Services
Ph: (867) 994-2600
jbronson@denisonenvironmental.com

Terry Szabo
Type II Mines Community Coordinator
Liard First Nation
Ph: (867) 536-2393
terrygermain@hotmail.com

Denison Environmental Services

Faro Mine Remediation Project
Projet d'assainissement de la mine Faro



Faro Mine Remediation Project

Activities Update

November 28, 2011

In 2011, the Faro Mine Remediation Project Team has been busy:

- Improving how we manage surface water runoff
- Collecting/updating information about how animals use the site
- Continuing planning for remediation (cleanup) of the site, including preparing for the YESAA process
- Securing a new contract for day-to-day site operations (new care & maintenance contract)
- Discussing how the 5 governments (Canada, Yukon, First Nations) will continue to work together now and in the future

How have we improved how we manage surface water runoff?

- Seeded the Grum Sulphide Cell with grass to reduce erosion of the soil (more planting next year)
- Constructed new ditches to divert runoff water safely to Vangorda Pit & away from the environment
- Built a large storage pond to safely store water
- Installed pump & pipeline to move excess water
- Lowered water levels in ponds/pits to give us more storage space for excess water in spring
- Planned for extra environmental monitoring

What information are we gathering about how animals use the site?

- YG Environment completed moose & sheep surveys throughout the territory this spring & summer & will share Faro-area results with the project team soon
- Bird & fish surveys were done this summer & fall on the Faro Mine Complex site to help us understand how they use the site & how the cleanup might affect them
- Similarly, a small mammal survey (looking at animals like hares, foxes, etc) will be done this winter

How are we planning for the remediation (cleanup) & the YESAA process ?

- Decided that Yukon and Canada will jointly lead the project through environmental & socioeconomic assessments (YESAA) & permits (Water Licence)
- Hired a Project Design Team – a company named CH2M HILL – to help with technical work
- Next steps: 1) finalize technical details of the overall plan, 2) identify how the cleanup project might effect the environment & people & 3) consult with communities as required by YESAA

Why are we writing a new contract for day-to-day site operations (C&M)?

- Contract was retendered this past summer because government must put out a new public tender for care & maintenance contract every 3 years or so
- This process is underway now – the present contract started in 2009 and ends in 2012, so YG needs to have a new contract in place soon
- Because one of our objectives is to ensure benefits for Affected Yukon First Nations & Yukoners, the new contract will have a Participation Plan for jobs, training & contracting opportunities (as it does now)

How will the 5 governments continue to work together?

- Chiefs continue to meet with government officials to discuss how their communities can benefit from & be involved in the project now and in the future – these discussions are ongoing
- Ideas now being worked on include a new land-based monitoring program to check on the health of the environment from the First Nations' viewpoint
- Do you have ideas about how you would like to see your community involved in the project? Please talk to your Chiefs & Community Coordinators

How will the 5 governments continue to work together now and in the future?

- New governance structure being developed for Faro Mine Remediation Project.
- FN Chiefs are meeting with government senior management and continue to discuss First Nation communities needs within the project.
- Working on identifying where First Nations can be involved in the project. Discussion ongoing.
- Ideas on how to be involved in project? Please talk to your Chiefs.

Introducing the First Nation Community Coordinators!

- The team meets weekly to work on improving opportunities for community residents & to help each other to keep you informed
- Have any questions on the project? Please see your community coordinators, they are here to help you!



Kathlene Suza
Ross River Dena Council



Ellie Marcotte
Selkirk First Nation



Terry Szabo
Liard First Nation

Faro Mine Remediation Project

Projet d'assainissement de la mine Faro

Yukon Government

Canada

Attachment 3A-4
C&M Community Meeting with SFN – Presentation, April 22, 2013



Faro Mine Remediation Project
Pelly Crossing Community Update

Kaori Torigai

April 22, 2013

Overview of Presentation

Project Update

- 2010 – 2012
  - Project Design Team
  - Completion of Grum Sulphide Cell Project
  - C&M Contractor
- Upcoming 2013 activities
  - Pelly Aquatics study planning
  - Infrastructure upgrades
  - Field Investigations

Activities in 2010

- AAM conducted a public tender process for a Project Design Team to complete a detailed design of the chosen remediation option.
- Grum Sulphide Cell Cover Project was publically tendered and largely completed by the fall.
  - Resloping
  - Placement of High Density Polythelene (HDPE) cover, similar to a type of plastic
  - Till/soil cover

Activities in 2010



GSC under construction in October 2010



GSC in summer 2011

Activities in 2011

- Awarded Project Design Team contract to CH2M Hill
  - International engineering firm with extensive experience in mine remediation
  - Develop detailed design for chosen closure option to submit to YESAA
- Grum Sulphide Cell completed
  - Final modifications and revegetation
- C&M contract publicly retendered as previous 3 year contract was coming to an end

Activities in 2012

- Project Design team conducted field studies
- Initial review of water treatment plant
- Development of a five year plan to guide project work
- Pelly River Aquatics study
  - Monitors water at approximately 20 locations as it leaves the site and makes its way to the Pelly River
  - Sampled the water in May, August and October
  - All samples in the receiving water environment downstream of the site met water quality standards.

C&M Activities for 2013

- Overall review of water treatment plant (WTP) for health and safety of employees
- Water treatment is on hold until review of WTP is complete
- Contaminated water from the Intermediate Pond will be pumped and stored in the Faro Pit
- Grum Pit water will be pumped to Vangorda Pit
- Implementing Vangorda sludge management system
- Tackifier used for tailings dust suppression

PDT Activities for 2013

- Field investigations for infrastructure projects
- Data collection for YESAA project proposal
- Advanced design for water treatment plant
- Preparation for required permitting for water treatment plant, hydraulic upgrades

Additional Activities for 2013

- AAM is working with Selkirk First Nations (SFN) Community Coordinator and SFN Technical Advisory Committee to involve SFN in the monitoring of the environment, including the Pelly River.

Faro Mine Remediation Project

Projet d'assainissement de la mine Faro

Yukon Government

Canada

Attachment 3A-5
Meeting with YESAB – Agenda, October 7, 2011

Agenda

Faro Mine Closure/YESAB Meeting
October 7, 2011 9:00 – 10:00 a.m.

YESAB Office - Whitehorse

Meeting Purpose: Team and Project Introductory Meeting

1. **Welcome and introductions**
2. **Faro Mine Closure Detailed Design Team introduction**
3. **Overview of proposed approach to development of Project Proposal**
4. **Project schedule**
5. **Next steps and short-term scheduling**

Attachment 3A-6
Meeting with YESAB - Agenda and Presentation, November 16, 2011

Agenda

Faro Mine Remediation Project/YESAB Meeting
November 16, 2011 10:30-12:00
Royal Bank Centre – 2nd Floor

Meeting Purpose: Project overview and discussion of consultation requirements

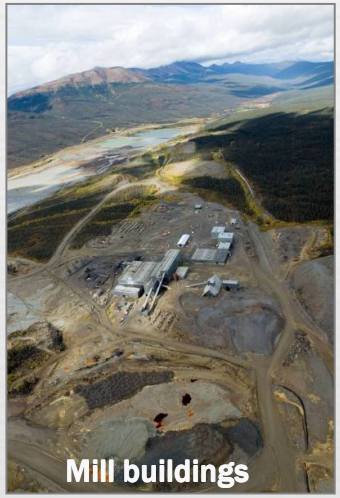
1. **Welcome and Introductions**
2. **Overview of Closure Options**
3. **Overview of Options Evaluation Process**
4. **Overview of Selected Closure Option**
5. **Consultation Requirements**
6. **Next Steps and Upcoming Meetings**



Faro Mine Project
Overview – *Alternatives, Evaluation and Selected Option*

YESAB, November 16, 2011

Faro Mine Closure
Arriving at a Closure Plan









January 2008

Establishing The Objectives

1. **Protect Human Health and Safety**
2. **Protect, and to the extent practicable, restore the environment including land, air, water, fish and wildlife**
3. **Return the mine site to an acceptable state of use that reflects pre-mining land use where practicable**
4. **Maximize local and Yukon socio-economic benefits**
5. **Manage long-term site risk in a cost effective manner**

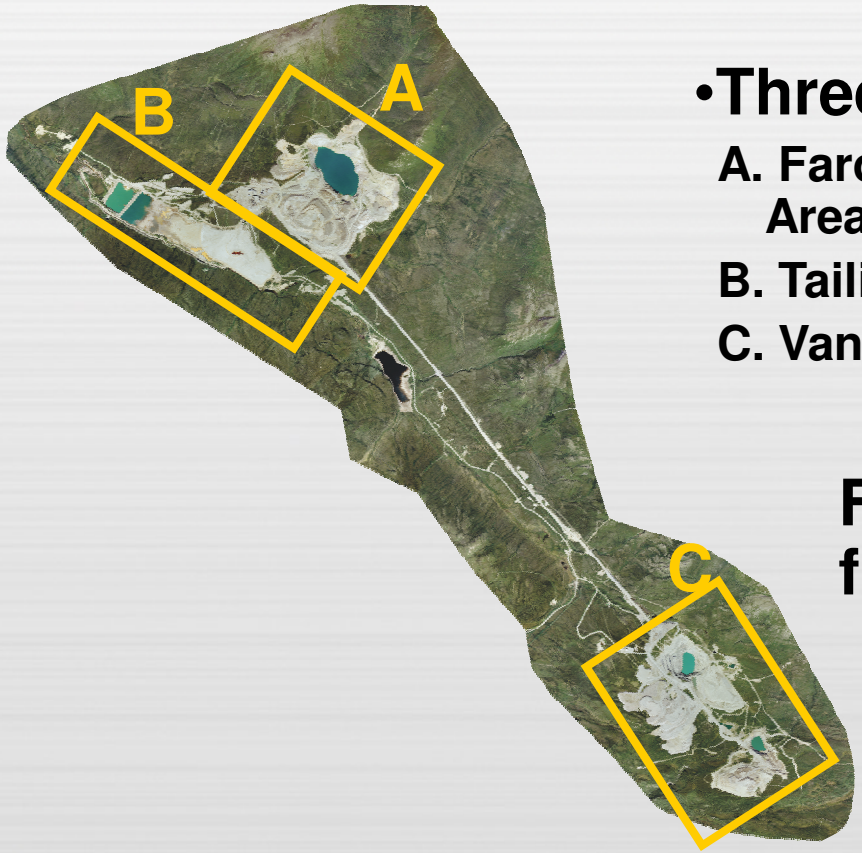
- **Workshops in communities.**
- **Interviews with elders (SFN) about concerns, expectations and objectives.**
- **Review and input from YG, SFN, RRDC, Town of Faro, INAC, DFO, EC. Specific information re: expectations.**
- **Overarching objectives approved by Oversight Committee**
- **Sub-objectives unique to each government.**

Understanding the issues

- To create a complete **final closure and remediation plan**, we gathered and studied information on a wide range of environmental issues.
  - From 2002 to 2005 - conducted technical workshops with consultants, governments (federal, territorial, First Nation, municipal), regulatory agencies, and others.
  - From 2003 to 2006 - completed over 90 technical studies.

2006 - Example Alternatives

From the studies and the workshop results, we created 12 “example alternatives”.



- **Three areas**
  - **A. Faro Pit and Waste Rock Area**
  - **B. Tailings Area**
  - **C. Vangorda/Grum Area**

Four alternatives for each area

<u>12 total</u>

Component	Option	Description of Option	Under Current Consideration?	Rational for Current Exclusion	Options Reports
Faro Creek Diversion	Upgrade to East	Construct new, larger Faro Creek Diversion on east side of pit, connecting to the North Fork Rose Creek.	y	Note: Implementation of this option is delayed for FM3	Golder 2004
	Upgrade to West	Construct new, larger Faro Creek Diversion on west side of pit, connecting to North Wall Interceptor (also upgraded) and Rose Creek d/s of the tailings impoundment.	n	Higher cost than the upgrade to the east. Requires substantial upgrading of the North Wall Interceptor.	Golder 2004
	Tunnel to East	Construct tunnel to divert Faro Creek on the east side of the pit, connecting to North Fork Rose Creek.	n	High construction costs.	Golder 2004
	Reroute to Faro Pit	Reroute Faro Creek into the Faro Pit via a channel around and/or over the Faro Valley Dump. Energy dissipation may be required to minimize mixing of pit water.	n	Flow through pit option no longer considered feasible re: water quality concerns.	
	Retain as is	Retain and maintain the existing Faro Creek Diversion.	y	Existing diversion will not be stable in long-term. Capacity for large floods is not adequate, and pit wall regression will ultimately lead to failure.	

2007 – Further Narrowing the Options

During 2006 and 2007, the 12 example alternatives were subject to:

- Independent Peer Review
- Community input
- Further technical studies

This allowed us to refine and condense the

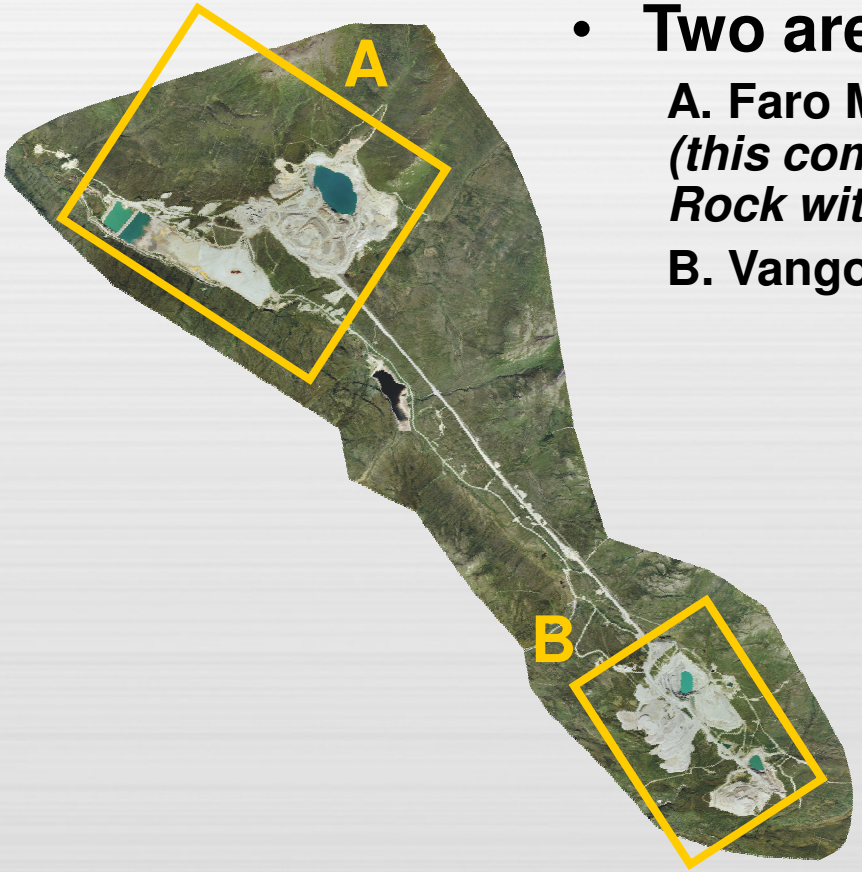
12 example alternatives

into

5 closure options

2007 - Closure Options

We now have 5 closure options.



- **Two areas**
  - **A. Faro Mine Area**
    (this combines the Faro Pit and Waste Rock with the Tailings Area)
  - **B. Vangorda/Grum Area**

3 options for the Faro Mine Area

2 options for the Vangorda/Grum Area

5 total

2007 – 5 Closure Options in Two Areas

Combined Faro Mine Area

•Move All Tailings	+	Upgrade Faro Creek Diversion and Cover/Revegetate Faro Waste Rock
or		
Cover Tailings with Soil	+	Upgrade Faro Creek Diversion and Cover/Revegetate Faro Waste Rock
or		
Move Some Tailings and Cover Some Tailings with Soil	+	Upgrade Faro Creek Diversion and Cover/Revegetate Faro Waste Rock

= 3 Combined Options

Vangorda/Grum Mine Area

Move Vangorda Waste Rock into Vangorda Pit

or

Cover Vangorda Waste Rock in Place

= 2 Options

Common Elements of the Options (1)

Any overall closure plan for the Faro Mine Complex will include some common things:

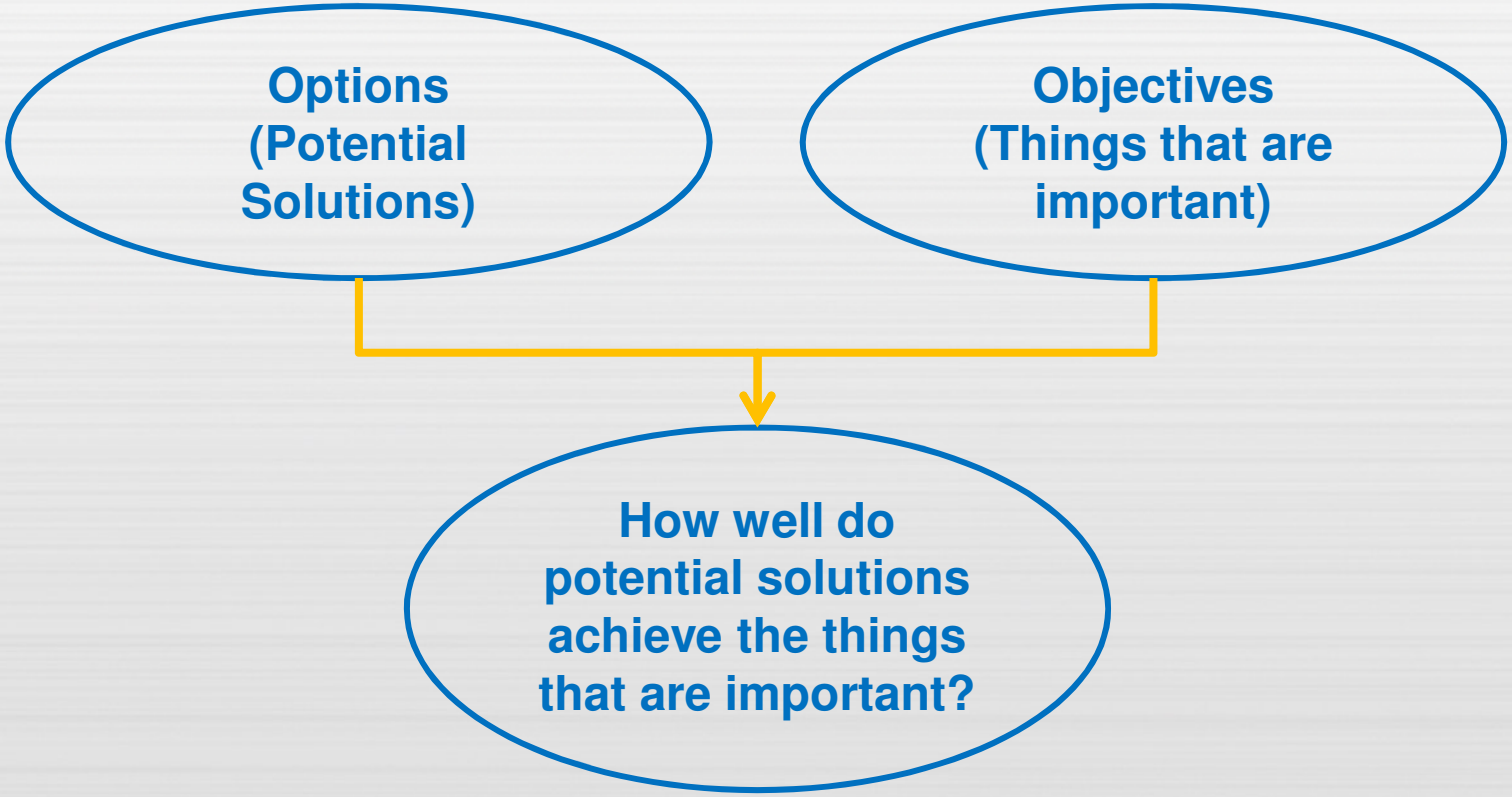
- Resloping and covering waste rock
- Revegetation of soil covers and other areas
- Diversion of clean water around the site
- Long-term collection and treatment of contaminated water
- Long-term management of water treatment sludge
- Long-term storage of water in pits
- Long-term maintenance of remaining site facilities (diversions, covers, water collection systems, water treatment systems, dams, etc.)
- Long-term monitoring of environmental conditions (water, animals, plants, climate, etc.)

Common Elements of the Options (2)

All of the closure options for the Faro Mine Complex are designed to do the following:

- Avoid unacceptable risks to public health and safety
- Avoid unacceptable risks to worker health and safety
- Meet appropriate environmental standards and guidelines, etc.

Options Evaluation Process (2007-2008)



Purposes of Options Evaluation Process

To provide Yukon, Federal and First Nations Governments with information needed to support well informed decisions about closure alternatives

- To compare remaining closure options with closure objectives (using a systematic methodology) – how well does each alternative perform against the objectives
- To identify discriminators and common elements between and among alternatives
- To document relevant assumptions, judgments, opinions and reasoning

One component - technical evaluation

- Systematic, rigorous and defensible process for evaluation alternatives
- Core Evaluation Team
- Multiple Variant Analysis
- Required clearly defined alternatives and objectives

Options Evaluation Team

Multiple Variant Analysis decision experts (experience with Nuclear Waste Management Organization)

- Lee Merkhofer
- Tony Hodge

Knowledgeable representatives bringing a range of perspectives for consideration/discussion

– Consultants
  - Randy Knapp, SENES
  - Daryl Hockley, SRK
  - Bill Slater, Bill Slater Environmental Consulting
– First Nation representatives and advisors
  - Ellie Marcotte, SFN
  - Kathlene Suza, RRDC
  - Dan Cornett, Access Consulting Group
  - Malcolm Foy, LGL Ltd.
– Yukon and federal government representatives
  - Stephen Mead, YG Assessment and Abandoned Mines
  - Mike Nahir, federal government, INAC

Objectives for Evaluation

Overarching Objectives

1. Protect Human Health and Safety
2. Protect, and to the extent practicable, restore the environment including land, air, water, fish and wildlife
3. Return the mine site to an acceptable state of use that reflects pre-mining land use where practicable
4. Maximize local and Yukon socio-economic benefits
5. Manage long-term site risk in a cost effective manner

Evaluation Objectives

1. Maximize public health and safety
2. Maximize worker health and safety
3. Maximize restoration, protection and enhancement of the environment
4. Minimize restrictions on traditional land use
5. Minimize restrictions on local land use
6. Maximize local socio-economic benefits
7. Maximize Yukon socio-economic benefits
8. Minimize cost

Options Evaluation Process Key Steps

Step 1: Identify performance measures

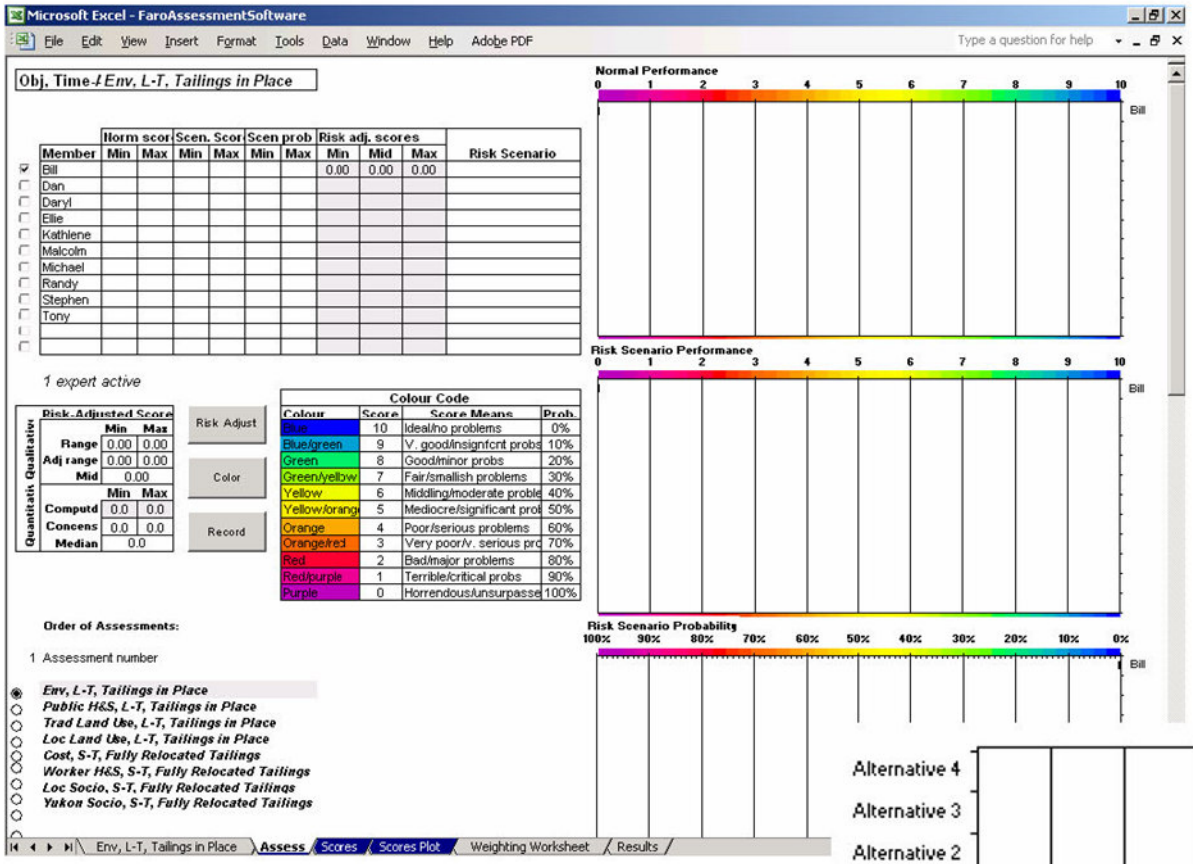
Step 2: Develop scoring scales

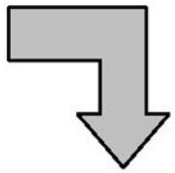
Step 3: Compile background information to describe performance

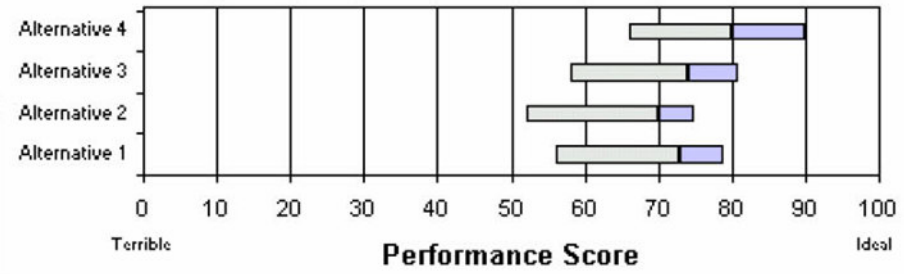
Step 4: Individual evaluation of performance

Step 5: Group evaluation of performance

A spreadsheet will be used to facilitate the recording and analysis of scores







General Conclusions

- For many objectives, there is little distinction between the alternatives for normal operations
  - Greater differences during short-term
  - Normal operations very similar in long-term
- For some objectives, the performance under risk scenarios is a discriminator
- Institutional risk is an important consideration for all alternatives
- Cost is a discriminator

Additional Options Evaluation Inputs

- Multi-day community workshops in Ross River and Pelly Crossing, with community evaluation of options. These workshops were designed and facilitated by the First Nation coordinators and their technical advisors.

- Discussion of technical options evaluation results with a working group comprised of representatives from government and regulatory agencies.

- Review of the technical evaluation results by the Independent Peer Review Panel.

Selection of a Remediation Plan

- Late 2008 – First Nations, Federal and Territorial Governments came to a consensus and jointly selected the proposed remediation plan having considered results of technical evaluation, community evaluations and peer review.

- December 2008 – Letters of agreement from all parties confirming selection.

Faro Mine Remediation Project
Overview of Selected Option

Faro Mine Complex: Site Overview

Faro Mine Area



Components

Faro Pit

Waste Rock (250M tonnes)

Tailings (70M tonnes)

Four Dams

Mill Buildings

Faro and Rose Creek Diversions

13km Haul Road

Vangorda/Grum Area



Components

Vangorda & Grum Pits

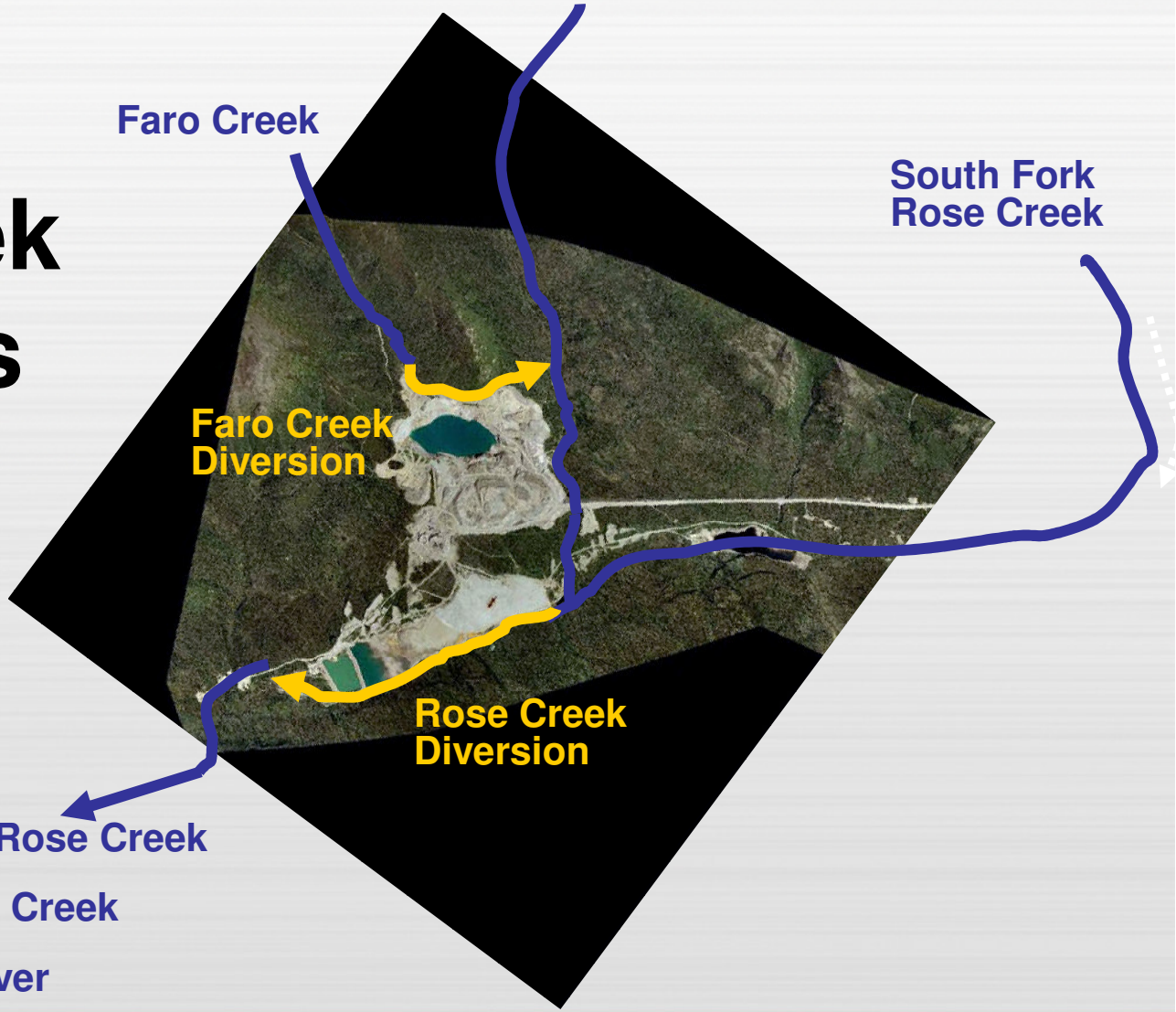
Waste Rock (70M tonnes)

No tailings

Vangorda Creek Diversion

Faro Mine Area

Faro and Rose Creek Diversions



Plan for Faro Mine Area

Use Faro Pit to store contaminated water

Reslope, cover and revegetate waste rock

Remove mill buildings and revegetate

Improve tailings dams

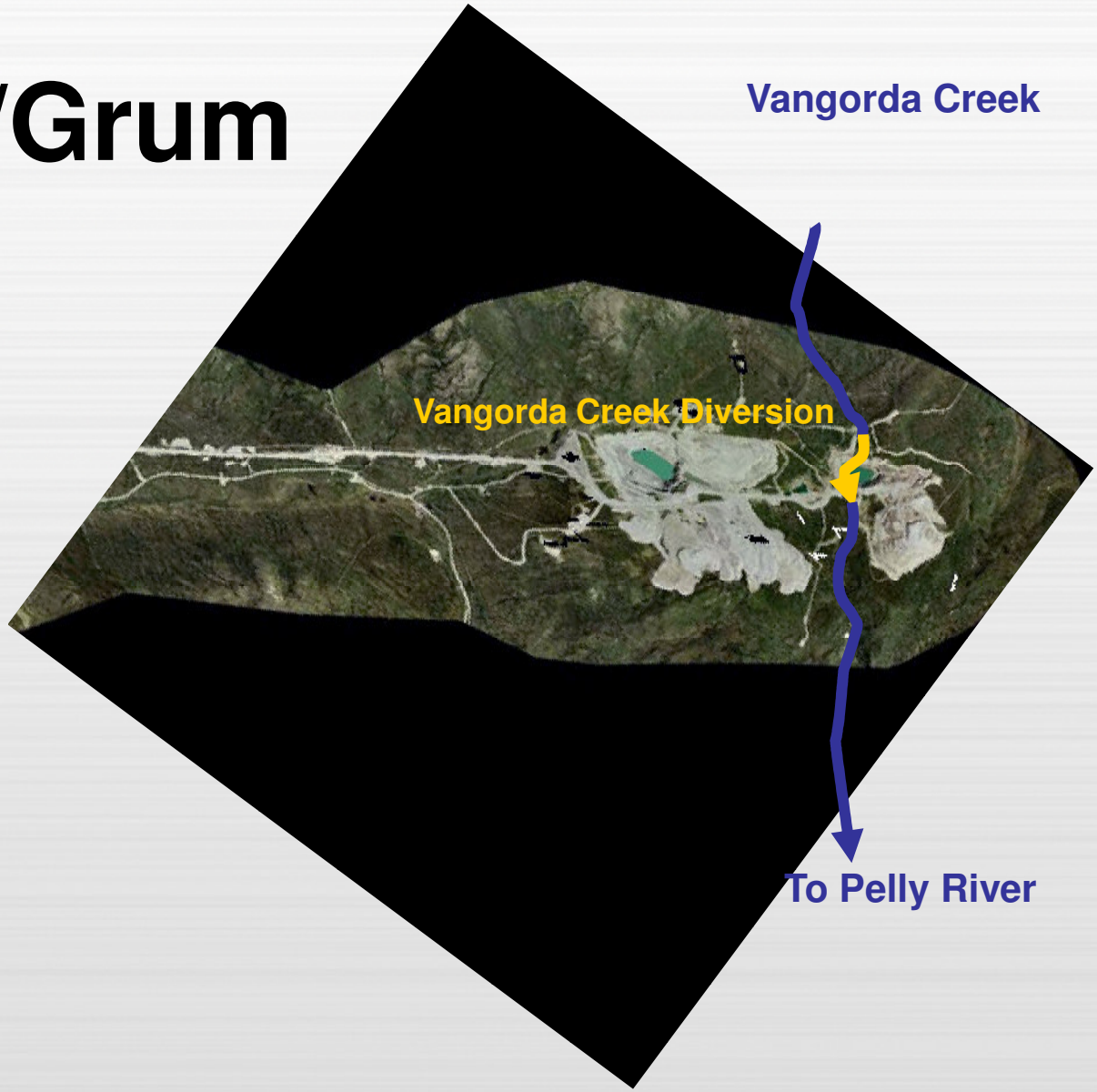
Cover tailings with soil

Upgrade Rose Creek Diversion

Upgrade Faro Creek Diversion & North Fork

Collect and treat all contaminated water

Vangorda/Grum Area



Plan for Vangorda/Grum Area

Vangorda Pit to store very contaminated water

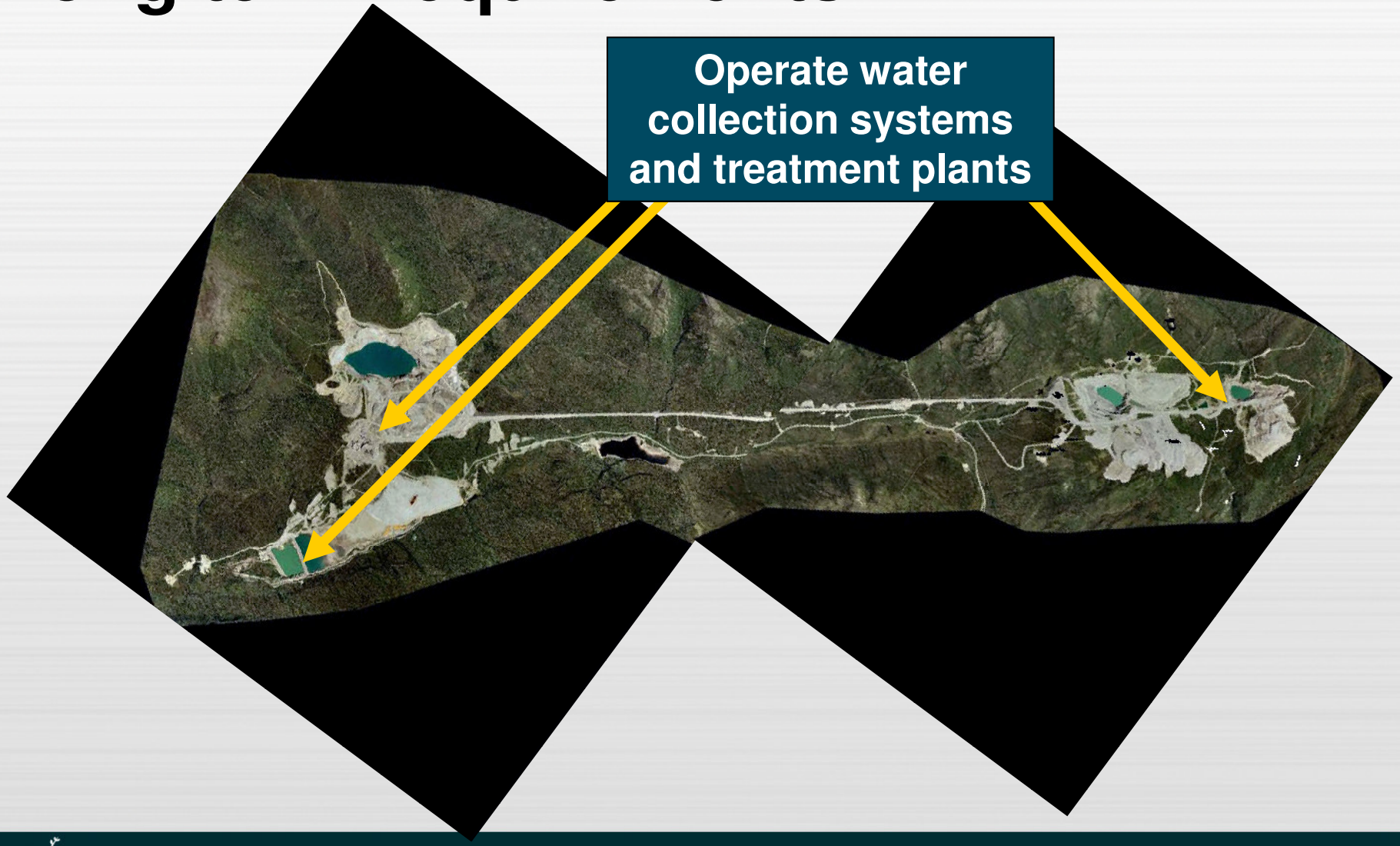
Grum Pit for less contaminated water

Reslope, cover and revegetate all waste rock in place

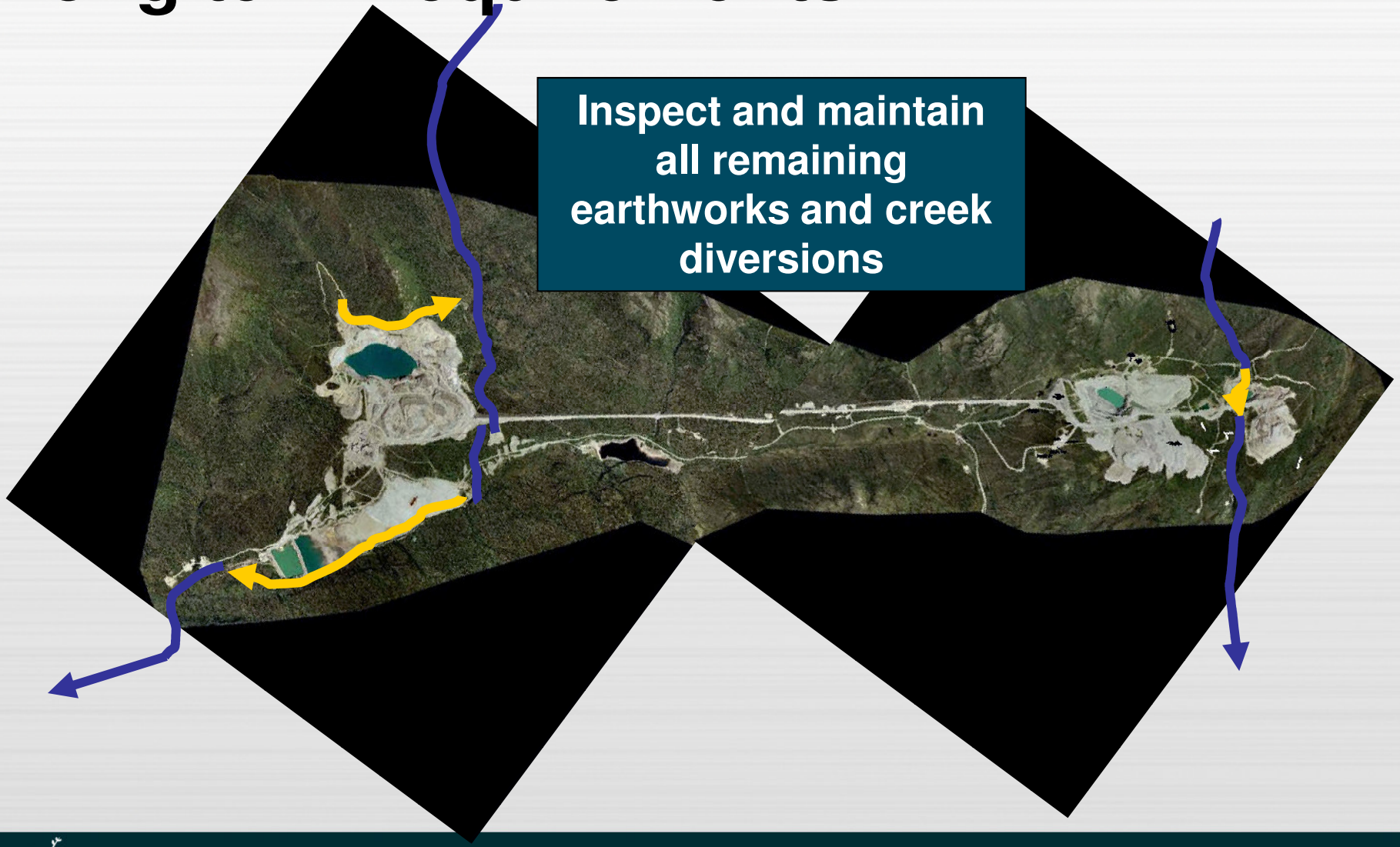
Upgrade Vangorda Creek Diversion

Collect and treat all contaminated water

Faro Mine Complex
Long term requirements



Faro Mine Complex
Long term requirements



Faro Mine Complex
Long term requirements



Consultation

As per section 50 (3) of YESAA:

AYFN:

- Selkirk First Nation
- Ross River Dena Council
- Liard First Nation

Communities

- Ross River
- Faro

Faro Mine Remediation Project

Projet d'assainissement de la mine Faro

Yukon Government

Canada

Attachment 3A-7
Meeting with YESAB - February 14, 2013 AAM
Letter to YESAB, April 9, 2013

Yukon
Energy, Mines and Resources
Assessment and Abandoned Mines
Box 2703, K-419
Whitehorse, Yukon
Y1A 2C6

February 14, 2013

Yukon Environmental and Socio-economic Assessment Board
Suite 200-309 Strickland Street
Whitehorse, Yukon
Y1A 2J9

Attention: Steve Caram
Project Assessment Manager

Re: Faro Mine Remediation Project – Assessment of Interim Works

Assessment Scenario

The Faro Mine Remediation Project (FMRP) has been working towards design and planning of the overall remediation works for the site for a number of years. The project is anticipated to cost approximately $ 700- 900million with construction works lasting between 10 to 15 years. This project is currently scheduled to be submitted to the Executive Committee of the Yukon Environmental and Socio-economic Assessment Board (YESAB) in the 2016/17 fiscal year.

Over the next several years the Government of Yukon (YG), through Assessment and Abandoned Mines (AAM), and Aboriginal Affairs and Northern Development Canada (AANDC) will work to prepare the design and assessment documentation. However, over the past fiscal year AAM and AANDC have identified a number of items at the Faro Mine Site for which the risks associated with human health and safety and the environment have reached levels requiring a response in a shorter time frame. While these activities may fall within the scope of activities that could be undertaken in the interest of public welfare, health or safety or of protecting property or the environment, the governments are evaluating the implications of submitting a YESAA project proposal separate from that of the overall plan, and containing the items described in the section below.

Scope of Project Proposal for Interim Works

AAM intends to include the following items in its project proposal to YESAB:

- ***Land Lease***
  At this time, AAM and AANDC do not have tenure over the land upon which the site is located. The land lease would help to achieve a number of objectives including protection of health and safety. Also, as the design of the overall plan requires extensive site investigations, a lease would provide a mechanism for this type of work to be conducted in a more expedient manner,

due to a reduction in the number of permits and licenses required. AAM is currently in the process of gathering some information that would support this application. Activities proposed as part of the land use work include security measures, road and trail development, and clearing of small areas for drilling and testing.

- ***Water Treatment Plant Construction***
  The Water Treatment Plant, located in the mill area of the Faro Mine Site, requires prompt replacement. This plant, built in 2001 using components of the old Faro Mill had a design life of 5 years. Whilst a number of interim repairs/upgrades and improvements have been completed over the years, recent evaluation work has concluded that the risks to human health and the environment posed by the existing treatment facility have reached levels that necessitate replacement in the near term. Based on the state of the plant as well as its functionality, AAM would seek to move forward with the construction of a new 8100 gpm treatment plant in advance of the overall remediation work, recognizing that this plant would be used during remediation, but would likely undergo additional modification or expansion in the future, as contaminant sources change at the site.

- ***Care & Maintenance***
  The purpose of care and maintenance is to maintain the site to prevent adverse effects on persons, property, and the environment, and to counteract, mitigate, and remedy any adverse effects that may occur.

  At this time, this work largely consists of the following operations and maintenance activities:
  - Operations include operating, maintaining, repairing, monitoring and managing the following:
    - Fresh water conveyance systems
    - Contaminated water storage, conveyance, collection and treatment systems (including the existing treatment facilities)
    - Dams and diversions
    - Stationary and mobile equipment
    - Sludge storage facilities
    - Tailings storage facilities (including dust management)
    - Open pits
    - Waste rock piles and ore stockpiles
    - Implementation of the preventative maintenance plan
    - Provision of emergency response capability and responding to emergencies
  - Maintenance includes operating, maintaining, repairing, and providing for the following:
    - Security, health, and safety for the site
    - Site buildings and infrastructure
    - Electrical distribution systems
    - Purchase and manage use of electricity, fuels, and lubricants
    - Roads and culverts
    - Waste oil heating system

- Faro housing
- Permits and licences as required

The care and maintenance program includes an extensive monitoring program to evaluate environmental conditions and physical and chemical stability of the site. These monitoring programs support an adaptive management plan.

- ***Down Valley Interim Hydraulic Upgrades***

  The Down Valley Tailings Facility contains 55,000,000 tonnes of acid-generating tailings located in the original valley of Rose Creek. The Intermediate Dam spillway and the Rose Creek Diversion require upgrades in order to allow them to safely pass no less than a 1-in-500-year flood event (132 m^3/sec). This was their original constructed design specification, which, over time has reduced due to erosion, emergency response etc. Despite the Intermediate Dam being rated as a "Very High" to "Extreme" risk dam based on the Canadian Dam Association (CDA) Dam Safety Guidelines 2007 (CDA, 2007), the existing spillway (capacity of 32 m^3/sec) cannot safely pass a moderate or major flood event without potentially failing the dam. Intermediate Dam failure may cause an environmentally damaging discharge of metals-laden tailings to Rose Creek, Anvil Creek, and the Pelly River that would result in a significant or major loss of critical fish and wildlife habitat that would be impractical or impossible to restore. Failure of the Secondary Dam in 1975 within the Rose Creek Valley resulted in a loss of wildlife habitat, with little recovery evident more than 35 years later. Based on the current state of the Intermediate Dam and Rose Creek Diversion, AAM would seek to move forward with the required upgrades in advance of the overall remediation work. A final remediation plan would see this system upgraded again to meet PMF/MCE design criteria.

  The proposed down valley interim hydraulic upgrades consist of the following elements:

  - Increase the existing Intermediate Dam spillway capacity by increasing the depth of the existing spillway channel. Relocate existing piping and lime mix tank that have been placed within the ID spillway.
  - Increase the height of the Intermediate Dam embankment crest by installing a geomembrane layer to extend the core to the dam crest and by adding concrete traffic barriers.
  - Protect the Intermediate Dam spillway channel from erosion by installing gabion mattresses.
  - Increase the Rose Creek Diversion capacity to pass the 500-year storm event, by removing vegetation, repairing raveled slopes on the dike and cut slope, and by filling in low spots on the dike crest.

At this time, the governments have identified the need for completion of these activities in the near-term, and are considering schedule and other implications associated with a YESAA assessment. If the assessment can be conducted without incurring undue risks to health and safety, the environment, or

property, these interim measures would be described in a project proposal and submitted for assessment. Based on our current understanding of the scope, AAM would be in a position to submit this project proposal to YESAB during the winter of the 2013/14 fiscal year. For discussion purposes, AAM is requesting a meeting with YESAB to discuss the level of assessment that would be required for the interim works described above.

Sincerely,



Patricia Randell
Manager
Assessment & Type II

Attachment 3A-8
Site Tour with YESAB - Agenda and Maps, July 23, 2013

AGENDA

YESAB Faro Site Tour

July 23, 2013

8:00 am	**Meet at the Entrance to the Town of Faro (Equipment)**
8:30 am	**Safety Briefing On-site**
9:00 am	**Tour Overview** - **Objective and Purpose**
9:30 am – 1:00 pm	**Faro Mine Area** - **Mill Area** - **Water Treatment Plant Site** - **Faro Pit, Waste Rock** - **Zone II Pit** - **Faro Creek Diversion** - **North Fork Rock Drain/Haul Road** - **Emergency Tailings Area** - **S-Wells** - **Rose Creek Tailing Area (Diversion, Tailings, Ponds, Dams, Discharge Point, Spillway, etc.)** - **Borrow Area**
1:00 pm – 1:45 pm	**Lunch**
1:45 pm – 4:00 pm	**Grum and Vangorda Mine Area** - **Vangorda Pit, Diversion** - **Vangorda Waste Rock** - **Grum Waste Rock** - **Vangorda Water Treatment Plant** - **Grum Pit, Waste Rock, Overburden** -
4:00 pm – 4:30 pm	**Sign out**

Faro Mine Site
YESAB Site Tour – July 23, 2013




19. Vangorda Water Treatment Plant
20. Grum Pit and Overburden Dump
15. Vangorda Pit and Diversion
18. Grum V15
17. Vargorda Dump Collection System
16. Vangorda Waste Rock and Cover Trials
1 km
1 mi
Northing: 6905297.97 Easting: 589965.66

Attachment 3A-9
Meeting with Yukon Environment - Meeting Notes, January 19, 2012

Faro Mine Remediation - Meeting Notes

Topic: Wildlife Information Requirements : Faro Mine Remediation Project

Date: January 19, 2012

Attendees: Patricia Randell, YG-AAM; Bill Slater, CH2M Hill; Julia Ahlgren, YG- Env.; Matt Clark, YG-Env.

1. Update and meeting purpose

Patricia R. described meeting purpose – to discuss wildlife information requirements for a YESAA Project Proposal. Patricia R./Bill S. provided status update regarding remediation planning for Faro Mine Complex and described project context (i.e. existing disturbed site).

2. Caribou

Matt C. – 2009 survey conducted. Also, observations during 2011 moose survey. There is substantial use of Subzone 445 by caribou, especially in early winter. Caribou observed close to the site, but not on site. Note that caribou are very sensitive to disturbance and will not use areas with significant activity.

Patricia R. – plan to conduct habitat mapping as part of project planning and for inclusion within the Project Proposal.

Matt C. – given project context, it is important to understand what caribou are using and how do we mitigate activities. But, this does not appear to be an issue for activities within the existing footprint. For activities outside of existing footprint, need to confirm that these are not areas of use.

Conclusion: No further specific investigations required, but utilize existing survey information combined with incidental observations and habitat mapping – with potential mitigation requirements or potential further investigations if activities will occur in or near areas of known caribou utilization.

3. Moose

Matt C. – Surveys completed in 2011 for regional area. Consistent with survey scope from 2004. Smaller survey conducted specifically in Subzone 445 in 1997. Initial data from 2011 survey should be available by end of month. Initial overview report completed this spring. Final report completed fall 2012. 1997 survey showed highest density of moose recorded in Yukon, but trend since then has been negative. Also, low bull numbers, suggesting high hunting pressures

Matt C. – Further information requirements: may consider looking at late winter utilization by moose. It is possible that Rose Cr. elevation is higher than used regionally. Recommendation is to identify lowest parts of affected area and compare with regional data about late winter utilization. If elevations are consistent, late winter survey may be warranted.

Notes finalized on March 1, 2012

Conclusion: Follow two-step process. First step to compare elevations in Rose Creek/Project Area to elevations of regional winter use areas. If elevations are consistent, consider late winter survey. If not, no further field investigation required.

4. Sheep

Matt C. – Surveys completed in June and July 2011. June to identify lambing areas and July to evaluate composition of sheep in the area. 2011 numbers are down from 2004, but 2004 numbers were highest recorded. Overall, appears to be healthy population. Issue for project will be how the sheep use the site, as it is a known migration corridor. Need to not restrict or discourage movement through the site, while still protecting sheep from site risks (e.g. pit water quality). Current observations confirm that 1980s investigations of migration corridors are still relevant.

Conclusion: No further work is needed to investigate migration corridors. Using 1980s work, combined with current observations of sheep on the site and habitat mapping should be adequate. Documentation of current observations may be required, but should be available through site logs.

5. Grizzly Bear

Conclusion: Denning habitat may be important in the area and is currently unknown. Habitat mapping should be the focus of work to characterize potential utilization of the study area by grizzly bear, for denning as well as other activities. Remediation plan should avoid creating conditions for denning directly on current disturbed areas where there will be underlying contaminated materials (i.e. don't encourage denning on constructed covers). Matt C. to speak with Ramona Maraj and provide AAM with further feedback.

Attachment 3A-10
Poster for Hunted Wildlife Organ Collection Program - Poster

ATTENTION
Hunters near the Faro area

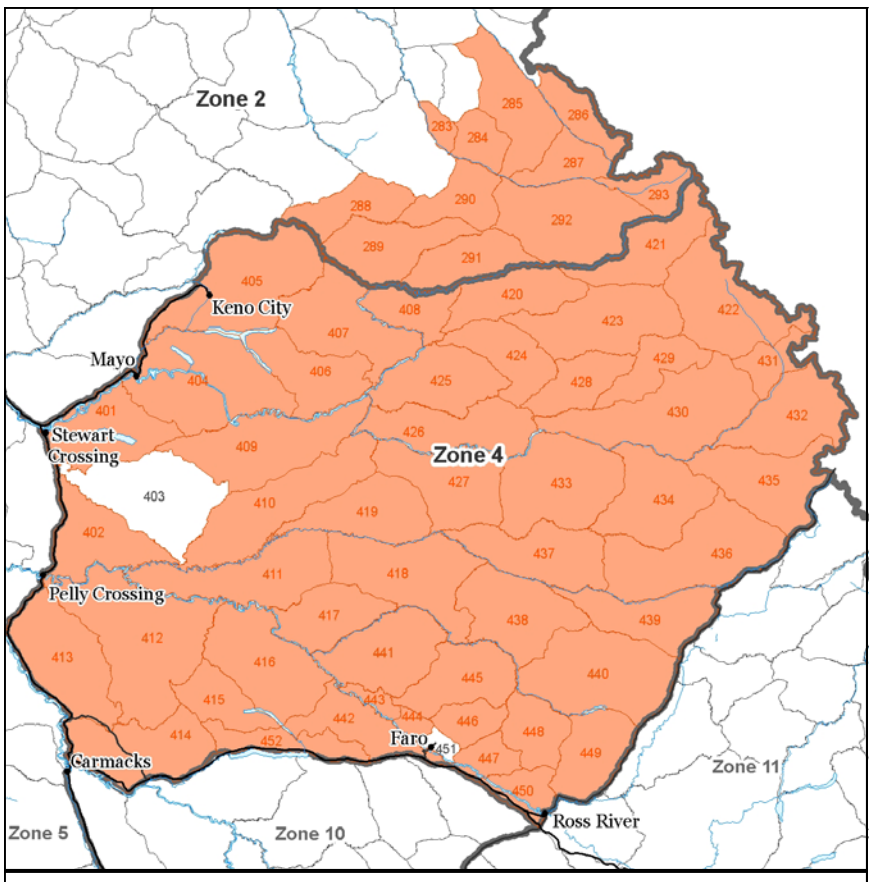
Yukon government needs your help in monitoring the health of wildlife in the Faro area.

Please donate samples of:

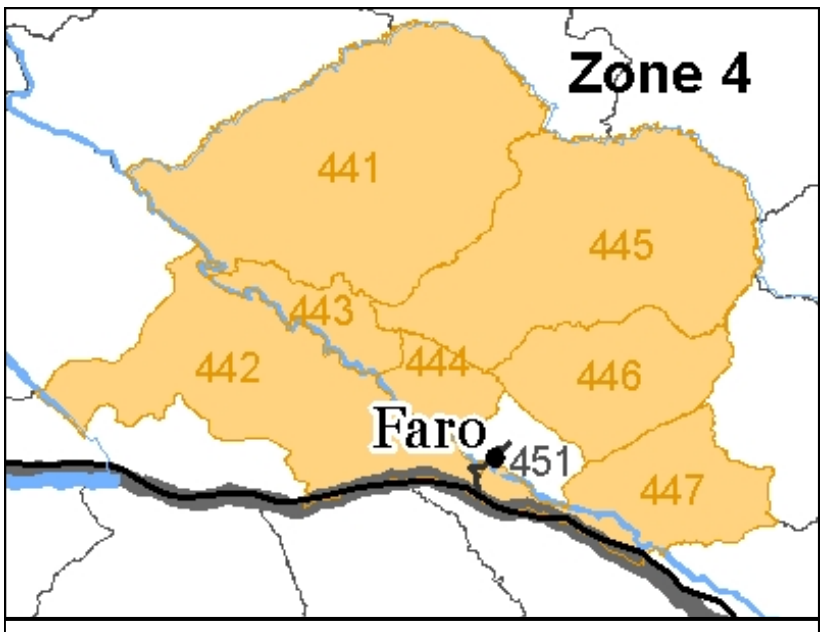
- kidney (whole)
- muscle
- liver
- incisor bar (front teeth)

From **caribou** hunted in Designated Game Management Zones 2-83 to 2-93 and all of Zone 4 (except for 4-03 and 4-51) or

From **moose and sheep** hunted in Designated Game Management Zones 4-41 to 4-47.



Caribou from Zones 2-83 to 2-93 and all of Zones 4 (except 4-03 and 4-51).



Moose or Sheep from Zones 4-41 to 4-47.

WHAT TO DO

- Please prepare liver and muscle samples to be the size and shape of a pound of butter.
- Put each sample in clean plastic bags.
- Freeze samples as soon as possible.
- Samples from different animals should be bagged separately.
- Please deliver the samples to any Environment Yukon—Game Branch Office before:

Monday, November 1, 2010

Thank you for your participation!

WIN A FREE CHARTER FLIGHT!

All hunters who bring in requested samples will be entered into a draw to win a free flight from Alpine Aviation. The flight can be used to fly the winner to their favourite spot next year. The draw will occur on **Tuesday, February 1, 2011**.

Gamberg Consulting
Environmental Research

alpine aviation

Yukon Government

For more information, please contact Yukon government at 867-456-6772 or toll free within Yukon at 1-800-661-0408, extension 6772.

Appendix 5A
Environmental Management Plan

Environmental Management Plan

Faro Mine Interim Works

February 28, 2014

Government of Yukon

Energy, Mines and Resources

Assessment and Abandoned Mines

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1 Background

1.1 Introduction

This environmental management plan (EMP) describes how environmental stewardship at the Faro Mine Complex is managed by the Yukon Government (GY). GY's role is to manage contractors who perform care and maintenance operations, or other physical works related to remediation.

An EMP is a site-specific plan developed to ensure that appropriate environmental management practices are followed during a project's construction and/or operation.

This EMP has been developed to ensure:

- Identification of current and potential human health and safety and environmental risks of the project or site;
- Risks associated with the project are properly managed (i.e. monitored and mitigated);
- Application of best management practice to the project or site; and
- Compliance with federal and territorial legislation.

To meet its environmental objectives, GY will employ a number management plans that include various mitigation measures and monitoring activities. This document provides summary descriptions of the purpose or content of each management plan.

1.2 Project Description

The Government of Yukon has been working towards design and planning of the overall Faro Mine Remediation Project (FMRP) for a number of years. While the FMRP is being prepared, YG will continue its activities on the FMC to protect, and minimize risks to human health and safety and the environment, as well as to support the development of the FMRP. These interim activities, collectively referred to as the Interim Works (IW), include the following tasks:

- Ongoing site operations;
- Site investigations in support of design and environmental characterization for the FMRP;
- The Down Valley Interim Hydraulic Upgrades (DVIHU) that comprise improvements in flood routing capacity for the Rose Creek Tailings Area (RCTA); and
- Ancillary activities associated with completing primary activities (e.g., accommodation for workers, utilization of borrow materials).

This EMP will apply to the IW activities which are further described in the sub-sections below.

1.2.1 Site Operations

The purpose of Site Operations is to maintain the site to prevent adverse effects on persons, property, and the environment, and to counteract, mitigate, and remedy any adverse effects that may occur.

This work largely consists of the following operations and maintenance activities:

- Operate, maintain, and repair the following components:
  - Fresh water systems;
  - Contaminated water systems;
  - Pumping systems;
  - Collection ditches;
  - Dams and diversions;
  - Contaminated water containment areas;
  - Contaminated water treatment systems;
  - Equipment;
  - Site buildings and infrastructure;
  - Electrical distribution systems; and
  - Roads and culverts.
- Perform sludge management.
- Perform tailings dust management.
- Implement the preventative maintenance plan.
- Provide emergency response capability and respond to emergencies.
- Provide security, health, and safety for the FMC.
- Purchase and manage use of electricity, fuels, and lubricants.
- Maintain all permits and licences as required.
- Implement an Affected Yukon First Nation and Yukoner Participation Plan.
- Provide site management and administration services.
- Comply with specified environmental standards.
- Conduct environmental and site monitoring.

The site operations program includes an extensive monitoring program to evaluate environmental conditions and physical and chemical stability of the site. These monitoring programs support an adaptive management plan.

1.2.2 Site Investigations

Development of the FMRP and design of remediation and closure elements requires extensive site investigation programs. These investigations will occur throughout the site and extend over the duration of the IW. Investigations will include the following types of activities:

- Drilling using various types of drilling equipment for the purposes of soil and rock sampling and also for the establishment of monitoring wells and installations.
- Conducting geotechnical investigation programs including test pitting, reconnaissance, drilling and sampling.
- Using water for a variety of programs including aquifer testing programs.

- Establishing, maintaining and operating various monitoring facilities including wells, flow measurement facilities, meteorological stations.
- Establishing, maintaining and operating test facilities to support reclamation research including cover trials and vegetation trials.
- Collecting vegetative material to support re-vegetation test programs.
- Conducting reconnaissance programs which may include use of helicopters.
- Utilizing heavy equipment to test remediation methods.
- Test pitting, drilling and sampling to support contaminated site assessment and the identification of borrow sources.
- Conducting heritage and archaeological assessment programs.
- Conducting water treatment test programs.
- Conducting field surveys and sampling programs for the physical and biological environment.
- Conducting geophysics and seismic refraction programs.
- Conducing surveying activities with associated line cutting and establishment of survey markers.

1.2.3 Down Valley Interim Hydraulic Upgrades

The DVIHU component of the IW is intended to address flood-related risks for the RCTA, thereby helping to reduce the likelihood of potential adverse effects on the environment. The DVIHU entails upgrading the hydraulic capacity of both the Intermediate Dam (ID) spillway and the Rose Creek Diversion (RCD) to provide capacity for the system to convey a 1-in-500-year flood event.

The DVIHUs have been designed as an option that can be completed in a timely and cost-effective way, thereby providing suitable risk management for the IW period prior to construction of the permanent flood routing facilities. The proposed works include:

- Increase the existing ID spillway capacity by increasing the depth of the existing spillway channel.
- Relocate existing piping and lime mix tank that have been placed within the ID spillway.
- Increase the height of the ID embankment crest by installing a geomembrane layer to extend the core to the dam crest and by addition of gabion mattresses.
- Protect the ID spillway channel from erosion by installing gabion mattresses.
- Increase the RCD capacity to pass the 1-in-500-year flood event, by removing vegetation, repairing raveled slopes on the dike and cut slope, and by filling in low spots on the dike crest.

The work is proposed for completion as soon as possible because the DVIHU are intended to provide temporary protection of the ID until implementation of the final closure plan.

2 Sediment and Erosion Control Plan

The Sediment and Erosion Control Plan (SECP) describes detailed measures to prevent sediment mobilization and erosion of exposed erodible materials. These measures are essential to minimize potential effects to the environment and ensure the stability of infrastructure. The SECP describes application of Best Management Practices (BMPs) and ensures compliance with relevant federal and territorial legislation (i.e. acts and regulations), permits and licences. Contractors will be required to develop plans in accordance with the SECP specific to the works/activities that they will be undertaking.

The SECP requires implementation of the following tasks prior to and during any activities that may expose erodible materials:

- Assessments of activities/works for their potential to cause the mobilization of sediments and erosion;
- Identification of mitigation measures for relevant activities/works and monitoring to ensure effectiveness (frequency dependent on risk and likelihood); and,
- Inspections to ensure the implementation of mitigation measures and compliance with relevant legislation, permits, licences and BMPs.

Standard mitigation measures identified in the SECP include:

- Minimize area of vegetation and soil disturbance;
- Minimize flow entering and flowing through work areas;
- Minimize the length of time that erodible materials are exposed;
- Minimize slopes of disturbed areas and material stockpiles;
- Avoid work during periods of high precipitation;
- Stabilize erodible materials as soon as practical through erosion control measures;
- Ensure the installation of erosion control measures before the commencement of works;
- Ensure that materials required for erosion control measures are available;
- Sediment barrier (e.g. straw bales, biofilter, brush barrier, pre-fabricated barrier) to capture and retain sediment;
- Geotextile sediment fence to reduce velocity and capture sediment; and,
- Sediment trap to pond water in order to allow sediment to precipitate.

3 Environmental Monitoring, Surveillance and Reporting Plan

The purpose of the Environmental Monitoring, Surveillance and Reporting Plan (EMSRP) is to track the effects of site activities so that potential environmental effects are identified before they become a problem. Environmental monitoring ensures environmental protection and compliance with legislation, permits and licences. It also confirms performance of BMPs. The EMSRP describes the monitoring activities that will be completed, as well as the practices and methodology to be employed by the teams responsible for conducting monitoring activities.

As identified in the EMSRP, monitoring effort depends on the sites, time of year, as well as the activities/works taking place. Annual monitoring programs are conducted at the Faro Mine, although additional monitoring will be conducted to verify the accuracy of predictions made in the IW Project Proposal effects assessment, the effectiveness of mitigation measures, and compliance with legislation, permits and licences. Additional monitoring effort will also be applied during the implementation of specific activities or works which have a higher risk and likelihood of affecting the environment. Should monitoring activities identify exceedences of prescribed thresholds, these will be brought to the attention of the relevant management personnel so that appropriate action may be taken (e.g. as specified in the adaptive management plan). The results of the data collected through the EMSRP, as well as the mitigation measures applied to address any exceedences, will be reported to the relevant regulatory agencies.

4 Emergency Response Plan

The emergency response plan (ERP) clearly defines what actions are required in response to the occurrence of high risk events (i.e. provides detailed guidance on how to respond to various emergency situations that could occur during normal operations).

The ERP identifies:

- What type of incident could occur;
- What general type of emergency response is required; and
- Any special response requirements.

The ERP provides an emergency telephone directory, roles of personnel responsible for the implementation of the ERP, a list of applicable legislation and standards, and an account of the different emergency scenarios and responses to these.

For each scenario, the ERP identifies the:

- The primary risks associated with the incident;
- How the incident may be identified and reported;
- Alarms or methods to alert persons of an emergency situation;
- The management response required;
- Any instructions specific to a scenario; and
- Contacts for specialist advice.

The ERP includes the following scenarios:

- Major Seismic Event/Earthquake;
- Open Pit Wall / Ramp Failure;
- Inrush into Open Pit;
- Animal Attack;
- White Out;
- Severe Electrical Storm;
- Severe Rain Storm/ Flood/ Freshet;
- Communicable Disease Outbreak: Human Epidemic;
- Vehicle Accident/ Incident;
- Heavy Equipment Break Through Ice;
- Dangerous Goods Truck Accident/ Incident;
- Light Vehicle Accident/ Incident;
- Heavy Vehicle Accident/ incident;
- Hazardous Substance Release;
- Water Treatment Plant Failure;
- Fire/ Explosion;

- Building Collapse;
- Working At Heights Accident/ Incident;
- Confined Space Accident/ Incident;
- Malicious Damage;
- Bomb Threat; and
- Armed Hold - Up/ Hostage Situation.

Specific plans, as described in the following sections, are appended to the ERP for emergency preparedness, these include:

- A Spill Contingency Plan (SCP); and
- Tailings and Water Management Structures Plans:
  - Emergency Response and Preparedness Plan (ERPP); and
  - Operations, Maintenance and Surveillance Manual (OMSM).

4.1 Spill Contingency Plan

The SCP provides a framework of responsibilities and response measures to be taken by staff and contractors when responding to spills. In the event of an accidental release of a deleterious substance, the implementation of the SCP will ensure that the necessary steps are taken to minimize the effects on human health and safety and the environment.

The SCP includes the following:

- Roles and responsibilities;
- Listing of products and activities which would require spill response (e.g., handling fuel and hazardous materials);
- Listing of spill response materials and equipment available on site;
- Training requirements;
- Spill containment procedures;
- Spill clean-up procedures;
- Notification and communication procedures;
- Reporting procedures (i.e. to applicable territorial and federal government agencies); and
- Listing of contacts.

4.2 Tailings and Water Management Structures Plans

The Faro Mine Complex is comprised of several tailings and water management structures. As per Canadian Dam Association Dam Safety Guidelines (2007), an Emergency Response and Preparedness Plan (ERPP) and an Operations, Maintenance and Surveillance Manual (OMSM) are required for retaining structures. Summaries of the contents of these documents are presented in the sections below.

4.2.1 Emergency Response and Preparedness Plan

The purpose of the ERPP is to provide a plan that includes mechanisms and processes for addressing potential failures of structures and equipment at the Faro Mine Complex. This ERPP describes the internal processes and procedures that would be undertaken in responding to a failure or potential failure at the site. Having an ERPP in place enables site personnel to be prepared in the event of an emergency. It also provides one component of a comprehensive facility management system for the tailings facility and associated structures. The goals of the ERPP are to firstly prevent the occurrences of emergencies and secondly reduce the impact of emergencies. In both cases the goal is to protect human health and safety, and the environment.

The ERPP includes the following components:

- Roles and responsibilities;
- Identification of a requirement for action (i.e. list of site conditions that necessitate an action under the ERPP);
- Plan activation, notification procedures and contacts; and
- Actions to prevent structure failure.

4.2.2 Operations, Maintenance and Surveillance Manual

This OMSM provides a documented framework for actions in order to ensure the safe operation, maintenance, and surveillance of water containment and conveyance facilities. The OMSM is a living document in that it regularly requires updating; information will be updated at a minimum of once per year, as well as at every change in critical personnel or contractors, and changes in procedures or conditions on-site.
As per the Canadian Dam Association Dam Safety Guidelines (2007), the OMSM includes:

- A site description;
- Operation information including roles and responsibilities, water management and flow control gauging and emergency systems;
- Maintenance information for all major facilities and infrastructure on site; and
- Surveillance information including inspections, instrumentation, response to unusual conditions, and documentation and follow-up.

The site operator is responsible for all on site operations including making immediate decisions required during an emergency, as well as ensuring all documentation is up to date and all procedures of the OMSM are followed. The OMSM specifies the operating procedures during normal, flood or drought, emergency, and unusual conditions.

Maintenance of site facilities is critical for safe and continuous operation as well as to ensure the integrity of the site components. The objectives of the maintenance program are to review and identify maintenance requirements, execute corrective measures, and repair all facility components as required.

The principal objective of the FMC physical structures surveillance program is to identify any conditions of concern (i.e. which could compromise the integrity of the structure) prior to them

becoming a problem. Early identification of those conditions allows issues to be addressed in a timely manner.

The program focuses on three areas of interest:

- Stability and deformation of embankments;
- Thermal conditions within the dams; and
- The quantity and quality of the water to be discharged.

5 Waste Management Plan

The Waste Management Plan (WMP) outlines the handling, containment, storage, transportation, recycling and disposal procedures specific to the different types of hazardous, solid, and special waste materials generated at the Faro Mine Complex (FMC). These procedures comply with current permits and licences as well as applicable territorial and federal legislation. Typical waste materials include:

- Domestic waste;
- Litter;
- Containers, drums, and barrels;
- Scrap metal;
- Tires;
- Treated timber;
- Waste oils and fluids;
- Waste chemicals; and
- Contaminated soils.

The WMP also identifies training requirements, waste characterization and sampling methods, as well as the forms required for documenting waste storage, inspection, transportation and disposal. Additionally, the WMP provides guidelines and practices to mitigate the effects of waste generation; for example:

- Materials will be used efficiently in order to minimize waste generation;
- When possible, materials that are less harmful to the environment will be used;
- Waste materials will be separated as recyclable and non-recyclable; and
- Waste will be handled in such a way to avoid attracting wildlife.

6 Wildlife and Habitat Management Plan

The Wildlife and Habitat Management Plan (WHMP) describes the management approaches and BMPs that are used to prevent and/or minimize adverse effects on wildlife and wildlife habitat, the monitoring and reporting procedures, and the roles and responsibilities of relevant positions. The WHMP provides considerations for all terrestrial, aquatic and riparian wildlife values.

The objectives of this WHMP include the following:

- Identify any activities that have the potential to result in adverse effects to wildlife and wildlife habitat, and describe those effects;
- Provide focused attention on risks to valued, rare and endangered species;
- Identify management approaches and BMPs to avoid and/or minimize potential adverse effects;
- Ensure effects are monitored and management strategies are adapted so as to ensure that mitigation measures are applied and are efficient;
- Ensure that management of wildlife and wildlife habitat are in compliance with territorial and federal legislation.

Examples of the mitigation measures found within the WHMP include:

- On-site communication of wildlife sightings to advise other personnel;
- Assess, delineate and avoid disturbance of habitats of ecological importance;
- Reduce footprint of works to the greatest extent possible;
- Implementation of speed limits to minimize dust and noise, and reduce collisions;
- Implementation of work that considers sensitive time periods (i.e. during the day and periods of the year) and sensitive areas (i.e. migratory routes);
- Remediate newly disturbed areas to the extent practicable (e.g. re-sloping and revegetation);
- Proper food waste disposal procedures (e.g. bear-resistant trash bins); and
- Prohibition against littering and feeding wildlife species.

7 Heritage Resources Management Plan

The Heritage Resources Management Plan (HRMP) assists in ensuring the immediate and ongoing identification, protection, and management of heritage resources at the FMC. This plan presents action items and communication protocols to assist with the orderly and successful management of heritage resources within the FMC.

The protection and management actions include:

- *Flagging and signage of known heritage sites to prevent impacts:*
  This will include making sure each known site is flagged with yellow flagging tape marked "No Work Zone". Signage will be added to each site with clear wording stating "No Disturbance Zone".
- *Creating, placing and reviewing heritage resources warning and information posters on site:*
  A poster will be created and put on display at Faro Mine Complex office reminding staff of the protected status of heritage resources; that known sites are marked (showing the type of flagging and signage used); and what to do in case of chance finds.
- *Heritage resources review of any future ground disturbances:*
  Any proposed ground disturbance activities, in areas that have not been the subject of heritage impact assessment, will be reviewed by heritage assessment staff prior to ground disturbance.
- *Flagging and signage of newly recorded heritage sites to prevent impacts:*
  Sites recorded in the future will be flagged and signed in the same manner as noted above.

The HRMP also provides two communication protocols:

- *Ground disturbing activities protocol:*
  This protocol will be used between equipment operators and the site manager to review areas of planned impacts compared to known heritage resources prior to heavy equipment use.

- *Chance finds protocol:*
  This protocol identifies the steps to take and the information to gather in the event that heritage resources are accidentally discovered during work activities.

The entire staff will be reminded of the protected status of heritage resources and instructed on what to do during each step in the management plan. If sites are planned to be impacted then individual site mitigation plans will be developed and implemented.

8 Occupational Health and Safety Plan

The objective of the Occupational Health and Safety Plan (OHSP) is to protect health and safety, manage risks, and promote safety awareness to all personnel and the public. The OHSP complies with the requirements identified in Yukon Occupational Health & Safety Act and Regulations and describes specific rules, practices, procedures and protocols to be followed by all personnel to mitigate health and safety hazards. The plan also includes all necessary forms, specific to the work being performed.

The OHSP communicates the following responsibilities:

- Work being performed must meet all legislated health and safety requirements;
- Supervisors have the responsibility to provide healthy and safe work conditions and ensure that all employees under their direction are appropriately trained;
- Employees have the responsibility to work safely and to report all unsafe or unhealthy conditions; and
- Contractors are responsible for ensuring they meet legislated health and safety requirements and that the rules, practices, procedures and protocols identified in the OHSP are adhered to.

The OHSP covers the following topics:

- Health and Safety Policy
- Hazard Assessment and Risk Control
- Safe Work Practices
- Safe Job Procedures
- Site Safety Rules
- Personal Protective Equipment
- Preventive Maintenance
- Training and Communication
- Inspections
- Incident Investigation & Reporting
- Emergency Preparedness
- Records and Statistics
- Occupational Health & Hygiene

Appendix 5B
Environmental Monitoring, Surveillance, and Reporting Plan

Draft

Environmental Monitoring, Surveillance, and Reporting Plan Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 6, 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon

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Acronyms and Abbreviations

AEMR	Annual Environmental Monitoring Report
AMP	Adaptive Management Plan
ARD	acid rock drainage
CVD	Cross Valley Dam
DO	dissolved oxygen
DOC	dissolved organic carbon
EMP	Environmental Management Plan
EMSRP	Environmental Monitoring, Surveillance and Reporting Plan
ETA	Emergency Tailings Area
FCD	Faro Creek Diversion
FMC	Faro Mine Complex
GID	Grum Interceptor Ditch
GSC	Grum Sulphide Cell
ID	Intermediate Dam
IW	Interim Works
LCD	Little Creek Dam
m	metre(s)
ML	metal leaching
NFRC	North Fork Rose Creek
NFRD	North Fork Rock Drain
NWID	North Wall Interceptor Ditch
OMSM	Operations, Maintenance, and Surveillance Manual
ORP	oxygenation reduction potential
QA/QC	Quality Assurance/Quality Control
RCD	Rose Creek Diversion
RCTA	Rose Creek Tailings Area
RISC	[British Columbia] Resource and Inventory Standards Committee
SFRC	South Fork Rose Creek
SPP	Sheep Pad Ponds
SIS	Seepage Interception system
TDS	total dissolved solids
TDS	total suspended solids
UGC	Upper Guardhouse Creek

VCD	Vangorda Creek Diversion
VNEID	Vangorda Northeast Interception Ditch
WRD	Waste Rock Dump
WTP	Water Treatment Plant
YESAA	Yukon Environmental and Socio-economic Assessment Act

SECTION 1

Introduction

The Environmental Monitoring, Surveillance, and Reporting Plan (EMSRP) defines the overarching monitoring objectives, monitoring design, and reporting to support the Faro Mine Interim Works (IW). The EMSRP outlines the monitoring for the IW to demonstrate the following:

- The project is executed as proposed and it performs as expected.
- Where performance differs from expectations that any adverse environmental effects are promptly identified and mitigated.
- The terms and conditions set out in the Yukon Environmental and Socio-economic Assessment Act (YESAA) Decision Document and any authorizations (e.g., Water Licence) are met.

The EMSRP outlines the anticipated environmental monitoring and reporting requirements for the Project related to aspects of water quality, meteorology, aquatic environment, wildlife and vegetation. The primary objectives of the environmental monitoring program are as follows:

1. Confirmation Monitoring – Confirmation monitoring is performed to define environmental conditions for comparison with future monitoring efforts. It is also used to describe natural conditions in areas not impacted by mine site operations.
2. Performance Monitoring – Performance monitoring is performed to evaluate the changes in environmental conditions resulting from actions or operations carried out as part of the IW. The monitoring data collected in these areas will support the evaluation of system effectiveness as well as support the design of potential improvements to system operations. Performance monitoring also includes, where applicable, compliance monitoring to determine whether the site operations are meeting conditions set out in the Water Licence.
3. Adaptive Management – adaptive management monitoring is performed to understand how environmental conditions in a particular area are changing, and whether a response is needed to address these changes to be protective of human health and the environment.

In addition, the EMSRP outlines the various components of the Geotechnical Monitoring Program that will be carried out to monitor the safety and integrity of the various physical structures on site including dams, diversions, and dikes.

This initial EMSRP will be updated to incorporate changes arising from of the terms of the YESAA Decision Document and terms and conditions that will be laid out in the Water Licence. The EMSRP is a “living document.” It will be regularly updated on the basis of management review, changes in site conditions, ongoing site investigations or other project related changes. Audits and management reviews of the EMSRP will be carried out annually in conjunction with preparation of the Annual Environmental Monitoring Report (AEMR), and throughout the year, if required. These reviews will provide a mechanism to assess the effectiveness of the various monitoring programs. Additionally, sampling programs may be modified based on evaluation of site wide data quality objectives, and by the specifications of a Quality Assurance Project Plan that is currently under development.

SECTION 2

Water Monitoring Program

2.1 Surface Water Monitoring Programs

Surface water has been extensively monitored at the Faro Mine Complex (FMC) for regulatory compliance, environmental monitoring, and closure planning purposes. Monitoring began during mine operations but has intensified since the cessation of mining activities in 1998. Surface water monitoring will continue to be a key component of the site environmental monitoring program to provide ongoing information for the following:

- Characterization of upstream/background surface water conditions
- Monitoring for changes in water quality and quantity on site that reflect the evolution of source areas within the mine complex
- Monitoring the downstream receiving environment, during the implementation of the project, to minimize impacts to the downstream receiving environment
- Providing for compliance monitoring as per the upcoming Water Licence for the IW
- Providing input to the site Adaptive Management Program (AMP)
- Providing for the ongoing collection of information that is required to support the closure planning process

2.1.1 Water Quality Program and Objectives

The primary objectives of the surface water quality monitoring program can be summarized as follows:

1. Confirmation Monitoring – Confirmation monitoring is performed to define baseline conditions for comparison with future monitoring efforts. It is also used to describe natural water quality conditions in areas not impacted by mine site operations. This type of monitoring will also be used to establish baseline conditions with respect to discharges from the site, specifically whether the discharge of impacted water from any portion of the site is currently resulting in degraded surface water quality.
2. Performance Monitoring – Performance monitoring is performed to evaluate the changes in surface water quality resulting from any action or operation affecting water quality and to confirm compliance with Water Licence effluent limits. This includes not only monitoring at locations internal to the FMC, but also locations in the receiving environment downstream of water management facilities such as the S-Wells Seepage Interception System (S-Well SIS) and the discharge from the Cross Valley Dam (CVD) Pond. The monitoring data collected in these areas will support the evaluation of the effectiveness of site water management systems as well as support the design of potential improvements to system operations.
3. Adaptive Management – Adaptive management monitoring is performed to understand how surface water quality conditions in a particular area are changing, and whether a management or mitigative response is needed to address these changes to be protective of human health and the environment.

The surface water quality monitoring program will consist of monitoring at stations that have been selected for characterization of site water quality based on the following criteria:

- Locations that would best represent conditions unaffected by mine-related disturbances, which are mostly located upstream of the site and provide information on background or reference water quality conditions – Reference
- Locations internal to the FMC that are used to monitor the water quality at key locations within the complex – Internal
- Locations that are used to monitor site discharges and sources of potential contaminant load to the receiving environment – Perimeter
- Locations that are used to monitor the conditions in receiving environment – Receiving

For implementation purposes, the FMC surface water quality monitoring program will continue to be carried out as two separate components: the Routine Water Quality Monitoring Program and the Pelly River Aquatic Monitoring Program. The surface water quality monitoring locations for both the Routine and Pelly Aquatics monitoring programs for the FMC are shown in Figure 5B-1, Figure 5B-2, and Figure 5B-3.

The Routine Water Quality Monitoring Program will be carried out by the contract site operator in accordance with the conditions of the care and maintenance contract. The Routine Water Quality Monitoring Program sample locations are listed in Table 5B-1 for the Faro Mine Area and Table 5B-2 for the Vangorda/Grum Area along with monitoring frequency. Water quality samples collected as part of the Routine Water Quality Monitoring Program will be analyzed for:

- Physical parameters including pH, specific conductance, total suspended solids, total dissolved solids and hardness;
- Anions and cations including ammonia-N, Nitrate-N, sulphate, chloride and alkalinity;
- Total organic carbon and dissolved organic carbon (field filtered) - except at internal stations; and
- Total metals and dissolved metals (field filtered).

At the time of sample collection field parameters will also be taken including pH, conductivity and temperature. In addition to the above water quality sample collection, quarterly toxicity testing, (96-hour LC50 acute toxicity) will be carried out at each of the site discharge locations: X5, X13, and V25BSP.

TABLE 5B-1
Faro Mine Area - Routine Water Quality Monitoring Locations
Faro Mine Interim Works

Station Name	Location Description	Frequency	Purpose
FAROCR	Outlet of Faro Creek Diversion (FCD)	M	Perimeter [a]
FCO	Old Faro Creek, Upstream of Faro Valley Waste Dump	3X	Internal [b]
GDHSECK	Lower Guardhouse Creek (LGC) at Intermediate Impoundment	3X	Internal
NF1	North Fork Rose Creek (NFRC) Site 1, Upstream of North Fork Rock Drain (NFRD)	M	Perimeter
NF2	NFRC Site 2, downstream of NFRD	M	Perimeter
R7	NFRC above FCD	M	Reference [c]
R8	NFRC, 100 metres (m) downstream of confluence with FCD	M	Receiving [d]
R9	NFRC, adjacent to Zone II waste rock dump (WRD)	M	Receiving
R10	NFRC, downstream of Zone II WRD and 100 m downstream of R9	M	Receiving
X2	NFRC, upstream of mine Access Road	M	Receiving
X3	South Fork Rose Creek (SFRC) at the Pumphouse Pond	M	Receiving
X3A	Rose Creek, downstream of confluence of north and south forks	M	Receiving
X4	ID Pond Decant (when discharging) / ID Pond at Spillway (when not discharging)	M	Internal
X5	CVD Pond Decant	WD	Perimeter
X5P	CVD Pond	M	Internal
X7	Faro Creek Canyon, downstream of mine Access Road	SF	Internal
X10	RCD below weirs	M	Perimeter
X14g	Rose Creek downstream of the Diversion	WD/M	Receiving

TABLE 5B-1
Faro Mine Area - Routine Water Quality Monitoring Locations
Faro Mine Interim Works

Station Name	Location Description	Frequency	Purpose
X22B	Faro Main Pit at Pumping Barge	M	Internal
	Emergency Tailings Area (ETA) combined collection from Pumping System	M	Internal
	ETA Bypass below Collection System	M	Internal
	ID Pond Pumping Barge	M	Internal

Legend

Frequency: SF = spring and fall; M = monthly; WD = weekly when discharging; WD/M = weekly when discharging/monthly otherwise; 3X = three times/year

[a] Perimeter stations are the interface between a mine source area and the external natural environment, where a contaminant may be released from the mine site to the environment.

[b] Internal stations are within the mine source area, and may receive contaminants released from the mine site.

[c] Reference stations are located upstream of the mine source area and reflect pre-mine water quality conditions.

[d] Receiving stations are located downstream of internal and perimeter stations and may receive contaminants released by the mine site.

TABLE 5B-2
Vangorda and Grum Area– Routine Water Quality Monitoring Locations
Faro Mine Interim Works

Station Name	Location Description	Frequency	Purpose
LCD	Little Creek Dam (LCD) Pond at Old Pumphouse	MO	Internal
V1	Vangorda Creek, upstream of Mine and Blind Creek Road	M	Reference
V2	Grum Creek, upstream of confluence Vangorda Creek, Main stem of Grum Creek below Tributary A	2M/M	Perimeter
V2A	Grum Creek, upstream of confluence with Moose Pond, adjacent to Tributary A, downgradient from V15	2M/M	Perimeter
V4	Shrimp Creek, upstream of Vangorda Creek confluence	M	Perimeter
V5	West Fork of Vangorda Creek at Gravel Pit	M	Receiving
V8	Lower Vangorda Creek at the Footbridge	3X M	Receiving
V22	Vangorda Pit at Pumping Barge	Q	Internal
V23	Grum Pit at Haul Road	Q	Internal
V24	Influent to Water Treatment Plant	WD	Internal
V25	Effluent from Vangorda WTP Sludge Pond	WD	Internal
V25BSP	Grum Interceptor Ditch below Sheep Pad Ponds	WD/M	Perimeter
V27	Vangorda Creek, just upstream of Shrimp Creek	M	

Legend

Frequency : 2M = twice monthly (May to October); M = monthly; Q = quarterly; WD = weekly when discharging; WD/M : weekly when discharging/monthly otherwise; MO = monthly during open water (May to October); 3X = three times/year

The Pelly River Aquatics Monitoring Program focuses solely on water quality in reference and receiving water locations including far-field locations in the Anvil/Rose Creek systems as well as the Pelly River. In addition, it includes locations that have been previously identified as potential sources of drinking and/or tea water by local First Nations. The majority of the monitoring locations in the Pelly River Aquatics Monitoring Program will continue to be sampled three times per year: spring, summer and fall, representing the three distinct flow conditions during the year (i.e., winter low flow, spring freshet and summer/fall). Exceptions include stations VW1, VW3, VGMAIN, V8, R4, R5, and A1, which will be sampled monthly. The program sample locations are listed in Table 5B-3.

TABLE 5B-3
Pelly Aquatic Monitoring Program - Water Quality Monitoring Locations
Faro Mine Interim Works

Station Name	Location Description	Frequency	Purpose
V8	Lower Vangorda Creek at the footbridge	M	Receiving
V17A	Creek from Grum Ore Transfer Pad	3X	Receiving
V20A	Dixon Creek upstream of mine workings	3X	Reference
VR	West Fork Vangorda Creek upstream of Haul Road	3X	Reference
VGMAIN	Main Fork Vangorda Creek downstream of mine but upstream of West Fork Vangorda Creek	M	Receiving
VW1	West Fork Vangorda downstream of landslide but upstream of VW2	M	Receiving
VW2	Tributary to West Fork Vangorda Creek which drains Grum west lobe	3X	Receiving
VW3	West Fork of Vangorda downstream of AEX Creek	M	Receiving
FC	Faro Creek above Diversion	3X	Reference
R1	SFRC upstream of Pumphouse Pond and Rose Creek Tailings Area (RCTA)	3X	Reference
R4	Rose Creek upstream of confluence with Anvil Creek	M	Receiving
R5	Anvil Creek downstream of Rose Creek after full mixing	M	Receiving
R6	Anvil Creek upstream of Rose Creek	3X	Receiving
W10	Upper Guardhouse Creek upstream of Northwest WRD	3X	Reference
X14	Rose Creek downstream of the Rose Creek Diversion	3X	Receiving
NWID	Northwest Interceptor Ditch upstream of diversion point	3X	Receiving
USFR	SFRC upstream of Haul Road	3X	Reference
Grum Corner (GCULV)	SFRC downstream of Haul Road and upstream of mine Access Road	3X	Other
K8	Reservoir Creek upstream of Mine Access Road	3X	Other
A1	Anvil Creek near confluence with Pelly River	M	Receiving
P1	Pelly River upstream of Vangorda Creek	3X	Reference
P4	Pelly River downstream of Anvil Creek	3X	Receiving

Legend

Frequency: M = monthly; 3X = three times/year during winter low flow, spring freshet, and summer/fall

Water quality samples collected as part of the Pelly River Aquatics Monitoring Program and the Routine Water Quality Monitoring Program will be taken on the same day, or within the same few days. All sampling and analysis will be conducted in accordance with the current edition of “Standard Methods for the Examination of Water and

Waste Water" and all samples will be analyzed by the same external accredited laboratory for the same suite of parameters. Quality assurance/quality control (QA/QC) samples will be collected as specified in the site quality assurance project plan. This will include the use of field blanks, trip blanks, equipment blanks, duplicate samples and split samples.

2.1.2 Hydrology Monitoring Program and Objectives

The existing Hydrology Monitoring Program will be expanded during the IW period as current records of continuous flow monitoring data for many monitoring sites are limited and the dates of record are not consistent among the various sites. Upgrades of a number of the existing hydrometric stations, as well as the installation of several new stations are required.

The objectives of the expanded Hydrology Monitoring Program are to expand the ongoing flow monitoring network in order to support water balance and water quality modeling studies and to assist in planning of hydraulic facility upgrades, water management design, and fish habitat compensation planning.

2.1.2.1 Hydrology Monitoring Program

The Hydrology Monitoring Program during the IW period will focus on collecting continuous streamflow data in (1) the Rose Creek catchment, which contains the Faro Mine Area, and (2) the Vangorda Creek catchment, which contains the Vangorda/Grum Area. This will be achieved by maintaining a number of the automated hydrometric stations and establishing up to three new stations. The final number of existing stations that will be maintained and new stations to be installed will be selected to provide sufficient hydrological characterization of the FMC areas potentially impacted by the IW activities. All hydrometric stations will be established or upgraded in accordance with accepted standardized practices and procedures, as outlined by the British Columbia Resource and Inventory Standards Committee (RISC) (BC Ministry of the Environment, 2009).

At each installed station, water surface elevation and barometric pressure data will be measured at fifteen minute intervals by automatic dataloggers. Solinst Barologger and Levelogger series (Gold and Edge models) will be installed to ensure consistency among the existing and new stations and the hydrologist will calibrate dataloggers and equipment. Discharge measurements will be conducted during routine site visits as well as during special visits to cover hydrologic extremes (i.e., baseflow to high event flow). Discharge measurements at the hydrometric stations will be performed using the velocity-area method using instantaneous velocity meters. The hydrologist will perform discharge measurements in accordance with RISC standards to ensure high accuracy data collection. Rating curves correlating stage and discharge will be will be developed for all hydrometric stations based on these measurements.

During each site visit the hydrologist will perform the following tasks:

- Maintain flow monitoring stations and data collection equipment at least monthly to confirm that no damage has occurred to the equipment and that the site is free of obstructions or other factors that would negatively impact the collection of flow data.
- Download surface water elevation data from the dataloggers and verify performance of the dataloggers
- Perform discharge measurements
- Record gauge heights and perform bench mark surveys to verify staff gauge elevations and calibrate gauging instrumentation

Hydrology monitoring will occur at the frequencies summarized in Tables 5B-4 through 5B-6.

The existing hydrometric station locations in the Faro Mine Area – Rose Creek catchment are summarized in Table 5B-4 and shown on Figure 5B-2. The existing hydrometric station locations in the Vangorda/Grum Mine Area – Vangorda Creek catchment are summarized in Table 5B-5 and shown in Figure 5B-3. Potential new hydrometric station locations in the Faro Mine Area and in the Vangorda/Grum Mine Area are summarized in Table 5B-6 and shown on Figures 5B-2 and 3.

TABLE 5B-4
Existing Hydrometric Station Locations in the Faro Mine Area
Faro Mine Interim Works

Location	Station Name	Frequency[a]	Measurement Device
Faro Creek	FCO	Monthly	V-notch weir and estimate
FCD	FDC-1	Continuous	Staff gauge
	FAROCR	Monthly	In-stream and estimate
NFRC	R7	Continuous	In-stream [b]
	R8	Monthly	In-stream
	R9	Monthly	In-stream
	R10	Monthly	In-stream
	NF2	Monthly	In-stream
	X2	Continuous	In-stream
S-Wells Area	NFRC SC-1	Monthly	In-stream and estimate
	NFRC SC-2	Monthly	In-stream and estimate
	NFRC SC-3	Monthly	In-stream and estimate
	NFRC SC-4	Monthly	In-stream
ETA	X7	Monthly	Estimate
	ETA Combined	Continuous	Volumetric [c]
	X23	Continuous	V-notch weir
	FCS-4	Monthly	V-notch weir
Cross Valley Dam Pond Seepage	X11	Weekly	V-notch weir
	X12	Weekly	V-notch weir
	X13	Weekly	Broad-crested weir
	Weir 3	Weekly	V-notch weir
North Wall Interceptor Ditch (NWID)	NWID	Monthly	In-stream and estimate
Lower Guardhouse Creek	GDHSECK	3/year	Estimate
SFRC	X3	Monthly	In-stream
RCD	X3A	Monthly	In-stream
Rose Creek	X10	Monthly	In-stream
	X14	Continuous	Staff gauge

[a] Continuous: level logger with continuous water level elevation and routine spot-flow measurements. All other spot-flow measurements taken on the noted frequency.

[b] An instantaneous velocity meter will used to perform in-stream measurements.

[c] Volumetric measurement using flow meter.

TABLE 5B-5
Existing Hydrometric Station Locations in the Vangorda/Grum Mine Area
Faro Mine Interim Works

Location	Station Name	Frequency[a]	Measurement Device
Vangorda Creek upstream of mine	V1	Continuous	In-stream
Vangorda Interception Ditch	V20	Weekly	Estimate
V15 Seepage Collection Ditch Area	V2	2/month	Estimate
	V2A	1 to 2/month	Estimate
Vangorda Water Treatment Plant (WTP), Sludge Pond discharge	V25	Weekly in summer	In-stream
Grum Interceptor Ditch, below Sheep Pad Ponds	V25BSP	Monthly/Weekly	V-notch weir
Vangorda Creek	V27	Continuous	In-stream
	V8	Continuous	In-stream
Shrimp Creek	V4	Monthly	In-stream

[a] Continuous: level logger with continuous water level elevation and routine spot-flow measurements. All other spot-flow measurements taken on the noted frequency.

TABLE 5B-6
Potential New Hydrometric Station Locations in the Faro and Vangorda Grum Mine Areas
Faro Mine Interim Works

Location	Station Name	Frequency[a]	Measurement Device
Rose Creek Upstream of NFRC Confluence	CH12-203-SG001	Continuous	In-stream
Vangorda Creek – Upstream of Grum Creek	CH12-303-SG001	Continuous	In-stream
Grum Creek	CH12-303-SG002	Continuous	In-stream

[a] Continuous: level logger with continuous water level elevation and routine spot-flow measurements. All other spot-flow measurements taken on the noted frequency.

2.1.2.2 Data Assessment and Reporting

Following site visits, the hydrologist will:

- QA/QC and post-process downloaded flow data and compile the data in Excel format.
- Extend the existing stage-discharge rating curve (if applicable depending on station configuration) for flows/stages that exceed maximum flow recorded at station to date.

In addition, a hydrology summary report, including updated stage-discharge curves and hydrographs, will be prepared for each station to be included in the AEMR.

2.1.3 Pit and Pond Water Levels Monitoring Program and Objectives

Monitoring of the pit and pond water levels plays an integral part of the water management at the FMC. As part of the Routine Monitoring Program, pit and pond water levels will continue to be measured at the following

locations as per the frequency listed in Table 5B-7: Faro Pit, Zone II Pit, ID Pond, CVP, Grum Pit, Vangorda Pit, LCD Pond, Moose Pond and the Grum Sulphide Cell (GSC) Pond.

TABLE 5B-7
Faro Mine Complex Pit and Pond Water Level Monitoring Table
Faro Mine Interim Works

Location	Frequency
Faro Pit	Continuous
Zone II Pit	Continuous
ID Pond	Continuous
CVD Pond	Monthly
Grum Pit	Monthly
Vangorda Pit	Continuous
LCD Pond	Continuous
Moose Pond	Twice/month
GSC Pond	After peak run-off events

2.1.4 Reporting

The results of the Routine Monitoring Programs will be summarized in the monthly site reports including water quality monitoring data, flow monitoring data and pit and pond water levels. A full detailed report of the surface water monitoring program will be included in the AEMR. Reporting for the Pelly River Aquatic Monitoring Program will consist of detailed field reports to be submitted following each sampling event that will include a full description of site conditions, water quality results, assessment and interpretation of the results.

2.2 Groundwater Monitoring Program

The purpose of the groundwater monitoring program for the FMC is to provide information for the following:

- Identify areas where impacted groundwater quality may represent a threat to surface water quality
- Monitor for changes in groundwater quality that reflect the evolution of source areas within the mine complex
- Improve understanding of the background groundwater quality in the vicinity of the FMC

2.2.1 Groundwater Monitoring Program Objectives

The primary objectives of the monitoring program include confirmation monitoring, performance monitoring, and adaptive management. Each of these objectives is described as follows:

- Confirmation Monitoring - Confirmation monitoring is performed to define baseline conditions for comparison with future monitoring efforts. It is also used to describe natural groundwater conditions in areas not impacted by mine site operations. This type of monitoring will also be used to establish baseline conditions with respect to surface water/groundwater interaction, specifically whether the discharge of impacted groundwater in any portion of the site is currently resulting in degraded surface water quality.
- Performance Monitoring - Performance monitoring is performed to evaluate the changes in groundwater quality resulting from the operation of any seepage interception system or other actions that may affect groundwater quality (such as surface water diversions or other mitigative measures). Currently at the FMC, the primary systems that will undergo performance monitoring are the ETA SIS and the S-Wells SIS. The operation of these systems has a direct impact on groundwater quality in the vicinity of the seepage interception systems and monitoring data collected in these areas will support the evaluation of system effectiveness as well as support the design of potential improvements to system operations.

- Adaptive Management - Adaptive management monitoring is performed to assess changes in groundwater conditions in a particular area, and whether a response is needed to address changes to be protective of human health or the environment. The process of adaptive management focuses on identifying potential sources of contamination that may evolve in the future as site conditions and contaminant transport change. At the FMC, this process generally involves the following:
  - Evaluation of evolving geochemical conditions within the waste rock dumps and ore piles
  - Forecasting the rate at which the neutralizing effect of the waste rock is degrading
  - Predicting if and when acid and metals generating reactions will become predominant

Once these chemical reactions become predominant, the mass flux from the source areas significantly increase, and the likelihood of increased areas of groundwater quality degradation downgradient of these sources greatly increases.

In adaptive management monitoring, the goal is to identify the likely pathways between these evolving contaminant sources and potential receptors, and collect groundwater monitoring data along these pathways to provide early warning of potential contaminant movement. In addition, the necessary data are collected to develop response strategies to effectively address the environmental threats.

2.2.2 Groundwater Monitoring Program

The proposed groundwater quality monitoring program consists of the routine monitoring of approximately 120 monitoring wells throughout the FMC (Figures 5B-4 and 5B-5). These monitoring wells are summarized in Table 5B-8. Also provided in Table 5B-8 is the general area where each of these wells are located and the recommended frequency for monitoring.

TABLE 5B-8
Faro Mine Complex Groundwater Quality Monitoring Wells
Faro Mine Interim Works

General Area	Approximate Number of Wells
CVD Area	12
ETA	8
Faro Rock Dumps	3
Grum Mine Area	9
ID	
Intermediate Impoundment	5
Mill Building Area	5
Original Impoundment	2
Second Impoundment	7
PumpHouse Pond	7
S-Wells	2
Toe Grum Dump	26
Toe North East Dump	3
Vangorda Mine Area	6
Zone II Outwash	13
Upper NFRC	10

All groundwater samples collected under this program will be analysed for the following parameters by an accredited external laboratory:

- Dissolved metals (field filtered)
- Unfiltered free cyanide
- Acidity
- Ferrous iron
- General chemistry parameters
  - Alkalinity (including calculated carbonate and bicarbonate) on samples with pH >4.5
  - Anions (sulphate, chloride, fluoride, nitrate, nitrite, and ortho-phosphate)
  - Ammonia-N
  - Dissolved organic carbon (DOC)
  - Total suspended solids (TSS)
  - Total dissolved solids (TDS)
- Field parameters
  - Time and date
  - Flow (sample pumping rate), purge volume, purge time
  - Water level depth (elevation)
  - Temperature, pH (temperature corrected), conductivity, dissolved oxygen (DO), oxygenation reduction potential (ORP), and turbidity using a YSI water quality meter and probe, calibrated daily

The proposed program was developed based on the current groundwater monitoring program at the FMC. As the remediation program proceeds, additional monitoring wells will be installed to fill critical data gaps that are identified. All new monitoring wells should be added to the groundwater monitoring program and sampled on a bi-annual basis for a 5-year period. These data are necessary to establish baseline groundwater quality conditions in the vicinity of each of the monitoring locations. After five years of data has been collected, the data set should be reviewed to determine whether the monitoring frequency should be modified for future monitoring activities.

2.3 Reporting

An annual groundwater monitoring report will be prepared and will present summarized observations, interpretation of analytical results and field data. This report will also include trend analysis, and associated conclusions and recommendations for the following year's sampling program. This report will be included as part of the AEMR.

SECTION 3

Seep Monitoring Program

A Seep Monitoring Program will be carried out at the FMC to continue the ongoing collection and data analysis of seeps from the Faro Mine Area, RCTA, and the Vangorda/Grum Area. Seep monitoring is critical to understanding the geochemical conditions at the FMC and it provides valuable data to measure changes in the geochemical conditions of the WRDs and tailings. This program will continue to include waste dump and pit seep monitoring, as well as seep monitoring in the RCTA and the ETA.

3.1 Seep Monitoring Program Objectives

The primary objectives of the Seep Monitoring Program are summarized as follows:

- To compare collected seep data with historical seep data and augment data gaps in the site seep data records
- To evaluate changes in the seepage chemistry which may indicate the evolution of source areas within the FMC with respect to acid rock drainage (ARD) and metal leaching (ML)
- To provide input to the site AMP
- To support ongoing assessment of geochemical characteristics (ARD/ML) of waste rock and tailings material
- To support ongoing development of the site-wide geochemical loading models in support of the closure planning process

3.2 Seep Monitoring Program

The Seep Monitoring Program covers the collection and data analysis of groundwater seepage (seeps) from the Faro Mine Area, RCTA, and Vangorda/Grum Area. Additional sampling including groundwater quality, geochemical testing of waste rock and tailings solids, soil, tailings pore water, and soil gas monitoring required to support development of the site-wide geochemical loading models for closure, will continue to be carried out under separate programs as part of the broader closure planning process.

Overall, the Seep Monitoring Program will consist of the following elements:

- Annual spring and fall seep monitoring within and around the waste dumps, pits, ETA, and RCTA, during which approximately 160 sites will be visited, observed, and measured for field parameters, if water is flowing. A subset of approximately 60 of these sites will be sampled for laboratory analysis. While conducting the seep surveys, sample collection for laboratory analysis will be added for any locations where field parameter measurements reveal significant changes in pH or conductivity compared to historical averages.
- New sampling stations will be established where water is observed flowing or can be inferred to have been flowing based on observations of moisture along flow paths or based on ponded water surfaces that were at the elevation of pond spill points.
- Fall sampling of boat accessible pit seeps where approximately 25 boat-access seeps will be visited. It is anticipated that field parameters and laboratory samples will be collected from approximately 10 locations.
- Routine monitoring as part of the Routine Monitoring program carried out by the contract site operator, of key sample locations around the site. These locations are monitored more frequently than the spring/fall seep program. Timing of the sampling of these sites by the site contractor during spring and fall will be tied to the broader Seep Monitoring Program to ensure consistency.

Foot-accessible seeps will be sampled twice per year, once during spring freshet and once in the late summer dry season. The spring seep sampling event will be performed after approximately 90 percent of the snow cover on the site has melted, and just prior to peak flow within the Pelly River. The fall seep sampling event will be conducted in September when the groundwater table is lower and ground conditions are thawed, in order to determine which seeps are flowing, compared to the snapshot provided during the spring event. While there are

no specific triggers for the exact timing of the fall sampling event in September, sampling should be conducted during low groundwater conditions as inferred from onsite monitoring well groundwater elevation data, and sampling should be timed during a dry period without excessive rain preceding or during sampling.

- Approximately 160 established foot accessible seep stations will be targeted for monitoring. These seep locations will be visited during the spring and fall sampling events, and field parameter measurements will be collected from every location found flowing. Observations of dry seeps and snow-covered locations will be recorded. Samples will be collected for laboratory analysis from a smaller subset of the seeps found flowing. A total of approximately 60 seeps are targeted for analytical sampling. An additional 20 bottle sets will be available during each sampling event to allow discretionary sampling of additional locations.
- Approximately 25 established boat-accessible pit seeps will be targeted for monitoring once per year in the fall, concurrent with the foot-accessible fall seep sampling event. Field parameter measurements and laboratory analysis samples will be collected from every location found flowing. Observations of dry seeps will be recorded.

The following is a list of field parameters that will be collected at each location:

- Time and date
- Seep flow rate
- Temperature, pH (temperature corrected), conductivity, DO, and ORP, using a YSI water quality meter and probe, calibrated daily
- Photographs of each site, capturing both general site appearance and close-up images of seepage flow paths
- Coordinates captured using a handheld global positioning system (GPS) unit
- Observations of precipitates, staining, or algae growth within seepage streams, and colour of water
- Observations of existing flagging marking the location
- Description of flowpath, including emergence point and downstream flow direction
- Observations of any other seepage sampling stations that lie along the same flowpath

Samples will be collected and sent for analysis at an accredited external laboratory for the following parameters:

- General chemistry parameters
  - Alkalinity (including calculated carbonate and bicarbonate) on samples with pH > 4.5
  - Anions (sulphate, chloride, fluoride, and nitrate and nitrite, ortho-phosphate)
  - Ammonia-N
  - DOC
  - TSS
  - TDS
- Dissolved metals (field filtered)
- Unfiltered free cyanide (only sampled for seeps flowing to receiving environment)
- Acidity
- Ferrous iron

Care will be taken during sampling to minimize sample turbidity and the collection of extraneous sediment and debris. Samples will be assigned a unique identification number, and QA/QC samples will be collected as specified in the site quality assurance project plan.

3.3 Reporting

An annual seepage monitoring report will be prepared and will present summarized observations, interpretation of analytical results and field data. This report will also include trend analysis, and associated conclusions and recommendations for the following year's sampling program. This report will be included as part of the AEMR.

SECTION 4

Meteorological Monitoring Program

Two onsite meteorological stations were established at the FMC on the Faro and Grum waste dump sites in December of 2003. The Faro Dump meteorological station is located close to the Main Dump, at an elevation of 1,200 metres above sea level. The Grum Dump meteorological station was located on the Grum Waste Dump before June 2010, at an elevation of 1,250 metres above sea level. To accommodate the GSC cover project, the station was moved on June 21, 2010, to a former gravel pit, located north of Grum overburden vegetation trials. When the Grum meteorological station was moved, efforts were made to verify that the station was installed at a similar location, elevation, and soil type to where it had been previously. Soil temperature, moisture, and heat flux sensors were reinstalled at the same depths as where they had been. The locations of the onsite meteorological stations are shown in Figure 5B-6.

4.1 Meteorological Monitoring Program Objectives

The objectives of the Meteorological Monitoring Program are to collect meteorological data required to support ongoing characterization of the meteorological conditions at the FMC, as well as to provide the required data to support the ongoing characterization of the hydrological environment and site water balance.

4.2 Meteorological Monitoring Program

The Faro Dump and Grum Waste Dump meteorological stations sensors measure the following climate parameters:

- Temperature
- Relative humidity
- Wind speed
- Wind direction
- Soil moisture
- Soil temperature (at two depths)
- Soil heat flux
- Net radiation
- Albedo
- Solar radiation (incoming)
- Snow depth
- Precipitation

Snow surveys will also be carried out at various locations around the site to provide valuable input to site water management.

Averages of sensor measurements taken every 5 seconds are logged on an hourly basis and meteorological station data are downloaded on a monthly basis. Maintenance of the meteorological stations will be carried out monthly to confirm that all instruments are functioning properly. Meteorological stations probes will be routinely calibrated as per manufacturers' specifications and non-functioning components will be replaced as required.

4.3 Reporting

Data collected from the meteorological stations will be used to report the monthly and annual climatic conditions observed at each station. Each month the downloaded data will undergo QA/QC, as well as post-processing, and will be summarized in the monthly site reports. A full report of the site meteorological data will be included in the AEMR.

SECTION 5

Geotechnical/Physical Monitoring Program

Regular monitoring of site earth structures is a critical component of the site operations activities during the IW. Inspections will continue to be carried out on most site earth structures which include, but are not limited to, the following structures:

- Faro Mine Area: CVD, ID, Secondary Dam, RCD, FCD, NWID, North Fork Rock Drain, K8 Rock Drain, and Faro Pit Slopes
- Vangorda/Grum Area: Vangorda Waste Dump (including seepage collection system), LCD, Vangorda Creek Diversion (VCD), Vangorda WTP Clarification Pond, Grum Overburden Dump and revegetation trials, Grum Settling Pond, V-15 Seepage Collection System and Moose Pond, Grum Interceptor Ditch, SPP, Vangorda Pit Slopes, Grum Pit Slopes, GSC Cover, and GSC Pond

5.1 Geotechnical/Physical Monitoring Program Objectives

The objectives of the Geotechnical/Physical Monitoring Program are to identify problems or potential problems with the earth structures on-site so that appropriate actions can be taken to address risks to human health and the environment.

5.2 Geotechnical/Physical Monitoring Program

The site Geotechnical/Physical Monitoring Program is divided into two main components: routine or operational inspections and formal geotechnical inspections/monitoring program. Routine or operational inspections are performed by site personnel and undertaken at least once a week. The formal geotechnical inspection/monitoring program, currently conducted annually by a qualified geotechnical engineer, will continue during the IW.

5.2.1 Operation Inspections

Routine operational inspections will be carried out to provide observations of site facilities. Weekly inspections will be carried out to provide observations of critical facilities to ensure that unusual or emergency events can be managed in a timely fashion. Monthly inspections will be performed in addition to weekly inspections and will entail more in-depth inspections of the earth dams and dykes as well as routine inspection of several other facilities not included in the weekly schedule. In addition, many of the facilities will undergo more frequent inspection particularly during spring freshet and during periods of active pumping, conveyance and treatment of water.

The routine environmental inspections will be typically performed and documented by the site environmental personnel. However, they may be performed and documented by any person working under the direction of the site manager who is reasonably knowledgeable regarding the environmental and geotechnical aspects of the site. Results of the inspections will be documented and where applicable any concerns noted and brought to the attention of the site manager.

Field-based site personnel will be trained to identify and document any potential hazards, damage or concerns. The site Operations, Maintenance, and Surveillance Manual (OMSM) will include detailed information and specific requirements and forms for these operational inspections. The results of the routine inspections will be documented in the monthly site reports and the AEMR.

Table 5B-9 and 5B-10 present a summary of the proposed weekly and monthly inspections for the Faro Mine Area. Tables 5B-11 and 5B-12 present a similar summary for the Vangorda/Grum Mine Area.

TABLE 5B-9
Faro Mine Area – Weekly Inspection Protocol
Faro Mine Interim Works

Facility	Monitoring Activity
CVD and CVD Pond	• Observe from the roads on the north and south and west (downstream) sides. • Is the pond water level acceptable? • Are the spillway and syphons functioning appropriately? • Does the dam appear stable (i.e., is there erosion, cracking, bulging, wet spots)? • Does seepage appear “normal” (three streams)?
ID and ID Pond	• Observe from the roads on the north and south sides. • Is the pond water level acceptable? • Are the spillway and syphons functioning appropriately? • Is the lime treatment system functioning appropriately? Any visible damage? • Does the dam appear stable (i.e., is there erosion, cracking, bulging, wet spots)?
Secondary Dam (Intermediate Dam access road)	• Observe road condition
RCD	• Drive length of channel including lower section and observe dike, backslope and bottom. • Is any cracking or sloughing visible along backslope? • Is any significant erosion or are any significant depressions apparent in the dike? • Is water channeling appropriately?
NWID	• Is any cracking or sloughing visible? • Is any significant erosion or are any significant depressions apparent? • Is water channeling appropriately?
West Valley Interceptor Ditch	• Is any cracking or sloughing visible? • Is any significant erosion or are any significant depressions apparent? • Is water channeling appropriately?
FCD	• Is any cracking or sloughing visible? • Is any significant erosion or are any significant depressions apparent? • Is water channeling appropriately?
North Fork Rock Drain	• Observe the rock drain from the edges of the Haul Road. • Is there any sloughing on the upstream and downstream faces? • Does the pond on the upstream side of the drain appear acceptable/normal?
K8 Rock Drain	• Observe the rock drain from the edges of the Haul Road. • Does the pond on the upstream side of the drain appear acceptable/normal? • Are flows passing normally? • Is there any accumulated sediment or debris?
Faro Pit Slope Instability Zones	• Observe the pit and pumping station from the pumping station. • Does the pit north east wall appear “normal”? • Does the inflow via the Faro Valley rock dump appear “normal”? • Is the pumping station functioning appropriately? • Is there any physical damage visible to the pumping barge or pipeline?
Faro and Zone II Pits	• Measure and record in-pit water levels.

TABLE 5B-10
Faro Mine Area – Monthly Inspection Protocol
Faro Mine Interim Works

Facility	Monitoring Activity
ID and CVD	• Perform detailed inspection of crests and toes by driving and/or walking each. • Note any significant cracking, erosion, sloughing, etc. • Record seepage flow estimates or weir staff gauge readings and pond levels. • Record any significant observations.
FCD	• Drive the length of the diversion at least as far upstream as the Faro Valley Waste Dump. • Is water flow channeling appropriately (i.e., flow over top of ice, ice jam)? • Is leakage from the channel excessive or visibly increased? • Are there visible indications of increased wall instability along the crest of the north east pit wall?

TABLE 5B-11
Vangorda/Grum Mine Area – Weekly Inspection Protocol
Faro Mine Interim Works

Facility	Monitoring Activity
Vangorda Waste Dump and Seepage Collection Systems	• Is any cracking or sloughing visible? • Is any significant erosion or are any significant depressions apparent? • Is water channeling appropriately?
LCD and Pond	• Drive the crest of the dam. • Is the pond level appropriate/ acceptable? • Does the dam appear stable (i.e., is there erosion, cracking, bulging, wet spots)? • Is there any visible damage to the pumphouse?
VCD	• Drive along the diversion flume. • Is the flume performing acceptably? • Is water channeling appropriately (i.e. flow over top of ice, ice jam)? • Are there signs of excessive or new damage or deformation to the flume or channel? • Are there signs of instability of the rock and soil slopes overlooking the flume?
Vangorda WTP and Clarification Pond Embankments	• Observe the Vangorda WTP Clarification Pond dike from the Blind Creek road and drive around the treatment plant. • Is the water level in the Clarification Pond acceptable? • Are the plant building and storage sheds secure? • Does the dike appear stable (i.e., is there erosion, cracking, bulging, wet spots)?
Grum Overburden Dump and Re-Vegetation Trials	• What is the condition of the sludge storage cell? • Is any significant erosion?
Grum Settling Pond	• Drive to and/or around the pond. • Is the water level acceptable? • Does the dike appear stable (i.e., is there erosion, cracking, bulging, wet spots)?
Moose Pond and V15 and Grum Creek Seepage Collection System	• Drive to the collection system and pond. • Is there any accumulated water? • Is inflow water channeling appropriately? • Are the pond water levels acceptable? • Is there any visible seepage coming out of the pond? • What is the condition of the pond wall? • Is there any ice or sediment build-up?

TABLE 5B-11
Vangorda/Grum Mine Area – Weekly Inspection Protocol
Faro Mine Interim Works

Facility	Monitoring Activity
Grum Interceptor Ditch	• Is any cracking or sloughing visible? • Is any significant erosion or are any significant depressions apparent? • Is water channeling appropriately?
SPP	• Observe the ponds from the haul road or drive onto the pond dikes. • Are the pond water levels acceptable? • Do the dikes appear stable (i.e., is there erosion, cracking, bulging, wet spots)? • Is the outflow channeling appropriately? (viewed from the road above the plunge pool) • Monitor erosion from Grum Overburden Dump
Grum Pit Wall Instability	• Observe the pit walls • Do the pit walls appear 'normal" or is there a notable change to their conditions?
Grum and Vangorda Pits	• Record estimates of water levels and other significant observations.

TABLE 5B-12
Vangorda/Grum Mine Site Area – Monthly Inspection Protocol
Faro Mine Interim Works

Facility	Monitoring Activity
Vangorda Waste Dump	• Drive to the toe of the dump. • Do the till berm and rock benches appear stable and secure?
Vangorda Creek Diversion	• Is the inlet to the culvert at the upstream end of the flume performing acceptably? • Is the outflow structure at the downstream end of the flume performing acceptably?
SPP, LCD and Pond, and Grum Settling Pond	• Estimate and record the pond water levels. • Inspect the crests and toes of the dam/dikes for signs of deterioration and document any seepage observed.
Grum Creek and Moose Pond	• Inspect the Moose Pond diversion. Is water channeling appropriately? • Is the Grum Creek road crossing functioning acceptably? • Is any water accumulating in the Moose Pond?

5.2.2 Formal Geotechnical Monitoring Program

An annual Geotechnical Monitoring Program will be carried out at the FMC that comprises the following components:

1. Two site visits by a professional engineer: (1) spring during freshet (geotechnical) and (2) fall (geotechnical and hydrotechnical) during low flow conditions, to examine and note site conditions. Observations and recommendations will be provided in a technical memo in the AEMR.
2. Monthly reporting (or as needed) to provide analysis of monitoring data collected by site staff with recommendations if issues noted.
3. Inspection of the following structures:
   - Faro Mine Area: CVD, ID, FCD, RCD, Faro Pit, and Zone II Pit.
   - Vangorda/Grum Area: Vangorda Waste Dump (including seepage collection system), LCD, VCD, SPP, Grum Creek and Moose Pond, Grum Settling Pond, and Vangorda and Grum Pits.

4. Preparation and submission of an Annual Geotechnical Inspection report in February of each year for submission to Government of Yukon.
5. Update of the Emergency Response Plan and OMSM for the various site structures as required.
6. Recommendations on frequency and sites to be incorporated into the geotechnical monitoring program.

In the Faro Mine Area, the following are the key components of the inspections program for each of the key facilities: CVD and Spillway, ID and Spillway, NWID, FCD, K8 and NFRD, RCD, RCD dike and back slope, and the toe of the slope along the RCD at pond elevation. The following specific items will be addressed, for each:

- CVD and Spillway
  - Inspect dam crest during the first visit (looking for longitudinal crack found in previous years) and inspect crest again during the fall visit (after crest has been re-graded in spring/summer to minimize surface water infiltration).
- ID and Spillway
  - Inspect and assess soil erosion conditions on the downstream slope of the ID during both visits. Provide recommendations for delineation of existing erosion and a program to monitor for potential change in slope conditions.
  - Measure sediment deposition over drainage measures on lower bench.
  - Inspect upstream slope for potential soil erosion of poorly armored shell material below rip rap surface and rip rap degradation (likely during fall visit when the water level of the pond is low). Check if wave or ice action is damaging dam and recommend corrective measures.
- NWID
  - Inspect sedimentation, ponding and gradients along entire length of channel. Toe erosion has been noted along the channel side slopes of the upper portion of the channel; assess and provide recommendations with regards to channel gradient.
  - Assess vegetation conditions in middle and lower portion of NVWID and provide recommendations.
- RCD
  - Inspect channel during peak flow conditions, noting performance after 2010 vegetation removal activities.
  - Note seepage from RCD to tailings impoundment area.
  - Reading of geotechnical instrumentation including, thermisters, piezometers, and slope indicators.
- Secondary Dam
  - Inspect the crest and side slopes of the Secondary Dam. The concentration will be on the areas adjacent to the NFRCD and the RCD.
- FCD
  - Inspect the condition of the diversion above the Faro Pit – particularly the overburden-bedrock interface - for identification of possible deteriorating performance or seepage from under the diversion that could undermine the Faro Pit wall and contribute to instabilities. Additionally, look for sloughing due to permafrost degradation. Exposed geotextile/bentomat liners in the diversion will be covered with rock armour. Any damaged geotextile/bentomat will be replaced prior to rock armour placement.
- Faro Pit Instability
  - Inspect the north and south instability zones to determine if significant recession or degradation of slope has occurred. This will include on-going monitoring of the instrumentation along the northeast Pit wall:

nine reference bars to monitoring pit wall regression and nine prisms to monitor pit wall movements. Provide recommendations for on-going monitoring and/or remediation.

In the Vangorda/Grum Area, inspections will cover the following: Vangorda WRD (including seepage collection system), LCD, VCD, Clarification Pond Embankments at the WTP, Grum Overburden Dump and revegetation trials, Grum Settling Pond, V-15 Seepage Collection System and Moose Pond, Grum Interceptor Ditch, Grum and Vangorda pit walls, and the SPP below the Grum Overburden Pile. The following specific items will be addressed, for each:

- Vangorda WRD
  - Inspect transverse drains, seepage collection channel, till starter dike, and rock pile, and note areas of sediment build-up in weirs and collection channel (particularly in upper reaches).
  - Inspect till starter dike for signs of instability, erosion gullies, subsidence, seepage, or salt deposition.
  - Inspect rock pile and note condition of old tension cracks.
- LCD
  - Inspect upstream and downstream slopes of the dam for erosion rill evolution.
  - Inspect downstream cracks at the end of the spillway outfall channel.
- VCD
  - Inspect freshet performance of channel during spring visit, noting any damage to the flume and cross braces as well as excessive seepage.
- Grum Pit Instability
  - Inspect the east wall slope instability zone of the Grum Pit to determine if recession or degradation of slope has occurred. Provide recommendations for ongoing monitoring and/or remediation.
  - Observe new cracks and ground deformation near reference rods.
- Moose Pond
  - Inspect the downstream slope of the retaining esker and ridge.

Generally, the engineer will make a visual assessment of the facilities; measurements and reading of instrumentation will not typically be carried out unless the engineer notes an unusual condition. Following the spring site visit, a *Summary of Recommendations Memo* will be prepared and reviewed with site staff so that recommendations on maintenance are conveyed immediately and directly to those responsible for the work.

5.2.2.1 Input, Review and Interpretation of Monitoring Data

The FMC has a number of instruments that are used to monitor the various structures at the site, including the following:

- 23 instruments in the ID, 14 of which are standpipes and 9 are pneumatic piezometers
- 15 instruments in the CVD, 10 of which are standpipes and 5 are pneumatic piezometers
- 13 instruments (pneumatic piezometers) in the RCD Dike monitoring the water levels and 8 slope indicators monitoring the stability of the area
- 6 piezometers in LCD measuring water level

Site staff will collect the required instrumentation readings for all instruments identified in the annual monitoring program. These instruments in the ID and CVD will be read three times a year, and those in the RCD Dike and LCD will be read bi-annually.

Monitoring data collected by site staff will include data from piezometer, thermistor, slope inclinometer, flow rate data, staff gauge, and pond water levels (CVP and ID Pond). All data will be provided to the engineer at the time of the site inspection and all subsequent data will be compiled by site personnel and then forwarded to the engineer. It is expected that the engineer will review data updates and provide commentary on any concerns that are noted. The engineer will provide a review of the frequency and sites involved in the geotechnical monitoring program and will make recommendations regarding revisions.

If required, the engineer will also update geotechnical stability analysis of the ID or other structures based on current conditions, including downstream slope and operating water levels.

5.2.2.2 Annual Geotechnical Performance Report

An Annual Geotechnical Performance Report will be prepared for inclusion into the AEMR. The annual inspection report will comprise the following information and be sealed by a professional engineer:

1. A written report detailing the inspection and interpretation of instrumentation data
2. Assembled instrumentation monitoring data and related plots
3. Recommendations regarding the monitoring season, including site inspections, surveys of structures, and monitoring of instrumentation

5.2.3 Third-party Dam Safety Reviews

According to the Canadian Dam Safety Guidelines (CDA, 2007), both the ID and the CVD will be due for their third-party safety review in 2014 because of their classification as “high” risk dams. This review will be carried out as part of the annual program in 2014. Future Dam Safety Reviews will be conducted in accordance with the frequency and guidance described in the Dam Safety Guidelines.

SECTION 6

Aquatic Environment Monitoring Program

The AEMP will be harmonized and integrated as much as possible with the Water Monitoring Program described in Section 2.1. Specifically the surface water quality and flow monitoring component of the AEMP will be covered by the Routine Monitoring Program and Pelly Aquatics Monitoring Program.

6.1 Aquatic Environment Monitoring Program Objectives

The objectives of the Aquatic Environment Monitoring Program are to assess the chemical and biological condition of the aquatic environments receiving mine drainage. The AEMP will integrate biological and chemical information for a weight of evidence approach. The following components of the FMC will be monitored:

- Surface water quality and flow
- Benthic invertebrate community monitoring
- Fish community and population assessment

6.2 Aquatic Environment Monitoring Program

6.2.1 Surface Water Quality and Flow

As part of the Pelly Aquatic Monitoring Program, water quality monitoring will be carried out at mine-exposed stations (V8, V17A, V20A, VGMAIN, VW1, VW2, VW3, R1, R4, R5, R6, W10, X14, NWID, A1, P1, and P4) as well as at five reference stations within the same drainages but upstream of mine influence (FC, R7, USFR, V1, and VR) and at two stations that have a history of drinking water use by First Nations (Grum Corner and K8). Aquatic Environment monitoring locations are shown in Figures 5B-1 to 5B-3. Additional stations may need to be added temporarily to the program on an as needed basis. Samples will be collected three times per year: spring, summer, and fall, representing the three distinct flow conditions during the year to capture representative high, low and mid-range concentrations (i.e., winter low flow, spring freshet, and summer/fall). Exceptions include stations VW1, VW3, VGMAIN, V8, R4, R5, and A1, which will be sampled monthly. Water samples will be collected and analyzed by an accredited external laboratory for the following:

- Physical parameters, including pH, specific conductance, TSS, TDS, and hardness;
- Anions and cations, including ammonia-N, Nitrate-N, sulphate, chloride and alkalinity
- Total and dissolved organic carbon (field filtered)
- Total and dissolved metals (field filtered)

At the time of sample collection field parameters (including pH, conductivity and temperature) will also be taken. Flows will be monitored at X2, X14 and V8, to allow for computation of loadings at these locations and tracking of potential changes in flow regimes over time. Flow measurements will be taken synoptic with chemical sampling to allow for accurate loadings estimates at those stations.

Should water quality monitoring indicate a substantial adverse change in surface water quality that might be associated with a change in toxicity to aquatic biota, samples of surface water will be collected from the affected areas for laboratory toxicity testing. The toxicity tests will include a variety of species representing different trophic levels and effects endpoints. Testing should be repeated if water quality continues to change, but would not need to be repeated if concentrations stabilize.

6.2.2 Benthic Invertebrate Communities

Benthic invertebrate communities will be assessed every three years at all of the water monitoring locations that are accessible to fish, starting in 2014. Community characteristics will be compared to those observed during the baseline period and to any other such surveys conducted at the site in the interim. Data will also be evaluated relative to an appropriate suite of synoptically sampled regional reference areas (i.e., having similar habitat characteristics) and will consider any changes in water quality that have been since the last cycle of study.

6.2.3 Fish

Routine monitoring of fish health and population characteristics and fish tissue metal concentrations is not recommended unless specific questions arise that necessitate fish sampling. This is because locally relevant species such as Chinook and grayling can move large distances between winter and summer habitats so the characteristics of individual fish may not reflect conditions in the areas in which they are captured. Also, population densities of these species, and slimy sculpin, are sufficiently low that it is very difficult to obtain sufficient sample sizes in any given area to support statistical comparisons of conditions among reference and mine-exposed areas. Also, lethal sampling should be avoided, if possible, to prevent population impacts that might be associated with the sampling program. There will be some fisheries related monitoring carried out in 2014 as part of the Site Investigations component of the IW and the results of these programs will be used to determine the need or frequency of subsequent programs.

6.3 Reporting

Each year following the benthic surveys, a monitoring report will be prepared summarizing the observations, interpretation of results and field data, including statistical comparison and assessment of changes, and associated conclusions and recommendations for the following year's sampling program. This report will be included as part of the AEMR for the year in which the program was completed.

SECTION 7

Wildlife Monitoring Program

The proposed Wildlife Monitoring Program continues and expands on the current site program that consists of the reporting of any incidental wildlife sightings that are reported to the site operator. This program is a more structured program that has been designed to meet the objectives outlined below, and will be integrated into the ongoing site investigations, inspections and operations programs. Given that the majority of the individuals contributing to the Wildlife Monitoring Program may not be specifically trained in biology or wildlife identification, a short "training" session will be provided to ensure consistency and clarity in the program execution. Resources for easy identification of bird type (duck, goose, swan, or gull), behaviours to watch for and basic information about animal tracks will be provided to carry out this program. In addition, field forms and direction will be provided to help simplify and add consistency to data collection.

7.1 Wildlife Monitoring Program Objectives

The objectives of the Wildlife Monitoring Program for the IW period are as follows:

- To monitor wildlife use of the FMC
- To identify where negative interactions with FMC components or IW activities may occur or are observed.
- To identify areas where seasonal or permanent wildlife presence/activity may negatively influence or hinder IW activities (beaver dams, bird nests etc.).
- To identify areas where seasonal or permanent wildlife presence/activity/health may be negatively affected by FMC activities.
- To assimilate the information which would allow for the development of updated mitigation measures in addition to those outlined in the associated Environmental Management Plan (EMP). This could include adjusting the timing, schedule, or method of tasks in order to protect or reduce-risk to wildlife, particularly during sensitive life stages such as during winter, during nesting, and while young are being reared.

7.2 Wildlife Monitoring Program

The wildlife monitoring program will consist of two main components:

1. Focused monitoring methods for avifauna
2. Incidental observation records for general wildlife

7.2.1 Focused Monitoring for Avifauna

A focused monitoring program for avifauna is proposed to collect site data which will allow site managers to determine whether mitigation measures aimed at reducing site usage by waterfowl are successful. This program is proposed to be performed in years one through three of the project, with an option for further monitoring if further adjustments to site mitigations are require. This program will focus on the period of highest site use by waterfowl (i.e., early May to mid-October), and will focus on pits, ponds and creek diversions where suitable waterfowl habitat has been identified. These areas include the following:

- Faro, Grum, and Vangorda Pits
- LCP
- Grum Settling Pond
- GSC Pond
- Moose Pond
- Grum Pit Slot Cut Pond
- SPP
- CVP

- ID Pond and any ponding on Original/Secondary and Intermediate Impoundment areas
- Rose Creek ponds including channel and diversion reach

At each location it is recommend that approximately 20 to 30 minutes be spent observing any avian activity. For each survey the following information will be recorded:

- Site name
- Time and duration of survey
- Weather during survey period (percent cloud cover, precipitation, temperature, wind (on the Beaufort Scale)
- Surveyor names
- UTM/location where survey took place
- For any bird activity/observations identified, the following will be recorded:
  - Bird type (duck, goose, swan, gull)
  - Behaviour/activity observed during survey time (e.g., diving, sleeping, or drinking)
  - Size of group
  - Age class (adult or duckling/gosling)
  - Any activity observed that suggests breeding or nesting within the FMC pits or ponds
  - The time during the survey the an observation was made (i.e., if the bird was already present at beginning of survey or arrived during the 20 minute period, or departed during the observation period)

The focused monitoring program is to be conducted by individuals trained in observational studies in avifauna to ensure accurate observations and recording. Site personnel and visitors will be encouraged to record similar information and details if and when incidental observations are made during their time on site.

7.2.2 Incidental Observation Record of General Wildlife

This program is intended to build on the current reporting of incidental wildlife sightings by site personnel for general sightings of wildlife at the FMC. The advantage of this component of the program is that it is carried out year-round, requires no additional resources, and consistently builds upon the current incidental data set for the FMC. This program of recording wildlife observations is to be conducted by site staff, contractors, and visitors on an ongoing basis throughout the year.

Throughout the year, personnel working at the site will be asked to report all observations of wildlife or wildlife signs while at the FMC (in footprint areas or at the site generally). These observations are relayed to the site operators (generally by radio), who will prompt personnel for the following information:

- Location
- Species or type of animal (e.g., grizzly or black bear if possible, or simply 'bear' if not identifiable)
- Group size
- Type of activity noted or interaction with personnel (e.g., feeding near pond, on road)

Personnel on site should be encouraged to provide the degree of detail that they are comfortable offering for an observation (i.e., to what degree they are comfortable with identification), and also should be encouraged to collect supporting information if possible, such as a photograph of the animal, tracks, or scat.

Care and maintenance site operators will maintain a log of the observations collected in a standard format database, which should include a set of fields to prompt complete collection of data for each event, including:

- Date and time
- Surveyors (personnel involved)
- Location
- Weather
- Details of the observation (as described above)

Each observation should be given a unique identifier, and any supporting data provided by personnel (e.g., photograph) will be stored by site operators with that identifier.

7.3 Reporting

Data collected from the Wildlife Monitoring Program will be summarized with monthly reporting of the following information:

- A summary of the incidental observations and supporting data
- Details of any specific monitoring efforts performed on site, such as waterfowl observations
- Identification of any potential for or realized human-wildlife conflict, and any mitigative measures carried out
- Photographs
- Raw data/record sheets

The information will also be summarized and included in the AEMR.

SECTION 8

Vegetation Monitoring Program

Vegetation patterns are determined by ecological interactions, physical and geochemical factors and are influenced by landscape position and topography, temperature, precipitation, substrate type and disturbance regime. Monitoring the relationships among plant community structure and composition and these environmental attributes is fundamental to understanding vegetation dynamics as well as the community changes that occur in response to IW activities, and any mitigation activities.

Changing conditions associated with IW activities could potentially impact vegetation around the FMC. The resulting changes in plant species composition, distribution and/or community interaction could subsequently affect ecosystem functions such as energy and nutrient exchange, carbon storage, biomass production and affect plant-animal interactions and habitat extent. The Vegetation Monitoring Program proposed for IW period is designed to complement existing information for the site while accomplishing the monitoring objectives outlined below.

8.1 Vegetation Monitoring Program Objectives

The vegetation monitoring program will have multiple objectives focused on characterization of vegetation communities and documenting trends in vegetation re-establishment on site:

- To monitor vegetation health and vigour in control and IW activity-adjacent areas of the FMC
- To identify where negative interactions with FMC components or IW activities may occur or are observed
- To identify areas where rare vegetation presence may negatively influence or hinder IW activities
- To identify areas where vegetation may be negatively affected by IW activities
- To monitor the project performance of re-growth for vegetation on the FMC (including revegetation plots)
- To assimilate the information and apply appropriate real-time mitigation measures in addition to those to be outlined in the associated EMP, such as changing timing/schedule/method of tasks to protect or reduce risk to vegetation

8.2 Vegetation Monitoring Program

The Vegetation Monitoring Program has been designed to sample vegetation over a temporal and spatial scale. The Vegetation Monitoring Program will commence July 2015 and be conducted within the months of July and August for the next 10 years. Specific sampling locations and permanent plots will be selected based on data collected from the 2014 vegetation and soil baseline study. For consistency and data comparability among data sets, the same methodology will be used for the duration of the Vegetation Monitoring Program. The Vegetation Monitoring Program will follow a standardized sampling methodology at each sampling location as outlined in the *Field Manual for Describing Terrestrial Ecosystems*, 2nd Edition (BC Ministry of Forests and Range and BC Ministry of Environment, 2010) and includes the following:

- Mapping: GPS mapping of each plot location and the permanent marker stake location
- Site characteristics: Photo taken for each of the main compass directions for each plot with description of slope, aspect, soil type, organic matter cover, evidence of water movement, erosion or sediment
- Species composition and percent cover for each species within each layer (canopy, shrub and ground) of the plot
- Species abundance for revegetation plots
- Health and vigour for each species within plot types (alive/dead, stress-level, evidence of browsing or insect damage)
- Rare plant identification

8.3 Reporting

Data collected from the Vegetation Monitoring Program will be summarized with annual reporting of the following information:

- Number of survey periods
- Survey dates and who completed the work
- Survey methods
- Survey results as per recorded data described above
- Discussion of results including any mitigative measures carried out
- Photographs
- Raw data/record sheets

It is recommended that a geodatabase be set up to maintain a georeferenced set of data for each monitoring plot. A report based on field notes, field data, and monitoring results will be produced for inclusion in the AEMR for the year in which the monitoring program was completed.

SECTION 9

Works Cited

American Public Health Association, American Water Works Association, Water Environment Federation. 2012. *Standard Methods for the Examination of Water and Waste Water, 22nd ed.*

British Columbia Ministry of the Environment. 2009. *Manual of British Columbia Hydrometric Standards*. Science and Information Branch, Resources Information Standards Committee (RISC).

British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment. 2010. 2010. *Field manual for describing terrestrial ecosystems, 2nd ed.*

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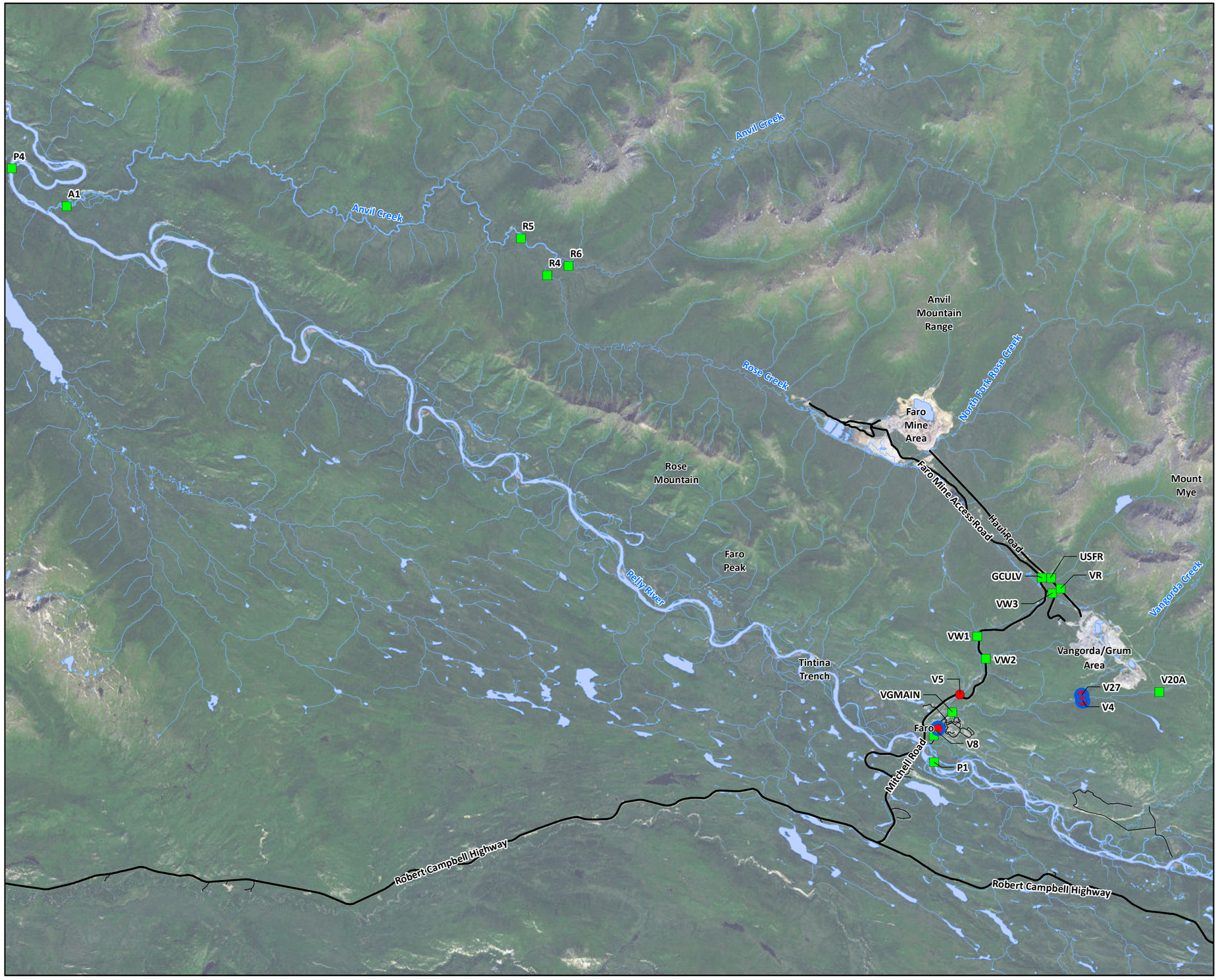

VICINITY MAP



LEGEND

- Hydrometric Station
- Pelly Aquatic SWQ Station
- Routine SWQ Station
- Major Road
- Minor Road

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
3. See Figure 5B-2 and Figure 5B-3 for monitoring stations at Faro Mine Area and Vangorda /Grum Area.

N

0 2,500 5,000 7,500 10,000

Metres

Created by: CRITIGEN

FIGURE 5B-1

Surface Water Quality, Hydrometric and Aquatics Monitoring Locations - Faro Mine Complex Overview

Faro Mine Interim Works

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VICINITY MAP



LEGEND

- Hydrometric Station
- Pelly Aquatic SWQ Station
- Routine SWQ Station
- Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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Metres

Created by: CRITIGEN

FIGURE 5B-2

Surface Water Quality, Hydrometric and Aquatics Monitoring Locations - Faro Mine Area

Faro Mine Interim Works

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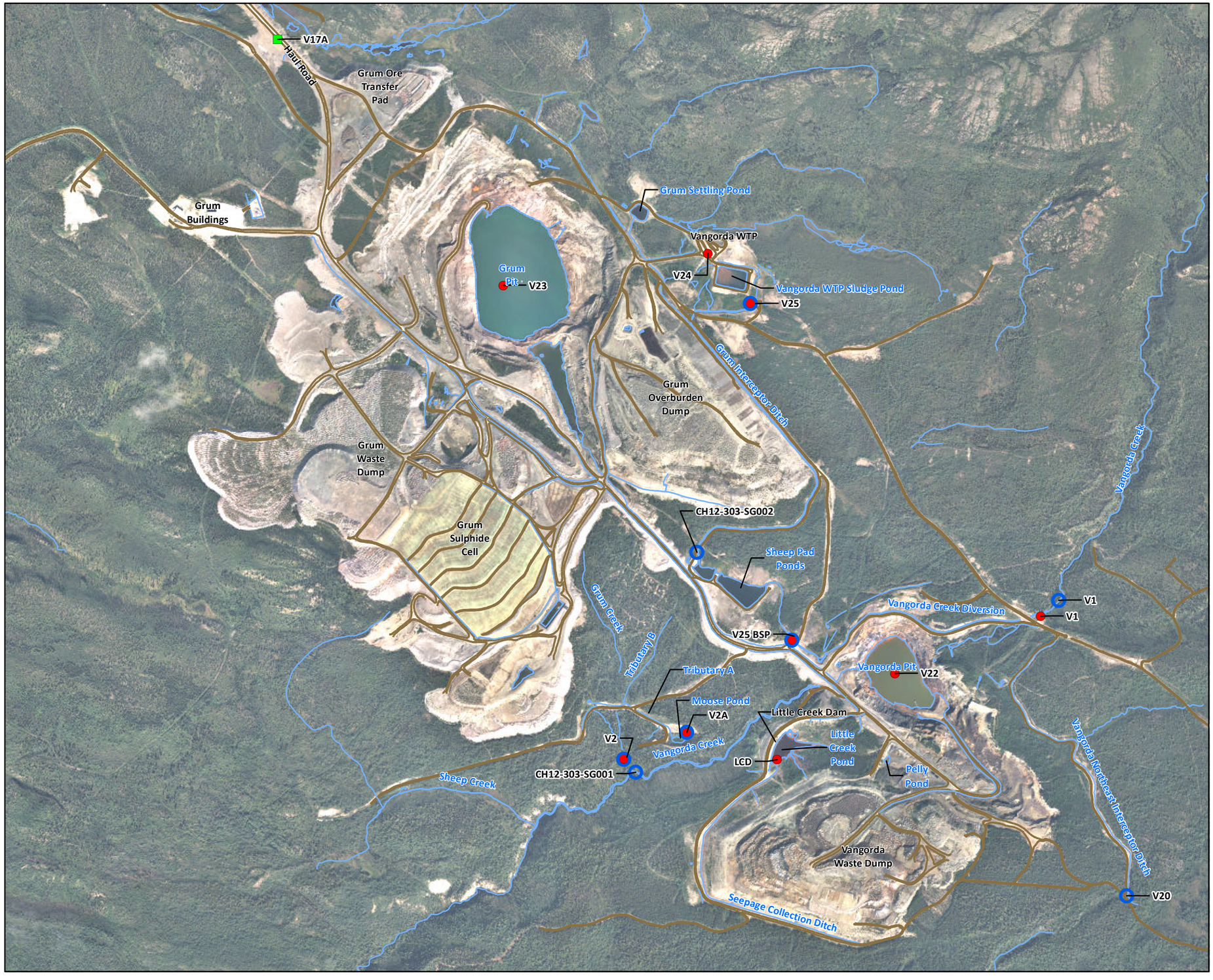

VICINITY MAP



LEGEND

- Hydrometric Station
- Pelly Aquatic SWQ Station
- Routine SWQ Station
- Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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Created by: CRITIGEN

FIGURE 5B-3
Surface Water Quality, Hydrometric and Aquatics Monitoring Locations - Vangorda/Grum Area
Faro Mine Interim Works

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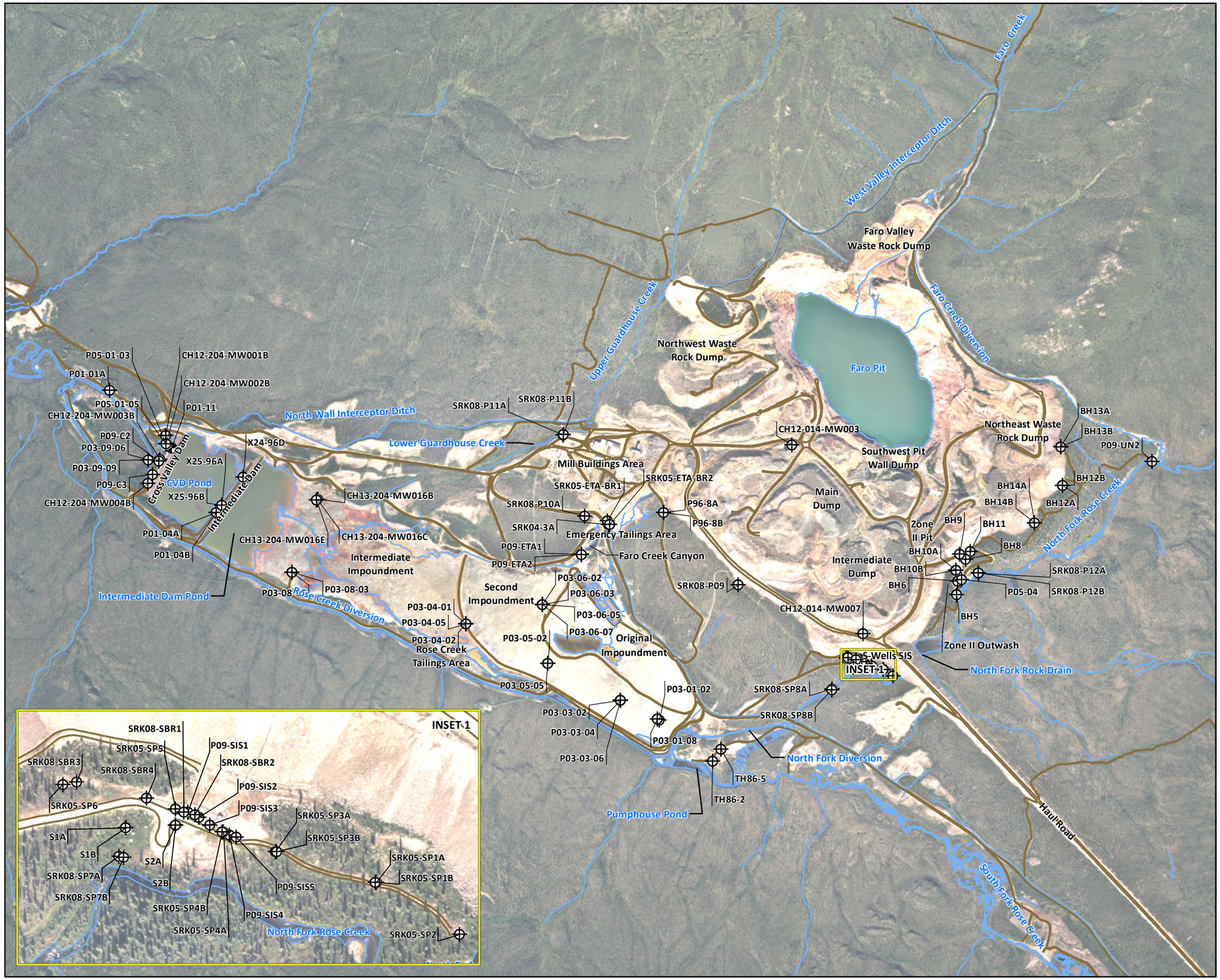

VICINITY MAP



LEGEND

- Borehole Location
- Monitoring Well Location
- Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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Metres

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FIGURE 5B-4
Groundwater Quality Monitoring Stations – Faro Mine Area
Faro Mine Interim Works

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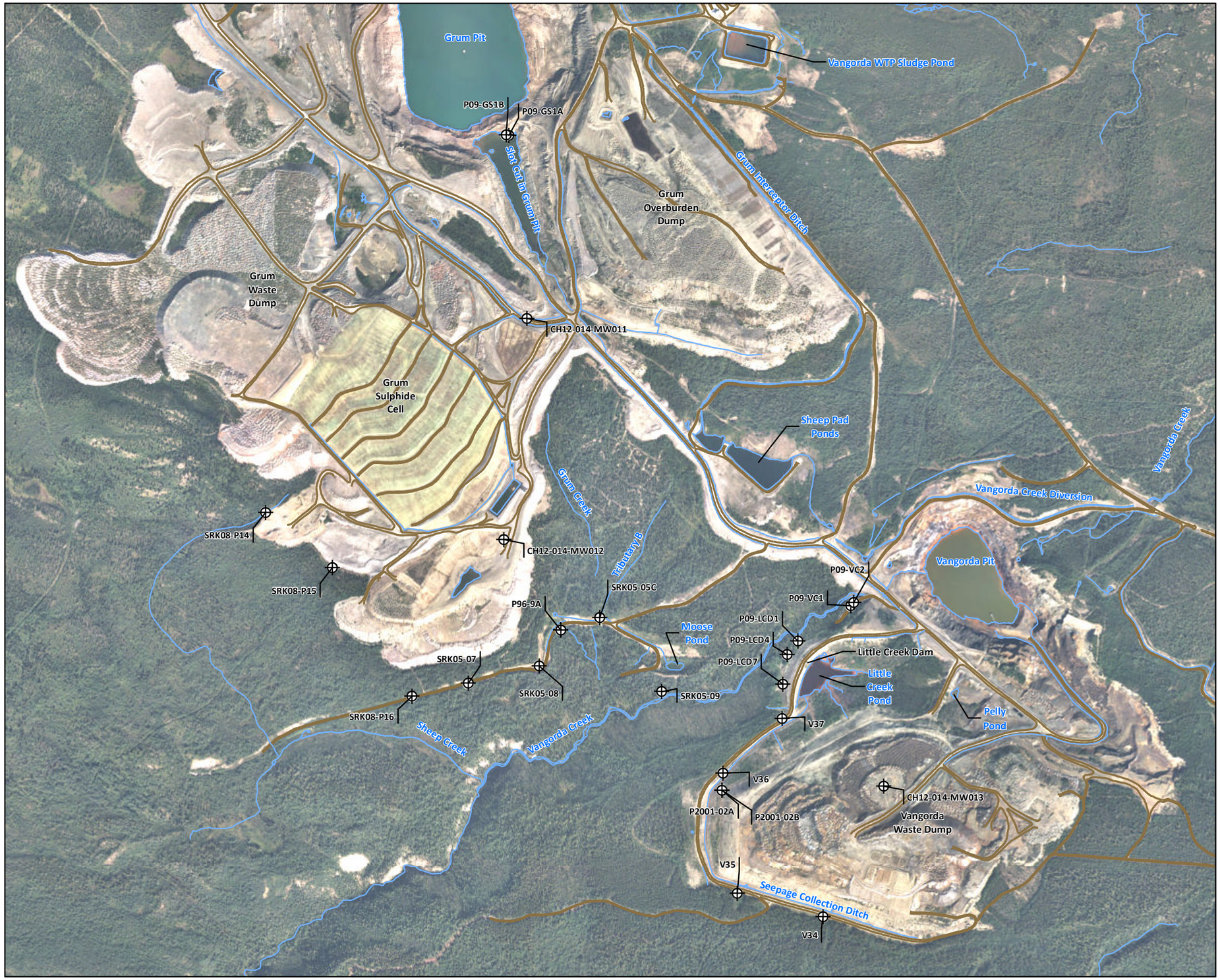

VICINITY MAP



LEGEND

- Monitoring Well Location
- Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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0 150 300 450 600

Metres

Created by: CRITIGEN

FIGURE 5B-5

Groundwater Quality Monitoring Stations – Vangorda/Grum Area

Faro Mine Interim Works

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VICINITY MAP



LEGEND

- Meteorological Station
- Major Road
- Minor Road

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 1,000 2,000 3,000 4,000
Metres

Created by: CRITIGEN

FIGURE 5B-6
Meteorological Stations - Faro Mine Complex and Town of Faro
Faro Mine Interim Works

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Appendix 5C
Adaptive Management Plan Framework for the Interim Works

Draft

Adaptive Management Plan Framework for the Interim Works, Faro Mine Remediation Project

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 6, 2014

CH2MHILL®

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Figure

5C-1 AMP Sequence of Activities

Acronyms and Abbreviations

AMP	Adaptive Management Plan
ARD	acid rock drainage
CVD	Cross Valley Dam
DVIHU	Down Valley Interim Hydraulic Upgrades
FMC	Faro Mine Complex
FMRP	Faro Mine Remediation Plan
ID	Intermediate Dam
IW	Interim Works
LGC	Lower Guardhouse Creek
NFRC	North Fork Rose Creek
NFRD	North Fork Rock Drain
RCAA	Rose Creek Alluvial Aquifer
RCTA	Rose Creek Tailings Area
SIS	Seepage Interception System
UGC	Upper Guardhouse Creek

SECTION 1

Introduction

The Government of Yukon Assessment and Abandoned Mines and the Government of Canada, as represented by the Government of Yukon and Aboriginal Affairs and Northern Development Canada are continuing work to prepare a final remediation plan, the Faro Mine Remediation Plan (FMRP), for the Faro Mine Complex (FMC). In the meantime, Government of Yukon and Aboriginal Affairs and Northern Development Canada will continue to undertake activities to protect, and minimize risks to, human health and safety and the environment and support the development of the FMRP. These interim activities, collectively referred to as the Interim Works (IW), are the subject of this Project Proposal and include:

- Ongoing site operations
- Site investigations in support of design and environmental characterization for the FMRP
- The Down Valley Interim Hydraulic Upgrades, which comprise improvements in flood routing capacity for the Rose Creek Tailings Area (RCTA) to reduce risks to human health and safety for the environment
- Ancillary activities associated with completion of these activities

The IW is fundamentally a continuation of activities that have been conducted at the FMC since mine operations ceased in 1998. These activities will continue until implementation of the FMRP, addressing the following two main purposes:

1. To control and reduce the effects of the existing FMC on human health and safety, and the environment
2. To compile sufficient site and environmental information to support design, assessment, and permitting for the FMRP

As part of the IW, ongoing site operations and the Down Valley Interim Hydraulic Upgrades are intended to achieve the first purpose by managing clean and contaminated water; maintaining, repairing and monitoring mine facilities and structures; implementing site security measures; monitoring site and environmental conditions; and, responding to changes in accordance with an Adaptive Management Plan (AMP) and risk assessment. Site investigation activities that are part of the IW are intended to achieve the second purpose.

In addition to water and site facilities that will receive active management as part of the IW, there are waters and facilities at the FMC that are recognized as representing potential environmental risks, which at this time do not require immediate intervention. Long-term management of these components will be addressed in the FMRP. For example, geochemical conditions at the site are deteriorating, leading to increased contaminant mobilization. Source control measures (e.g., covers) that will be part of the FMRP will reduce mobilization and transport of contaminants. The design, permitting, and procurement for the FMRP will take several years, during which the IW are intended to manage effects and risks at the FMC while recognizing that the overarching objectives will be most effectively fulfilled by the FMRP. In the interim, as part of the IW, a short-term management strategy is required to monitor the potential degradation of conditions to the point where active intervention might be required before the implementation of the FMRP and to provide a framework so that appropriate management actions are implemented for ongoing protection of the environment.

An AMP is a management tool that provides a framework for implementing this short-term management strategy. This document provides the conceptual framework of the IW AMP. This framework builds on the current FMC AMP (Gartner Lee Limited, 2004). The final IW AMP will be developed and finalized as part of the Water Licencing process, which will include the definition of the specific thresholds or triggers for each AMP event.

SECTION 2

Approach to the Adaptive Management Plan

2.1 Objectives for the AMP

The AMP is a management tool that provides a consistent and predictable framework for responding to unforeseen environmental conditions that might result from the degradation of mine-related facilities and waters. The AMP provides the site operator with a pre-planned framework within which decisions can be quickly and efficiently made and provides regulators with the security of a consistent and predictable approach to unforeseen events.

The AMP takes the Precautionary Principle Approach: it provides a mechanism to identify potential environmental risks as they emerge and provides for a management response before an environmental impact occurs.

To be effective, the AMP must be linked to a monitoring program that is designed to provide an indication of when management intervention is necessary. This assures that the necessary data for the assessment of environmental conditions is being collected for evaluation against predetermined "triggers" or "thresholds."

Since the specific environmental conditions that may be encountered are, by definition, unknown, the AMP should not provide detailed description of specific management responses. The AMP, rather, should provide general descriptions of a range of possible responses that may be adapted or otherwise used to guide the design of an appropriate response that best suits the needs of the specific environmental conditions that are encountered. This approach is inherent to the fundamental purpose of the AMP.

Areas where there is uncertainty about site conditions, or where possible future conditions could lead to unacceptable environmental effects, have been identified, and the AMP provides a strong adaptive management approach that will be used to monitor, detect, and respond to changing conditions. Such an approach includes the following key components:

- Proactive monitoring to detect changing conditions in areas of expected uncertainty within a timeframe that allows for effective response.
- Clear and defensible triggers that will assure timely implementation of effective responses.
- Appropriate measures that can be undertaken to address unacceptable conditions and performance.

For the IW, there are three broad types of uncertainty that will be addressed through the AMP:

- When implementation of specific management responses will be required. For example, interception and collection of seepage water from the Zone II Outwash area is not required until water quality in the vicinity begins to show signs of deterioration. The timing of when this might occur is not known.
- Where implementation of specific management responses will be required. Depending on groundwater and seepage pathways, it is unclear where potential future contaminant sources could emerge.
- How the implemented measures/mitigations have performed. For example, the S-Wells Seepage Interception System (SIS) is currently intercepting contaminated water from the area immediately downgradient of the Intermediate Dump. Depending on downstream water quality, this system may not be performing adequately to assure the ongoing protection of North Fork Rose Creek (NFRC).

2.2 AMP Events

There are eight discrete events that comprise the AMP framework for the IW. These events represent anticipated environmental conditions that may decline to the point that may require a management response during the 10-year period of the IW. These events specifically focus on areas where deteriorating water quality conditions may affect receiving environments. If required, additional events will be developed as part of the final AMP to incorporate issues/concerns raised during the Environmental Assessment process.

The following eight events are included in the AMP framework:

1. Degraded Groundwater Quality in the Rose Creek Alluvial Aquifer (RCAA).
2. Degraded Water Quality in NFRC below S-Wells SIS.
3. Degraded Water Quality in NFRC below North Fork Rock Drain (NFRD).
4. Degraded Water Quality in NFRC above NFRD.
5. Degraded Water Quality in seepage from the Faro Northwest Waste Dumps.
6. Degraded Water Quality in Rose Creek, downstream of FMC facilities.
7. Degraded Water Quality below the Grum/V15 Collection System.
8. Degraded Water Quality in Vangorda Creek, downstream of FMC facilities.

The conceptual AMPs for each of these proposed events are described individually in subsequent sections.

2.3 Common Elements

To maintain consistency within the AMP framework, each of the AMP events is described according to common elements. These common elements provide a structure that will ensure that a consistent approach is followed for each event and that the AMP will be proactive in detecting changes and implementing appropriate responses before any unacceptable environment effects occurring. The following common elements form part of each specific AMP event.

- Event – This element describes the specific event that is addressed by the AMP.
- Possible Environmental Consequence – This element describes the environmental consequences that could arise if the event was allowed to proceed without appropriate response.
- Narrative Response Trigger – This is a narrative description of the trigger for the AMP event and leads to the development of the specific indicators and thresholds. In general, the narrative response trigger states that monitoring indicates that a specific type of unacceptable condition is occurring.
- Specific Indicators – This element describes the environmental parameters to be monitored and assessed as part of the AMP. These indicators will be selected to provide early detection of relevant changes in environmental conditions or system performance. They should be representative of the issue being monitored and assessed, easily measured, and reproducible.
- Thresholds – This element defines conditions, in terms of specific indicators, that would lead to actions being taken. They may be a series of staged thresholds or multiple thresholds for an individual AMP event. The specific thresholds for each AMP event will be defined in the final IW AMP, which will developed and finalized as part of the Water Licencing process.
- Monitoring Requirements – This element describes the monitoring that will be carried out to support implementation of the AMP. Parameters and general locations for sampling are discussed as part of the AMP framework. The proposed trigger locations for the AMP are presented in Figures 5B-1 to 5B-5 in Appendix 5B. Specific monitoring requirements will be defined as part of the final IW AMP. Physical inspections and visual monitoring can also form part of the monitoring requirements. Monitoring requirements may change at various stages of the AMP.
- Evaluation of Monitoring Results – This element describes the methods and frequencies that will be used to evaluate the monitoring data and determine whether specific thresholds have been reached or exceeded.
- Approach to Development of Response/Mitigation/Intervention – This element describes the overall approach to responses to be implemented if thresholds have been reached or exceeded. In most cases, the responses will include a range of actions that may be taken to address the events. The selection of the appropriate responses would depend on changed site conditions or system performance.

The sequence of AMP elements is presented in Figure 5C-1, which illustrates how the AMP will be applied to individual AMP events.

Within the context of implementing the AMPs, there will be an ongoing need to understand the validity of monitoring results and confirm the circumstances of threshold or trigger activation. This validation and confirmation process will be conducted in a timely manner and is necessary to verify that response actions are applied in the appropriate circumstances. For each AMP element, if monitoring identifies conditions that are approaching or meeting triggers or thresholds, a stepped response will be implemented for validation and confirmation. Although presented in a sequential order, some steps may occur concurrently or may be eliminated, depending on the individual circumstances of the trigger activation. In all cases, the approach to responses will be such that it expedites the process of responding to the trigger activation.

The initial response to the trigger will be the verification of the monitoring information. This will involve a comprehensive analysis of the laboratory results. The water quality at the trigger locations may then require re-sampling if warranted (i.e., quality assurance/quality control data or field notes indicates sampling issues/errors).

The second step will be a comprehensive analysis of the other related monitoring results from the locations including the monitoring data collected for this AMP and other relevant monitoring data, possibly including results collected for other associated AMP events. The goal of this analysis is to provide for a preliminary identification of the cause of the trigger activation.

The third step will be an analysis of the timing and potential consequences of trigger activation on the receiving environment. The results of this analysis will be used as a basis for the development of an appropriate response plan to prevent or mitigate any identified or predicted impacts and to highlight any required modifications to the monitoring program. Modelling may also be used to assess the effectiveness and impact of various mitigative options.

Following this analysis, the next step may be to increase monitoring intensity (parameters, locations, and frequency) to verify and understand the cause/source of the trigger activation.

2.4 Annual Review and Reporting

An annual review will be completed that assesses the adequacy and appropriateness of the elements of each event such as trigger locations, specific indicators and thresholds, and monitoring requirements. Updates, amendments, or other changes to the AMP will be recommended as part of the annual review.

Each AMP Event includes a management review of the relevant data. The results of these reviews will be reported, where a trigger occurs, monthly. The results of these reviews will also be summarized in the Annual Environmental Report.

SECTION 3

AMP Event 1, Degraded Groundwater Quality in the Rose Creek Alluvial Aquifer

3.1 Description

Groundwater in the RCAA is affected by seepage released from the Faro Waste Dumps via the former Faro Creek drainage and by contaminants released from the pore water of the surface tailings impoundments. This groundwater has the potential to become contaminated to the degree where discharge from the aquifer to Rose Creek may result in sustained adverse effects on the Rose Creek aquatic receiving environment. The groundwater quality in the RCAA is measured at various locations within the RCTA and downstream from the RCTA. Within the RCTA, groundwater quality is measured using multi-level wells with sample points in the tailings, near the tailings/aquifer interface and deep within the aquifer.

The environmental consequences of degraded water quality in the RCAA include the potential exposure of aquatic resources, terrestrial resources, and human resource users to increased levels of contaminants in Rose Creek, Anvil Creek, and the Pelly River.

Since the degradation of groundwater quality is anticipated to occur progressively from the source area (tailings) in a downgradient direction, the AMP for monitoring and addressing degrading water quality in the RCAA consists of three components to provide for early detection of emerging trends. The first component will focus on identifying the migration of contaminants of concern from the tailings into the aquifer. The second component will focus groundwater quality in the aquifer under the tailings upstream from the Intermediate Dam (ID), and the third will focus on groundwater quality downgradient of the Cross Valley Dam (CVD).

3.2 Narrative Triggers

Component 1 – Monitoring of the contaminant fronts in the tailings and underlying soils indicates that the zinc front has arrived at the tailings/aquifer interface. Monitoring locations in this stage will be selected to show early arrival/advanced fronts.

Component 2 – Monitoring of indicator parameters indicates that the water quality in the RCAA is degrading and there is an increasing trend in contaminant concentrations in the aquifer at target locations upstream from the ID.

Component 3 – Monitoring of indicator parameters indicates that the water quality in the RCAA is degrading and there is an increasing trend in concentrations of indicator parameters in the aquifer at target locations downstream from the CVD.

3.3 Specific Indicators and Thresholds

The following are specific indicators for the three components of the RCAA AMP:

Component 1 – Acidity, sulphate, alkalinity, pH, conductivity, dissolved iron, dissolved magnesium, and dissolved zinc concentrations in and below the tailings in the northern portion of the upper RCAA where the acid and zinc fronts are most likely to be further advanced.

Component 2 and Component 3 – Acidity, sulphate, alkalinity, pH, conductivity, dissolved iron, dissolved magnesium, and dissolved zinc concentrations will be monitored to support this AMP.

The selection of these parameters for use provides a comprehensive suite of indicators of the site conditions, allowing early detection of changes and effective tracking of changes over time.

The following are thresholds or triggers for the three components of the RCAA AMP, which will initiate an action for the specific indicators:

Component 1 - A statistically significant increasing trend in acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations or a statistically significant decreasing trend in pH and alkalinity at the base of the tailings and immediately below the base of the tailings in the RCAA, at selected multi-level monitoring wells.

Component 2 – Either of the following two thresholds or triggers will initiate the AMP for Component 2 for water quality in the RCAA at target locations upstream from the ID:

- A statistically significant increasing trend in acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations or a statistically significant decreasing trend in pH and alkalinity in the aquifer
- Acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations increase to a predefined threshold value or pH and alkalinity decrease to a percentage of a predefined threshold value

Component 3 – Either of the following two thresholds or triggers will initiate the AMP for Component 3 for water quality in the aquifer at target locations downstream from the CVD:

- A statistically significant increasing trend in acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations or a statistically significant decreasing trend in pH and alkalinity in the aquifer
- Acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations increase to a predefined threshold value or pH and alkalinity decrease to a percentage of a predefined threshold value

3.4 Monitoring Requirements

Component 1 – Acidity, sulphate, alkalinity, pH, conductivity, dissolved iron, dissolved magnesium, and dissolved zinc concentrations in multi-level wells that include sample points in the tailings, near the tailings/aquifer interface, and below in the aquifer. The specific locations of these wells will be chosen to cover the spatial and temporal variability in the movement of the fronts (i.e., coarse and fine tailings, timing of placement, or proximity to downstream extent of tailings). The frequency of monitoring will be determined based on the site-specific characteristics of the sample locations and will range from annual to quarterly.

Component 2 – Acidity, sulphate, alkalinity, pH, conductivity; dissolved iron, dissolved magnesium, and dissolved zinc concentrations in wells that include sample points in the aquifer upstream from the ID. The specific locations of these wells will be chosen to cover both spatial and temporal variability in the movement of contaminants in the aquifer. The frequency of monitoring will be determined based on the site-specific characteristics of the sample locations and will range from annual to quarterly.

Component 3 – Acidity, sulphate, alkalinity, pH, conductivity; dissolved iron, dissolved magnesium, and dissolved zinc concentrations in wells that include sample points in the aquifer downstream from the CVD. The specific locations of these wells will be chosen to cover both spatial and temporal variability in the movement of contaminants in the aquifer. The frequency of monitoring will be determined based on the site-specific characteristics of the sample locations and will range from annual to quarterly.

In addition to the indicator parameters, other secondary parameters will also be monitored to track changes associated with the aquifer. These include, but are not limited to, dissolved manganese; dissolved calcium; and other dissolved trace metals such as copper, cadmium, arsenic, selenium, and thallium. Additional monitoring information that may be required for analysis should the AMP triggers be activated include water quality data and water level data from other monitoring well locations associated with the RCTA. In addition, surface water quality monitoring stations associated with the RCTA may also be relevant if a trigger is activated.

3.5 Evaluation of Monitoring Results

The management review of the relevant groundwater quality data will be carried out within 1 month of receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns

and data issues. A more comprehensive review will be carried out as part of the annual review, including detailed data and trend evaluation.

3.6 Approach to Responses

Verification and confirmation of the trigger activation will be conducted as described in Section 2.3. Groundwater modelling may be used to support the analysis and indication of the contaminant transport pathways and the rate and development of contaminant loading to the receiving environment. This information will be used to assess the potential effects on the receiving environment and may also be used to assess the effectiveness of various mitigative options.

A response plan will subsequently be designed with the intent of mitigating the predicted adverse effects. This plan might include either of the following:

- Mitigation of the source area(s)
- Installation of an appropriate collection system to intercept the portions of aquifer flow to prevent adverse effects in Rose Creek

SECTION 4

AMP Event 2, Degraded Water Quality in North Fork Rose Creek below S-Wells SIS

4.1 Description

Water quality in NFRC below the S-Wells area has been affected by rock dump seepage and contaminated groundwater from the Main/Intermediate Waste Dumps. From 2006 to 2008, AMP triggers established as part of the current FMC AMP were repeatedly activated with statistically significant increasing concentrations of zinc and sulphate exceeding the established thresholds in NFRC as measured at X2. In response to the continued trigger activation at X2, a detailed assessment and investigation was carried out in 2008 in the S-Wells area. Results of these groundwater and surface water quality investigations indicated high levels of contaminants near NFRC, with a component of the contaminated groundwater discharging into the creek. Increasing trends in contaminant levels were also evident within the creek, particularly in the winter low-flow period. The likely source of the contaminant loading to the S-Wells area was identified as the Main and Intermediate Waste Dumps.

The S-Wells SIS is a first-phase groundwater interception system installed in winter 2009 in the S-Wells area. With the SIS, contaminated water is intercepted, collected, and pumped to the Faro Pit year-round. This system was upgraded in the autumn of 2009, and in 2010 several design modifications were implemented to address specific issues, including the installation of a second, larger pipeline to accommodate freshet flows. Water that is not captured by the S-wells SIS continues down the flowpath toward NFRC.

This AMP element is intended to identify if the performance of the S-Wells SIS is meeting its intended objective of minimizing the discharge of contaminated water to protect NRFC and to identify other potential sources of contaminant loading to NFRC. The water quality in NFRC downstream of the S-Wells SIS is measured monthly at Station X2, along with flow.

The environmental consequence of degraded water quality in NFRC is the potential exposure of aquatic resources, terrestrial resources, and human users of these resources to increased levels of contaminants in NFRC, Rose Creek Diversion, and, possibly, further downstream in Rose Creek, Anvil Creek, and the Pelly River. Zinc is currently the primary contaminant of concern, and zinc and sulphate are currently the primary indicators of acid rock drainage (ARD) in NFRC.

4.2 Narrative Trigger

Monitoring of surface water downgradient of the S-Wells SIS in NFRC indicates that water quality is starting to degrade or change and contaminants are advancing towards receiving environments. Monitoring locations and indicators will be selected, where appropriate, for early detection.

4.3 Specific Indicators and Thresholds

The specific indicators that should be measured in NFRC at X2 to provide the information necessary to support this AMP are:

- Total and dissolved zinc
- Sulphate

The following are thresholds or triggers for the S-Wells SIS AMP that will initiate an action for any of the specific indicators:

- A statistically significant increasing trend in zinc or sulphate concentrations at X2; or
- Increase in zinc or sulphate concentrations to a predefined threshold value

The specific threshold values will be defined to be “proactive” and “protective” and provide sufficient advance warning of changes in the receiving environment. Where warranted, this may include the development of seasonal thresholds: open-water and under-ice conditions.

4.4 Monitoring Requirements

The monitoring information required is monthly total zinc, dissolved zinc, and sulphate concentrations measured at X2. Additional monitoring information that is required for analysis, should the AMP triggers be activated, includes surface, groundwater, and seepage water quality and flow data from locations upgradient of X2. Both water quality and flow data are essential as they enable not only the analysis of contaminant concentrations, but loadings as well. In addition, information regarding the performance of the S-Wells SIS will be used for analysis, including pumping volumes, water quality of water transferred to Faro Pit, water levels in collection sump and wells, and visual presence of seepage bypassing the system as noted in routine visual inspections.

4.5 Evaluation

The management review of the relevant water quality data will be carried out monthly upon receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns and data issues. As part of the monthly assessment, a comprehensive review will be carried out, including detailed data and trend evaluation.

4.6 Approach to Responses

Verification and confirmation of the trigger activation will be conducted as described in Section 2.3. This may include more intensive and focused monitoring and evaluation of potential pathways and effects. A response plan will subsequently be designed based on the trigger analysis with the intent of mitigating potential adverse effects in NFRC. This plan, where appropriate, may include both short-term and long- term mitigation measures.

If the source of contamination is identified to be because of seepage bypassing the SIS, then a short-term mitigation measure may be implemented while a longer-term mitigation plan is prepared. This might include pumping, berming, ditching, or other means to prevent receiving water quality from being further degraded in the short-term. If the source of contamination is identified to be because of a contaminant load resulting from sources other than seepage bypassing the SIS, then similarly a short-term mitigation may be implemented.

A longer-term mitigation would then be implemented to provide security until the implementation of the FMRP. This could include the design and implementation of appropriate collection system modifications to the SIS or design and implementation of additional interception and collection systems.

SECTION 5

AMP Event 3, Degraded Water Quality in North Fork Rose Creek below North Fork Rock Drain

In the autumn of 2013, a new sourceload to NFRC developed in the area of NFRD, which resulted in zinc concentrations in NFRC (NF2, X2) and at X14 above concentrations previously measured at these locations. The issue was originally identified through routine monitoring of water quality in Rose Creek at X14, and comparison was made with thresholds and targets laid out in the current FMC AMP and site water management protocols. Consistent with the current FMC AMP (Gartner Lee Limited, 2004), a detailed monitoring program and investigation was implemented to delineate the source of this new load. Based on the results of that program, the source of the increased zinc loading to NFRC is believed to be seepage from the Intermediate Dump Sulphide Cell. The increased loading associated with this source is most likely because of "break through" of a natural seep, possibly because of depletion of attenuation along the flow path, in a drainage channel beneath NFRD (Government of Yukon, 2013). According to the current FMC AMP, a response plan has been developed and is currently being implemented to locate and intercept this source. The development of AMP Event 3, Degraded Water Quality in NFRC as part of the IW AMP framework, is pending completion of the ongoing investigation and response plan implementation.

SECTION 6

AMP Event 4, Degraded Water Quality in North Fork Rose Creek above North Fork Rock Drain

6.1 Description

Water quality in NFRC upstream from NFRD could be affected by contaminated groundwater and seepage from waste dumps (Intermediate, Northeast, and Zone II Waste Dumps), seepage or overflow from the Zone II Pit, and seepage from the Zone II Outwash area. Seepage water from the Northeast Waste Dumps and from the former Zone II Pit (i.e., water that is not captured by the Zone II pumping well) contributes to NFRC, upstream from NFRD. In addition, seepage water in the waste dumps adjacent to the Zone II Pit catchment that is not captured by the well continues along a flowpath toward the Zone II Outwash area and NFRC. Groundwater quality associated with the Zone II Outwash area indicates that groundwater flowing towards NFRC is impacted with elevated concentrations of sulphate and zinc (CH2M HILL, 2014a) and support the need for continued monitoring and assessment of water quality trends in this area.

Surface water quality in NFRC upstream from NFRD is routinely monitored at several locations along the reach adjacent to the Northeast Waste Dumps and the Zone II Outwash area: R9, R10, and NF1. In addition, seepage and groundwater quality in the area is also monitored as part of the site monitoring program (CH2M HILL, 2014b).

6.2 Narrative Trigger

Monitoring of indicator parameters denotes that the water quality in NFRC is degrading with increasing concentrations of indicator parameters, and there is an increasing trend in concentrations at target seep and groundwater monitoring locations downgradient of the Zone II Outwash area and/or the Northeast Waste Dumps.

6.3 Specific Indicators and Thresholds

For seep and groundwater monitoring locations, the following are specific indicators that will be measured to provide the information necessary to support this AMP:

- Acidity, alkalinity, pH, and conductivity
- Dissolved iron, dissolved magnesium and dissolved zinc
- Sulphate

The specific indicators were selected to be proactive and provide advance warning of changes in seepage and groundwater quality; initially there will be an increase in magnesium and sulphate, followed by an increase in zinc.

The following are specific indicators for surface water quality monitoring locations:

- Total and dissolved zinc
- Sulphate

The following are thresholds or triggers for seepage and groundwater quality that will initiate an action for the specific indicators:

- A statistically significant increasing trend in acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations or a statistically significant decreasing trend in pH and alkalinity in the aquifer; or
- Acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations increase to a predefined threshold value or pH and alkalinity decrease to a percentage of a predefined threshold value.

The following are thresholds or triggers for surface water quality that will initiate an action for the specific indicators:

- A statistically significant increasing trend in zinc or sulphate concentrations at target seep locations; or
- Increase in zinc or sulphate concentrations to a predefined threshold value.

The specific threshold values, similarly, will be defined to be proactive and protective and will provide sufficient advance warning of changes in the receiving environment. Where warranted, this may include the development of seasonal thresholds: open-water and under-ice conditions.

6.4 Monitoring Requirements

The monitoring information required is dissolved magnesium, dissolved zinc, and sulphate in seeps and groundwater wells associated with the Zone II Waste Dumps, Northeast Waste Dumps, Zone II Outwash area, and Intermediate Dump. Monitoring locations will be selected to evaluate areas where there are known or anticipated pathways for ARD products and to provide for adequate characterization of the water quality associated with seepage from these areas. Frequency of monitoring will be determined based on the site-specific characteristics of the sample locations.

The monitoring information required for the surface water component is monthly total zinc, dissolved zinc, and sulphate concentrations measured at R9, R10, and NF1. Additional monitoring information that is required for analysis, should the AMP triggers be activated, includes other surface, groundwater, and seepage water quality and flow data from locations upgradient from NFRD. Both water quality and flow data is essential, as they enable not only the analysis of contaminant concentrations, but loadings as well.

6.5 Evaluation

A management review of the relevant surface water quality data will be carried out monthly upon receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns and data issues. As part of the monthly assessment, a comprehensive review will be carried out, including detailed data and trend evaluation.

A management review of the relevant seepage and groundwater quality data will be carried out within 1 month of receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns and data issues. A more comprehensive review will be carried out as part of the annual review, including detailed data and trend evaluation.

6.6 Approach to Responses

Verification and confirmation of the trigger activation will be conducted as described in Section 2.3. This may include more intensive and focussed monitoring and evaluation of potential pathways and effects. A response plan will subsequently be designed based on the trigger analysis with the intent of mitigating potential adverse effects in NFRC. This plan, where appropriate, may include both short-term and long-term mitigation measures.

If the source of contamination is identified to be runoff or seepage from all or a portion of the FMC facilities, then a short-term mitigation measure may be implemented to control migration of contaminants at the source while a longer-term mitigation plan is prepared. This might include pumping, berming, ditching, or other means to prevent receiving water quality from being further degraded in the short term. A longer-term mitigation system would then be designed and in such a way as to provide security until the implementation of the FMRP. If the source of the contamination is identified to be groundwater flow that is too deep for interception by surface ditching, then a groundwater interception plan, or another long-term remedial measure, may be designed and implemented.

SECTION 7

AMP Event 5, Degraded Water Quality in Seepage from the Faro Northwest Waste Dumps

7.1 Description

The Faro Northwest Waste Dumps are located primarily in the Guardhouse Creek watershed. There are two main contributors of flow in the Guardhouse Creek area: Upper Guardhouse Creek (UGC) and Lower Guardhouse Creek (LGC). UGC flows adjacent to the Faro Northwest Waste Dumps (along the westernmost edge) and may partially flow under the Northwest Waste Dumps. UGC ultimately flows to the CVD area, bypassing collection systems, and into Rose Creek (upstream of X14). UGC flows through mainly unimpacted terrain, with the exception of several seeps originating from the Northwest Waste Dumps. Monitoring of these seeps indicate that water quality is being affected by the Northwest Waste Dumps (CH2M HILL, 2014a).

LGC originates from waste dump seeps with mine-influenced water quality that flow into a ditch across from the Warehouse Building and from this ditch to the ID Pond, where the water is captured for treatment. Concentrations of sulphate and zinc in LGC have been increasing steadily. Seepage water emanating from the south toe of the Northwest Waste Dumps (Northwest Lower Waste Dump), contributes to X23 and to LGC. Although the seepage from the Northwest Lower Waste Dump remains internal to the FMC water management system, this seepage is impacted, with trends of decreasing alkalinity and increasing sulphate and zinc (CH2M HILL 2014a), and may be representative of the geochemical conditions in the Northwest Waste Dumps as a whole. Increasing constituent concentrations from these seeps indicate the possibility of future water quality effects associated with seepage from the Northwest Waste Dumps to UGC, and support the need for the proactive monitoring and assessment of seepage associated with the Northwest Waste Dumps.

7.2 Narrative Trigger

Monitoring of indicator parameters indicates that water quality in seeps associated with the Northwest Waste Dumps is degrading and there is an increasing trend in concentrations at target seep locations associated with the Northwest Waste Dumps. Monitoring locations will be selected for early detection and indication of ARD products migrating towards aquatic receptors.

7.3 Specific Indicators and Thresholds

The following are specific indicators that should be measured to provide the information necessary to support this AMP:

- Acidity, alkalinity, pH, and conductivity
- Dissolved iron, dissolved magnesium, and dissolved zinc
- Sulphate

The specific indicators were selected to be proactive and provide advance warning of changes in seepage water quality; initially there will be an increase in magnesium and sulphate, followed by an increase in zinc and decrease in alkalinity.

The following are thresholds or triggers for the Northwest Waste Dumps AMP that will initiate an action for the specific indicators:

- A statistically significant increasing trend in acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations or a statistically significant decreasing trend in pH and alkalinity in the aquifer; or
- Acidity, sulphate, conductivity, dissolved iron, dissolved magnesium, or dissolved zinc concentrations increase to a predefined threshold value or pH and alkalinity decrease to a percentage of a predefined threshold value.

The specific threshold values, similarly, will be defined to be proactive and protective and provide sufficient advance warning of changes in the receiving environment.

7.4 Monitoring Requirements

Dissolved magnesium, dissolved zinc, and sulphate will be monitored in seeps downgradient from the Northwest Waste Dumps. Monitoring locations will be selected to evaluate areas where there are known or anticipated pathways for ARD products and to provide for adequate characterization of water quality associated with seepage from the Northwest Waste Dumps. Frequency of monitoring will be determined based on the site-specific characteristics of the sample locations.

Additional monitoring information that may be required for analysis, should the AMP triggers be activated, includes water quality data and water flow data from other monitoring locations downgradient from the Northwest Waste Dumps. This includes monitoring locations in UGC and LGC. Currently there are no groundwater monitoring wells in the area of the Northwest Waste Dumps, but groundwater monitoring well installations are planned for the summer of 2014. Once established, these wells will be included in the monitoring requirements for Northwest Waste Dumps AMP.

7.5 Evaluation

The management review of the relevant water quality data will be carried out within 1 month of receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns and data issues. A more comprehensive review will be carried out as part of the annual review, including detailed data and trend evaluation.

7.6 Approach to Responses

Verification and confirmation of the trigger activation will be conducted as described in Section 2.3. Once trigger activation is confirmed, the specific responses will include the development and implementation of a program to monitor and investigate contaminant transport pathways to support a comprehensive understanding of concentrations, loadings, trends, travel times, and potential impacts to the receiving environment. This information will be used to determine the need for mitigative action.

SECTION 8

AMP Event 6, Degraded Water Quality in Rose Creek Downstream of Mine Site Facilities

8.1 Description

Water quality in Rose Creek downstream of the FMC facilities could be negatively affected by surface and groundwater inflows from FMC facilities, waste dumps, the RCTA, and existing water treatment plant discharges. The water quality in Rose Creek immediately downstream of the FMC is measured at Station X14. Water quality in Rose Creek is also measured farther downstream at the confluence with Anvil Creek (R4).

The potential environmental consequence of degraded water quality in Rose Creek is exposure of the aquatic resources to increased levels of contaminants, which may lead to an overall degradation in the downstream aquatic receiving environment. Zinc is currently the primary contaminant of concern in the receiving environment, and zinc and sulphate are currently key indicators for assessing changes in Rose Creek water quality. However, the consideration of degraded water quality should also include other metals that could originate from the FMC.

8.2 Narrative Trigger

Monitoring of surface water quality in Rose Creek downstream from the FMC indicates that the downstream water quality is starting to degrade or change and ARD products are advancing towards receiving environments. Monitoring locations and indicators will be selected for early detection.

8.3 Specific Indicators and Thresholds

The following are specific indicators that will be measured in Rose Creek at X14 to provide the information necessary to support this AMP:

- Total and dissolved zinc
- Sulphate

The following are thresholds or triggers for the Rose Creek AMP that will initiate an action for the specific indicators:

- A statistically significant increasing trend in zinc or sulphate concentrations at X14; or
- Increased zinc or sulphate concentrations to a predefined threshold value.

The specific threshold values will be defined to be proactive and protective and provide sufficient advance warning of changes in the receiving environment.

8.4 Monitoring Requirements

The monitoring information that is required monthly (or weekly when discharging) includes total zinc, dissolved zinc, and sulphate concentrations measured at X14. Additional monitoring information that is required for analysis, should the AMP triggers be activated, includes surface water, groundwater, and CVD seepage (Weir 3, X11, X12, and X13) water quality and flow data from locations upstream of X14. Both water quality and flow data are essential as they enable not only the analysis of contaminant concentrations, but the amount of loadings as well. The monitoring locations required are surface water quality stations located upstream in Rose Creek (Rose Creek Diversion, NFRC, and South Fork Rose Creek),UGC, surface seepage from the CVD, effluent flow from the CVD Pond, and surface flow and seepage from other FMC facilities. Groundwater quality beneath and downgradient from the RCTA, monitored as part of the Routine Monitoring Program and the RCAA AMP, will also provide important information should the Rose Creek AMP be activated.

8.5 Evaluation

The management review of the relevant water quality data (X14) will be carried out monthly upon receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns and data issues. As part of the monthly assessment, a comprehensive review will be carried out, including detailed data and trend evaluation.

8.6 Approach to Responses

Verification and confirmation of the trigger activation will be conducted as described in Section 2.3. This may include more intensive and focussed monitoring and evaluation of potential pathways and effects. A response plan will subsequently be designed based on the trigger analysis, with the intent of mitigating potential adverse effects in Rose Creek. This plan, where appropriate, may include both short-term and long-term mitigation measures.

If the source of contamination is identified to be runoff or seepage from all or a portion of the mine facilities, then a short-term mitigation measure may be implemented to control migration of contaminants at the source while a longer-term mitigation plan is prepared. This might include pumping, berming, ditching, or other means to prevent receiving water quality from being further degraded in the short term. A longer-term mitigation system would then be designed and in such a way as to provide security until the implementation of the FMRP. If the source of the contamination is identified as groundwater flow that is too deep for interception by surface ditching, then a groundwater interception plan, or another long-term remedial measure, may be designed.

SECTION 9

AMP Event 7, Degraded Water Quality below the V15 and Grum Creek Pumping System

9.1 Description

Seepage from the Grum Waste Dump surfaces at the base of the waste rock pile on the southeastern side, just upgradient from V15 and Grum Creek. In 2006, increasing concentrations of zinc were observed at the V15 seep sampling location that corresponded to elevated concentrations of zinc in the lower portion of Grum Creek draining into Vangorda Creek (Station V2). In 2007, a seepage collection ditch was installed to convey seepage from V15 into an existing ditch routing upper Grum Creek water to Moose Pond, away from lower Grum Creek. In 2011, in response to continued increasing contaminant levels at V15 and the potential effects to the receiving environment, a collection sump and pumping system were installed: V15 and Grum Creek Pumping System. The pumping system at V15, located east of the Grum Waste Dump, consists of an insulated and heat-traced, 76-millimetre high-density polyethylene pipeline, a power supply, and pump (Denison Environmental Services, 2011). The system can redirect seepage from the Grum Waste Dump (V15, upper Grum Creek, or both) to the Vangorda Pit. When the system is not operated, discharge flows to Moose Pond. Currently the system is operated during peak freshet and storm event flows only, with Moose Pond receiving “normal” flows (Tracey Parkin, Personal Communication, 2013). Water in Moose Pond infiltrates through the ground, ultimately discharging into Vangorda Creek. During peak flow events, if the pumping system is not operating or not capable of handling the entire volume, there is the potential for discharge of contaminated, sediment-laden water directly to Vangorda Creek.

This AMP element is intended to identify if the performance of the V15 and Grum Creek Pumping System, including the use of Moose Pond and associated infiltration through the ground, is meeting its intended objective of minimizing the discharge of contaminated water and sediment to protect Vangorda Creek.

Surface water quality in the area is routinely monitored at V15, Moose Pond (V2A), and lower Grum Creek (V2). Seepage and groundwater quality is measured downgradient of Moose Pond at Moose Seep and Moose Well. The water level in Moose Pond is also routinely measured.

9.2 Narrative Trigger

Monitoring of surface water, groundwater, and seepage water quality at target locations downgradient from the Grum/V15 collection system or Moose Pond indicates that water quality downgradient is starting to degrade or change and contaminants are advancing towards receiving environments. Monitoring locations and indicators will be selected, where appropriate, for early detection.

9.3 Specific Indicators and Thresholds

The following are specific indicators that will be measured to provide the information necessary to support this AMP:

- Total (surface water samples only) and dissolved zinc
- Total suspended solids (surface water samples only)
- Sulphate

The following are thresholds or triggers for the Grum/V15 AMP that will initiate an action for the specific indicators:

- A statistically significant increasing trend in zinc or sulphate concentrations at trigger locations; or
- Increase in total suspended solids, zinc, or sulphate concentrations to a predefined threshold value.

The specific threshold values will be defined to be proactive and protective and provide sufficient advance warning of changes in the receiving environment. Target monitoring locations will include, but not be limited to, V2, Moose Pond (V2A), Moose Well, and Moose Seep.

9.4 Monitoring Requirements

Total zinc (surface water only), dissolved zinc, total suspended solids (surface water only), and sulphate at key locations downgradient of the Grum/V15 collections system including V2, Moose Pond (V2A), Moose Well, and Moose Seep. The specific locations will be chosen to cover both spatial and temporal variability in the movement of contaminants towards Vangorda Creek. The frequency of monitoring will be determined based on the site-specific characteristics of the sample locations and will range from annual to bi-weekly. Additional monitoring information that is required for analysis, should the AMP triggers be activated, includes surface and seepage water quality and flow data from locations upstream of the collection system including V15 and Grum Creek upstream of the collection system (GC Weir). Both water quality and flow data are essential, as they enable not only the analysis of contaminant concentrations, but loadings as well.

9.5 Evaluation

The management review of the relevant water quality data will be carried out monthly upon receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns and data issues. As part of the monthly assessment, a comprehensive review will be carried out including detailed data and trend evaluation.

9.6 Approach to Responses

Verification and confirmation of the trigger activation will be conducted as described in Section 2.3. This may include more intensive and focussed monitoring and evaluation of potential pathways and effects. A response plan will subsequently be designed based on the trigger analysis, with the intent of mitigating potential adverse effects in Vangorda Creek. This plan, where appropriate, may include both short-term and long-term mitigation measures.

If the source of contamination is identified to be because of excessive flows during peak flow events resulting in bypassing of the collection system, then a short-term mitigation measure may be implemented while a longer-term mitigation plan is prepared. This might include pumping, berming, ditching, or other means to prevent receiving water quality from being further degraded in the short term. If the source of contamination is identified to be because of the contaminant load resulting from the exfiltration from Moose Pond to Vangorda Creek, then similarly a short-term mitigation may be implemented, including extending the operational period of the collection system.

A longer-term mitigation would then be implemented to provide security until the implementation of the FMRP. This could include the design and implementation of appropriate collection system modifications.

SECTION 10

AMP Event 8, Degraded Water Quality in Vangorda Creek Downstream of Mine Facilities

10.1 Description

Water quality in Vangorda Creek downstream from the FMC facilities could be negatively affected by surface and groundwater inflows from FMC facilities, waste dumps, and water treatment plant discharges. The water quality in Vangorda Creek downstream from the FMC is measured at Station V8 at the foot bridge in the Town of Faro. Water quality in Vangorda Creek is also routinely measured farther upstream in the main arm at V27 and in the west arm at V5.

The potential environmental consequence of degraded water quality in Vangorda Creek is exposure of the aquatic resources to increased levels of contaminants, which may lead to an overall degradation in the downstream aquatic receiving environment. Zinc is currently the primary contaminant of concern in the receiving environment, and zinc and sulphate are currently key indicators for assessing changes in Vangorda Creek water quality. However, the consideration of degraded water quality should also include other metals that could originate from the FMC.

10.2 Narrative Trigger

Monitoring of surface water quality in Vangorda Creek downstream of the FMC indicates that the downstream water quality is starting to degrade or change and ARD products are advancing towards receiving environments. Monitoring locations and indicators will be selected for early detection.

10.3 Specific Indicators and Thresholds

The following are specific indicators that should be measured in Vangorda Creek at V8 to provide the information necessary to support this AMP:

- Total and dissolved zinc
- Sulphate

The following are thresholds or triggers for the Vangorda Creek AMP that will initiate an action for the specific indicators:

- A statistically significant increasing trend in zinc or sulphate concentrations at V8; or
- Increased zinc or sulphate concentrations at V8 to a predefined threshold.

The specific threshold values will be defined to be proactive and protective and provide sufficient advance warning of changes in the receiving environment.

10.4 Monitoring Requirements

The monitoring information that is required monthly (or weekly when discharging) is total zinc, dissolved zinc, and sulphate concentrations measured in Vangorda Creek at V8. Additional monitoring information that is required for analysis should the AMP triggers be activated includes surface, groundwater, and seepage water quality and flow data from locations upstream from V8. Both water quality and flow data are essential as they enable not only the analysis of contaminant concentrations, but loadings as well. The monitoring locations required are surface water quality stations located upstream in the Vangorda Creek drainage, site discharges from V25BSP, and surface runoff and seepage from FMC-related facilities in the drainage. Groundwater quality at the Vangorda /Grum Area monitored as part of the Routine Monitoring Program and the Grum V15 AMP will also provide important information should the Vangorda Creek AMP be activated.

10.5 Evaluation

A management review of the relevant water quality data in Vangorda Creek at V8 will be carried out monthly upon receiving the laboratory analysis report to compare monitoring data for thresholds and identify immediate timing concerns and data issues. As part of the monthly assessment, a comprehensive review will be carried out, including detailed data and trend evaluation.

10.6 Approach to Responses

Verification and confirmation of the trigger activation will be conducted as described in Section 2.3. This may include more intensive and focused monitoring and evaluation of potential pathways and effects. A response plan will subsequently be designed based on the trigger analysis, with the intent of mitigating potential adverse effects in Vangorda Creek. This plan, where appropriate, may include both short-term and long-term mitigation measures.

If the source of contamination is identified to be runoff or seepage from all or a portion of the FMC facilities, then a short-term mitigation measure may be implemented to control migration of contaminants at the source while a longer-term mitigation plan is prepared. This might include pumping, berming, ditching, or other means to prevent receiving water quality from being further degraded in the short term. A longer-term mitigation system would then be designed and in such a way as to provide security until the implementation of the FMRP. If the source of the contamination is identified to be groundwater flow that is too deep for interception by surface ditching, then a groundwater interception plan, or another long term remedial measure, may be designed.

SECTION 11

Works Cited

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Figure

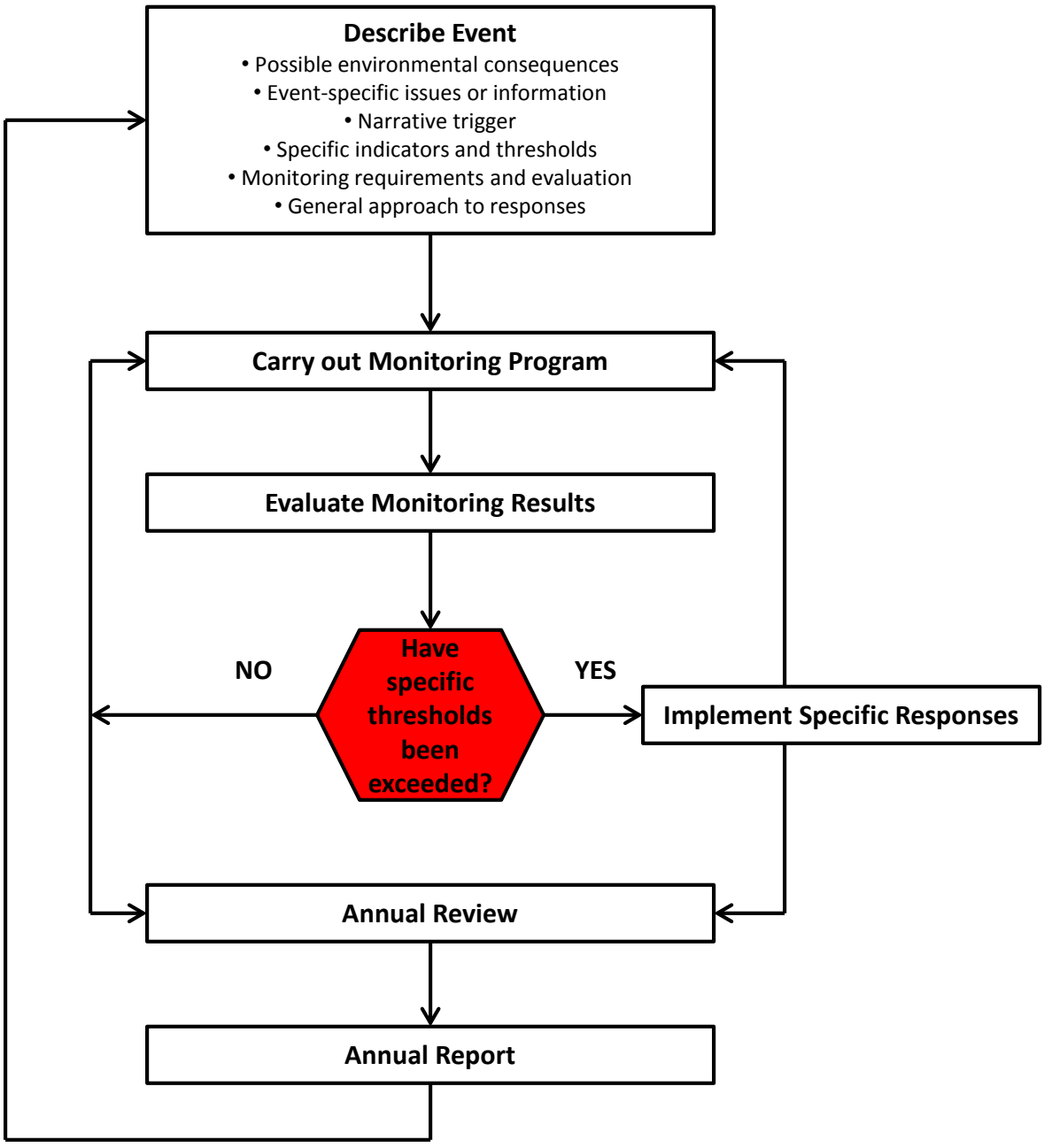

FIGURE 5C-1
AMP Sequence of Activities
Faro Mine Interim Works

Appendix 5D
C&M Risk Assessment

Draft

C&M Risk Assessment
Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 7, 2014

CH2MHILL®

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Acronyms and Abbreviations

AANDC	Aboriginal Affairs and Northern Development Canada
AMP	Adaptive Management Plan
CVD	Cross Valley Dam
CVD Pond	Cross Valley Dam Pond
FCD	Faro Creek Diversion
FMC	Faro Mine Complex
FMEA	Failure Modes Effects Analysis
IW	Interim Works
ID	Intermediate Dam
ID Pond	Intermediate Dam Pond
RCD	Rose Creek Diversion
VCD	Vangorda Creek Diversion
YG	Government of Yukon

SECTION 1

Introduction

The Government of Canada, as represented by the Government of Yukon (YG) and Aboriginal Affairs and Northern Development Canada (AANDC), conduct annual qualitative risk assessments to identify and characterize physical and operational risks at the Faro Mine Complex (FMC). In accordance with the *Federal Contaminated Sites Action Plan, Decision Making Framework* (Government of Canada, 2013) and the *Contaminated Sites Management Policy* (AANDC, 2002), risk characterization and management play important roles in decision-making and prioritization for activities at contaminated sites managed under the Federal Contaminated Sites Action Plan. The results of the annual qualitative risk assessments guide work planning for site operations. This report describes the risk assessment process used by YG and AANDC, summarizes the results of the 2013 operational risk assessment, and describes how the results will be used to guide activities undertaken during the Interim Works (IW). These risk assessments are qualitative, and are intended to characterize physical hazards at the FMC, especially related to the effects potential failure modes could have on the environment, costs, and human health, and safety.

Additional risk assessment tools provide information and analysis to support remediation planning at the FMC. For example, combinations of qualitative assessments of physical hazards, as described in this report, and quantitative assessments of ecological and human health risks, are used to support decision-making for the Faro Mine Remediation Project. This report does not provide the results of quantitative risk assessments.

YG and AANDC track ongoing risk evaluations and responses in a comprehensive database that records changes in risks over time, as well as mitigation responses. This document summarizes results for 2013, but it does not provide details about underlying assumptions or how the risks have evolved.

SECTION 2

Operational Risk Assessment Methods

Annual operational risk assessments for the FMC follow an approach developed by AANDC. The qualitative risk assessment approach is a form of Failure Modes Effects Analysis (FMEA) that AANDC applies at sites it manages under the Federal Contaminated Sites Action Plan. The FMEA is a systematic and comprehensive account of potential events and scenarios (failure modes) that could result in adverse consequences to the environment and to human health and safety. The methodology requires a qualitative characterization of the consequences of failure and the likelihood of failure for specific failure modes. Applying this systematic and consistent approach to risk assessments provides a framework for informed decision-making about priorities for site activities and risk mitigation actions in accordance with the objectives of AANDC's *Contaminated Sites Management Policy "*to provide a scientifically valid, risk management based framework for setting priorities, planning, implementing and reporting on the management of contaminated sites" (AANDC, 2002).

Deloitte and Touche Inc. initiated the FMEA for the FMC in 2002, establishing a baseline for future risk assessments. As part of ongoing operations, YG and AANDC convene an annual operational risk assessment workshop to update the FMEA, taking into consideration current site conditions, mitigative activities that have taken place, monitoring results, and improved understanding of site processes. These workshops bring together teams of experts (i.e., site owners, site managers, site operators, remediation plan designers, engineers, environmental experts, and site technicians) to conduct a joint site inspection, combined with a systematic re-evaluation of previously identified risks and a characterization of newly identified risks. These operational risk assessments focus on events and consequences that may affect the environment, cost, or human health and safety. AANDC and YG use other forums to address other types of consequences like legal requirements and community relations.

The annual FMEAs consider each FMC component (e.g., Rose Creek Diversion [RCD] and the water treatment system) and characterize risks for each component using the following steps:

1. **Identify potential failure modes.** These could be natural causes (e.g., earthquake, flood), engineering failures (e.g., structural failure of building), human error (e.g., operator error, inspector error, mischief, or vandalism), or prediction errors (e.g., uncertainty in geochemical predictions, or underestimates of flood events).
2. **Describe failure modes and consequences arising from failure modes.** For these assessments, the failure consequences focus on effects on the environment, cost, or human health and safety (both site workers and the public). For example, a flood causing a dam failure would often have environmental consequences and also cost consequences associated with cleanup and repair. On the other hand, deteriorating water quality at a seepage collection system may only have cost consequences because of increased cost for water treatment.
3. **Characterize consequences of failures.** Table 5D-1 describes the "Consequence Categories" applied for the FMC, providing specific consequence descriptors for each consequence type (e.g., an event that leads to a cost increase of $500,000 to $2,500,000 has a "moderate" cost consequence). Consequences can be very low, minor, moderate, major, or critical.
4. **Characterize likelihood of failure modes.** Table 5D-2 describes the "Likelihood Categories" applied for the FMC, providing specific likelihood descriptors for each likelihood category (e.g., a scenario that would be expected to occur approximately once every 30 years would be assigned a likelihood of "possible"). Characterizing likelihood requires carefully considering the entire failure mode scenario, not just a specific part of the failure event. For example, a flood that overtops the FCD has a specific likelihood, while a flood that overtops the FCD and leads to the Faro Pit being filled and overtopped has a much smaller likelihood.
5. **Characterize the risk rating.** Table 5D-3 illustrates the risk matrix used to assign an overall risk rating for each failure mode. The risk rating is a combination of likelihood and consequence with ratings of low, moderate, moderately high, high and very high. AANDC and YG's site activities and responses to risks are defined by the risk ratings where "low" risks require ongoing tracking and re-evaluation, while "very high" risks require development and implementation of immediate responses.

6. **Identify risk mitigation measures.** For risks ranging from “moderate” to “very high,” the final step in the annual FMEA is to describe appropriate mitigation that could be applied to reduce or eliminate the risk. The identified actions support the development of work plans for the upcoming year.

AANDC and YG use a comprehensive risk database to track all identified FMC risks over time. The system allows site managers to monitor ongoing risk trends, keeping track of risks that are increasing over time and risks that have been addressed or reduced by mitigative activities.

AANDC and YG intend to continue applying an FMEA approach for identifying and characterizing environmental, cost, and human health and safety risks at the FMC during the period of the proposed IW. The results of monitoring programs and of condition evaluations (in accordance with the Adaptive Management Plan) will be important inputs for these ongoing risk assessment updates. These inputs will provide evidence about changing conditions and problematic trends at the FMC.

When considering the results of the annual operational risk assessments for the FMC, it is important to recognize that the risk characterizations assume continued active site operations. While the assessments consider failure modes that include operator error, they do not consider failure modes involving the complete discontinuation of site operations. This is a reasonable assumption for operational risk assessments that are used to identify and prioritize remedial actions while overall remediation planning and implementation continues at the FMC. The annual operational risk assessments assume the Faro Mine Remediation Project will be implemented in the foreseeable future, and will address long-term risks. As such, the likelihoods of failure events are characterized on the basis of current conditions. The need to mitigate risks during the IW considers the likelihood of failure during that period only. For example, the current risks associated with flood conveyance for the Rose Creek Tailings Area led to conclusions that the Down Valley Interim Hydraulic Upgrades are necessary to sufficiently reduce likelihood of failure during the period of approximately 8 to 10 years before final improvements can be completed. Risk assessments to support development of the permanent remediation plan consider the likelihoods of failure over much longer periods of time, but are not addressed in this report, as they are relevant to the Faro Mine Remediation Plan.

TABLE 5D-1
Consequence Categories
Faro Mine Interim Works

Consequence Categories	Very Low	Minor	Moderate	Major	Critical
1. Environmental Impact	No impact	Minor localized or short-term impacts	Significant impact on valued ecosystem component	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function	Serious long-term impairment of ecosystem function
2. Consequence Costs	< $100,000	$100,000 - $500,000	$ 500,000 - $2.5 Million	$2.5-$10 Million	>$10 Million
3. Human Health and Safety	Low-level, short-term subjective symptoms; no measurable physical effect; no medical treatment	Objective but reversible disability/impairment and /or medical treatment/injuries requiring hospitalization	Moderate irreversible disability or impairment to one or more people	Single fatality and /or severe irreversible disability or impairment to one or more people	Multiple fatalities

TABLE 5D-2
Likelihood Categories
Faro Mine Interim Works

Assigned Likelihood	Descriptive	Health Events Only	Frequency of Occurrence for Other Events
Almost Certain	Happens often	1 case / 100 person-years	High frequency (more than once every 5 years)
Likely	Could easily happen	1 case / 1,000 person-years	Event does occur, has a history, once every 15 years
Possible	Could happen and has happened elsewhere	1 case / 10,000 person-years	Occurs once every 30 years
Unlikely	Hasn't happened yet but could	1 case / 100,000 person-years	Occurs once every 100 years
Very Unlikely	Conceivable, but only in extreme circumstances	1 case / 1,000,000 person-years	Occurs once every 1000 years

TABLE 5D-3
Risk Assessment Matrix
Faro Mine Interim Works

Likelihood	Consequence Severity				
	Low	Minor	Moderate	Major	Critical
Almost Certain	Moderate	Moderately High	High	Very High	Very High
Likely	Moderate	Moderate	Moderately High	High	Very High
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High

SECTION 3

2013 Risk Assessment Results

YG and AANDC convened the annual operational risk assessment workshop from October 22 to 24, 2013, in the Town of Faro. The goal was to identify and characterize current physical and operational risks at the FMC. Workshop participants provided a broad range of management, engineering, regulatory, and operational expertise and included representatives of YG, AANDC, the site operations contractor, the design and regulatory contractor, and the Independent Engineer. The workshop included a site inspection, followed by a detailed discussion and characterization of risks for each key mine component.

Tables 5D-4, 5D-5, and 5D-6 summarize the most significant environmental, cost, and human health and safety risks, respectively. The risks identified in these tables are the highest risk rating associated with each specific failure mode. Many of the risk scenarios would have consequences in more than one category, and these are all tracked in the risk database. However, for the summaries in this report, only the category(ies) with the highest rating appear in the tables. Also, the tables do not provide information about the analysis and assumptions that underlie the determination of the likelihood and consequence categories.

For example, Risk 1.3 identified in Table 5D-5 (1-in-500 to 1-in-1000-year return period flood, causing a breach of the Intermediate Dam [ID] with release of contaminated water through the Cross Valley Dam Pond [CVD Pond] but not a failure of the Cross Valley Dam [CVD] or release of tailings to the environment) has a clear environmental consequence in addition to a cost consequence. The event would contaminate downstream receiving environments, and would lead to cleanup and repair costs. The details recorded in the database describe analyses confirming the CVD spillway could convey a 1:500-year event; therefore, likelihood of tailings release is reduced, and the event sequence is a reasonable scenario. The release of contaminated water to the receiving environment, as described in the scenario, would cause adverse effects but they would likely be reversible, especially since they would occur during a period of extremely high flow with substantial dilution. This would result in, at most, a consequence category of “major” for environmental risk, “significant impact on valued ecosystem component and medium-term impairment of ecosystem function.” The cost to repair facilities would probably exceed $10,000,000, resulting in a consequence category of “critical” for cost risk. As a result, the summary tables only identify this risk in the cost category. This summary approach provides a valuable perspective because it is the highest risk rating for each event that defines the priorities for mitigative actions and annual work planning.

The following sections summarize environmental, cost, and human health and safety risks from the 2013 operational risk assessment.

3.1 2013 Environmental Risks

The 2013 operational risk assessment did not identify “high” or “very high” environmental risks for the FMC. This outcome illustrates the success of ongoing risk management evaluations and responses at the FMC, where actions have been taken to reduce environmental risks falling in these categories. Three environmental risks have ratings of “moderately high,” indicating that mitigation plans should be developed and implemented. The scenarios with “moderately high” environmental risks are described below along with responses that will be undertaken in the coming year.

- **A piping failure of the ID leads to release of contaminated water through the CVD Pond.** The status of the ID is addressed through ongoing monitoring programs, rendering the event unlikely.
- **Wind erosion from tailings causes contamination of surrounding land, affecting ecosystem health.** Dust control protocols should be revised to minimize wind erosion. These protocols have been developed as part of the IW Project Proposal and will be part of licence applications.
- **Contaminated water migrates below the CVD Pond, resulting in escape of contaminated water to environment.** The Adaptive Management Plan includes monitoring and thresholds that will guide the timely design and implementation of groundwater collection systems. Existing pumping wells could be used to

collect the affected water immediately. A collection system is currently being designed, and extensive aquifer testing has been completed to support this design.

3.2 2013 Cost Risks

The 2013 operational risk assessment identified three "high" cost risks for the FMC. These risks require appropriate mitigation responses to be developed and implemented immediately. The following paragraphs describe the "high" cost risks, alongside proposed responses that will be undertaken in the coming year.

- **The failure of the pit wall below the FCD, causingFaro Creek to flow into the pit for approximately 8 weeks.** This event would incur substantial additional costs to treat water and to repair the FCD. While the costs of repair cannot be addressed without constructing a new diversion (part of the Faro Mine Remediation Project), the treatment costs can be reduced by having pipe and pumps onsite to establish a temporary diversion quickly.
- **Poor water quality in the CVD Pond prevents discharge, requiring a change in water management strategy because storage and discharge through the CVD Pond is no longer functional.** Water quality changes in the CVD Pond in 2013 demonstrated this is a substantial risk, and it required the implementation of temporary filtration at the CVD Pond. Continuation of this approach, as well as other more cost-effective measures to address water quality concerns are under investigation.
- **Contaminated water migrates below the CVP, resulting in the escape of contaminated water to the environment.** Additional costs would arise because of requirements to implement groundwater collection and treatment. The Adaptive Management Plan includes monitoring and thresholds that will guide timely design and implementation of groundwater collection systems. A system is currently being designed, and extensive aquifer testing has been completed to support this design.

The 2013 operational risk assessment identified numerous "moderately high" cost risks. Many of these are associated with conveyance of extreme flood events through the Rose Creek Tailings Area, either in the RCD or through the ID spillway, or both. The Down Valley Interim Hydraulic Upgrades, proposed as part of the IW, focus on addressing these risks. Another series of "moderately high" cost risks are associated with potential changes in seepage collection requirements from waste rock dumps. The Adaptive Management Plan addresses seepage at these locations via monitoring and response thresholds. The effective implementation of this adaptive management approach led to the construction of the S-Wells seepage interception system that has provided protection of aquatic values in the North Fork Rose Creek since 2009. Similar responses will be implemented at other locations, as needed.

3.3 2013 Human Health and Safety Risks

The 2013 operational risk assessment identified two "high" human health and safety risks for the FMC. These risks require appropriate mitigation to be developed and implemented immediately. They are described herein, alongside mitigative actions that will be undertaken in the coming year.

- **Faro Pit wall failure occurs while personnel and equipment are working on the FCD.** This is a new risk identified in 2013, reflecting concern about heavy equipment operation along the FCD near the pit wall and potential implications on physical stability. Stability under these circumstances will be evaluated further, and appropriate responses developed.
- **Worker breaks through the ice and/or falls into water, resulting in injury or death.** Operational procedures and training have been implemented for working on ice or water. However, working on ice and water is inherently hazardous and some risk remains.

The 2013 operational risk assessment identified numerous "moderately high" human health and safety risks. Several of these are related to unauthorized access to onsite facilities by members of the public. Ongoing improvements to site and building security will reduce the likelihood of such events. The fact that the Mill Building is no longer in use for water treatment also eliminates the need for daily access by site staff and equipment,

providing opportunities for more effective access control. Some additional “moderately high” risks are associated with other uses of the Mill Building. Reduced overall use of that facility will reduce these risks. Finally, a new risk identifies potential worker health and safety effects associated with the daily operation of the proposed interim water treatment system in an area that may have high lead concentrations. Further investigation will identify the scope of the risk, and remedial measures may be required to address this risk.

TABLE 5D-4

2013 Characterization of Environmental Risks (Excluding "Low" Risks)

Faro Mine Interim Works

Likelihood	Consequence Severity					Risk Events
	Low	Minor	Moderate	Major	Critical	
Almost Certain						**1.4** Piping Failure of ID causing release of water/tailings to CVD Pond, with possible release of water from CVD Pond to environment. **8.4** Failure of CVD because of pit wall collapse, resulting in Vangorda Creek flowing into Vangorda Pit, filling and overflowing the pit, followed by the eventual discharge of contaminated water only to Vangorda Creek channel. **16.1** Extreme wind leads to erosion of tailings and offsite contamination, which affects health of local environment (humans, vegetation, wildlife). **28.4** Contaminated water migrating below CVD Pond results in escape of contaminated water to environment. **26.2** Seepage through Secondary Dam causes contamination in RCD, which leads to water quality issue. **33.1** Any delay to the interim water treatment system so that it is not operational for 2014 results in filling the Faro Pit beyond 1153 metres above sea level or increased inflows to Zone II. **36.1** Water level in ID Pond is higher than can be managed by current pumping system results in release of contaminated water into the receiving water environment through the CVD Pond. **14.6** Continued seepage through Grum Waste Dump discharging into Moose Pond leads to exfiltration to Vangorda Creek at unacceptable levels. **14.7** Catastrophic failure of Moose Pond leads to contamination of Vangorda Creek because of failure to divert additional flows.
Likely		33.1	16.1			
Possible		26.2, 36.1, 14.7	28.4			
Unlikely			8.4, 14.6	1.4		
Very Unlikely						

Note:
ID Pond = Intermediate Dam Pond

TABLE 5D-5

2013 Characterization of Cost Risks (Excluding "Low" and "Moderate" Risks)

Faro Mine Interim Works

Likelihood	Consequence Severity					Risk Events
	Low	Minor	Moderate	Major	Critical	
Almost Certain			**28.1**			**7.1** Failure of pit wall below FCD leads to Faro Creek flowing into the Faro Pit for approximately 8 weeks. **28.1** CVD Pond poor water quality prevents discharge through the CVD Pond and requires change to water management strategy, resulting in inability to store/release treated water in CVD Pond. **28.4** Contaminated water migrates below CVP results in escape of contaminated water to environment. **1.1** Earthquake induced liquefaction leads to failure of both ID and the CVD and a release of contaminated water and up to 10-20% of volume of tailings. Note: ID meets Maximum Credible Earthquake. **1.2** Probable Maximum Flood event exceeds the capacity of the ID spillway, leading to release of tailings and water to environment. **1.3** A 500- to 1,000-year return period flood event exceeds the capacity of the ID spillway, breach of the ID, release of contaminated water and 10-20% of the total volume of tailings to the CVD Pond. The CVD Pond spillway releases contaminated water to the environment, but the tailings are contained in the CVD Pond. **2.1** Seismic event results in a breach of the CVD and release of treated water and sludge. **4.1** Failure of Little Creek Dam and release of contaminated water in to Vangorda Creek. **6.1** Slope failure of the RCD resulting in outflow to ID Pond and exceedance of ID spillway capacity, overtopping and failure of ID with release of contaminated water and 10-20% of the total volume of tailings to the CVD Pond. The CVD Pond spillway releases contaminated water to the environment, but the tailings are contained in the CVD Pond. **6.2** Ice formation over extended length of time in RCD, overtopping into ID Pond, failure of ID, release of contaminated water and 10-20% of the total volume of tailings to the CVD Pond. The CVD Pond spillway releases contaminated water to the environment, but the tailings are contained in the CVD Pond. **6.3** Debris flow originating in the tributaries to the west of RCD blocks the channel, filling, overtopping, and failure of the ID with a release of contaminated water and 10-20% of the total volume of tailings to the CVD Pond. The CVD Pond spillway releases contaminated water to the environment, but the tailings are contained in the CVD Pond. **6.4** Seismic induced failure of the RCD over a 50- to 100-metre portion of channel, discharge (low volume – low velocity) into the ID Pond. Water with elevated concentrations of zinc (minimal suspended solids) fills the ID Pond, flows out via ID Pond Spillway, into and out of the CVD and into the receiving environment. **8.4** Failure of VCD because of pit wall collapse resulting in Vangorda Creek flowing into Vangorda Pit, filling and overflowing the pit, followed by the eventual discharge of contaminated water only to Vangorda Creek channel. **8.5** Collapse or failure of VCD Drop Structure, total blockage, overflowing road access and into the Vangorda Pit (not including peak flows, which is included in failure of VCD event). Environmental impact because of erosion of road and sediments entering the receiving environment. **30.1** Flood event causes a breach of RCD and leads to a breach of ID and release of tailings and water. **30.3** Catastrophic structural failure of the RCD during a 1:50 to 1:100 return event caused by overtopping/ erosion of fuse plug and/or high seepage stresses in dike, breach of dike, or uncontrolled flow of RCD into the ID Pond for a period of 1 month. ID Pond spillway conveys majority of flow into CVD, short circuits the CVP, and leads to discharge of undiluted IP overflow into the environment. **12.2** Monitoring shows need to collect and treat additional contaminated water from Faro Rock Dumps. **13.4** Monitoring shows need to collect and treat additional contaminated water from Vangorda Waste Dump. **14.2** Monitoring shows need to collect and treat additional contaminated water from Grum Waste Dump. **15.1** Monitoring shows need to collect and treat additional contaminated water from Grum Ore Transfer Pad.
Likely			**8.5, 12.2**			
Possible			**4.1, 6.4, 30.3, 13.4, 14.2, 15.1**	**7.1, 28.4**		
Unlikely				**2.1**	**1.3, 6.1, 6.3, 8.4, 30.1**	
Very Unlikely					**1.1, 1.2, 6.2**	

Note:
VCD = Vangorda Creek Diversion

TABLE 5D-6

2013 Characterization of Human Health and Safety Risks (Excluding "Low" Risks)

Faro Mine Interim Works

Likelihood	Consequence Severity					Risk Events
	Low	Minor	Moderate	Major	Critical	**7.3** Faro Pit wall failure occurs while personnel and equipment are working on the FCD.
						34.1 Worker breaks through the ice and/or falls into water, resulting in injury or death.
						22.1 Structural failures of Mill Building or component, or by impact of existing condition, causes injury or death to site staff or contractors.
Almost Certain						**22.2** Unauthorized access to Crusher and Coarse Ore buildings by public leads to serious injury or fatality.
						22.3 Unauthorized access to utilized buildings by public results in serious injury or fatality.
						22.4 Unauthorized access/entry to Mill Buildings by public leads to serious injury/fatality.
Likely			**33.2**			**19.2** Worker fatality results from condition/operation of the electrical distribution system.
						19.3 Fatality of public caused by unauthorized access and interaction with power distribution system, most likely because of theft of copper.
Possible				**34.1**	**7.3**	**33.2** Possible contaminants (lead dust, zinc, coal) in the proposed location for replacement water treatment plant causes health and safety issues.
						9.1 Unauthorized access to Faro Pit wall leads to injury or fatality (Fall Hazard).
Unlikely				**22.1, 22.2, 22.3, 22.4, 19.2, 19.3, 9.1, 9.3, 10.2, 11.2**		**9.3** Rockfall near Faro Pit walls causes injury or death.
						10.2 Unauthorized access to Vangorda Pit wall leads to injury or fatality (fall hazard).
						11.2 Unauthorized access to Grum Pit wall leads to injury or fatality (fall hazard).
Very Unlikely						

SECTION 4

Application of Risk Assessment Findings to Faro Mine Interim Works

The YG convenes risk assessment workshops annually in the autumn, and maintains a database that tracks the identification, evolution, and mitigation of risks over time. The results of the yearly risk assessments guide annual work planning for the FMC, justifying annual budgets. Risk assessments provide rationale for annual work plan budgets associated with site operations (e.g., monitoring requirements and changes in water management approaches), site investigations to address evolving areas of concern (e.g., drilling programs in areas of evolving groundwater conditions), mitigation measures to address risks (e.g .replacement or re-alignment of piping), or equipment replacement (e.g. water treatment equipment or heavy mobile equipment). In this context, risk assessment will continue to be one of the planning tools used throughout the IW to annually identify site actions and activities, and prioritize spending.

SECTION 5

Works Cited

Aboriginal Affairs and Northern Development Canada (AANDC). *Contaminated Sites Management Policy.* 2002. August.

Government of Canada. *Federal Contaminated Sites Action Plan, Decision-Making Framework.* 2013. May.

Appendix 5E
Spill Contingency Plan (TEES)

Faro Mine

Spill Contingency Plan

Version #: 1

February 26, 2014

Government of Yukon

Energy, Mines and Resources

Assessment and Abandoned Mines

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IMPORTANT NOTE

In the event of a spill go to Section 3

1 Introduction

The Spill Contingency Plan provides a framework of responsibilities and response measures to be taken by staff and contractors when responding to spills. In the event of an accidental release of a deleterious substance, the implementation of the Spill Contingency Plan will ensure that the necessary steps are taken to minimize the effects on human health and safety and the environment.

Under the Yukon *Environment Act*, a spill is defined as follows:

"spill" means a release of a substance (a) into the natural environment; (b) from or out of a structure, vehicle, or other container; and (c) that is abnormal in quantity or quality in light of all the circumstances of the release; or (d) in excess of an amount specified in the regulations.
"substance" means a hazardous substance, pesticide, contaminant, or special waste.

1.1 Regulatory Requirements

The regulatory requirements in the Yukon, as it relates to spills, are stipulated under *Part 11 – Spills* and under the *Spills Regulations* of the Yukon *Environment Act* (see Appendix A and Appendix B).

Spills Regulations

The Yukon *Spill Regulations* were developed pursuant to Section 147 of the Yukon *Environment Act* and came into force January 1, 1997. The regulations establish thresholds of various substances which, if quantities spilled are in excess of those amounts, constitute a spill under the Act.

The territorial regulations further require the reporting to the Yukon Spills Report Centre when such an event occurs. A report to the Yukon Spills Report Centre also constitutes a report to Environment Canada so only a single call is required. See Section 4.1 for further details.

With respect to the Faro Mine Complex (FMC), the most common substances which could result in a potentially reportable spill are presented in Table 1.1 (below).

Table 1.1: Reportable Substances Commonly Found at Site

Common Name	Classification	Reportable Threshold
Propane	Flammable Gas (Division 1 of Class 2)	Any amount of gas from a container larger than 100 L, or where the spill results from equipment failure, error or deliberate action or inaction
Gasoline, Diesel Fuel, Heating Fuel, Bulk Oil, Waste Oil	Flammable Liquids (Class 3)	200 L
Lime Solids or Lime Slurry	Class 8	5 kg or 5 L
Sodium Hypochlorite	Class 8	5 kg or 5 L
Contaminated Water	Class 8	Any amount of water containing concentrations of zinc, lead, total suspended solids or other materials in excess of allowable releasable concentrations. Any release of mine waters from a non-approved release point.

Contaminated Site Regulations

In the event of a spill, all remediation activities must be conducted in accordance with the *Contaminated Site Regulations* of the Yukon *Environment Act*. The *Contaminated Site Regulations* establishes cleanup standards, processes for identifying and investigating contaminated sites, and permits for managing contaminated material within the Yukon. See Appendix C for a guide to *Contaminated Site Regulations*.

Storage Tank Regulations

The Yukon *Storage Tank Regulations* were developed pursuant to Section 146 of the Yukon *Environment Act*. Section 5 of the regulations specifies above ground storage tank capacities that require a permit (i.e. petroleum product tank [4,000 L] and hazardous material tank [2,000 L]) and Section 8 specifies the requirement of a permit to remove, abandon or decommission tanks of these sizes. Section 11 specifies the inventory records that need to be maintained and the reporting requirements in the event of any discrepancies as stipulated in that section. See Appendix D for this regulatory document.

Transportation of Dangerous Goods Regulations

The *Transportation of Dangerous Goods Regulations* pursuant to *Transportation of Dangerous Goods Act* identifies the classification of various substances and outlines the federal restrictions with respect to the packaging, handling, placarding and transport of those substances.

2 Spill Preparedness and Prevention

2.1 Training

Spill prevention and response is included in the site worker orientation and reiterated at safety meetings during the treatment season. Employees participating in or authorizing program activities involving spill prevention, containment or counter measures shall receive training such that they acquire the competence, knowledge (including regulatory requirements) and skill necessary for the safe and comprehensive performance of the duties assigned. Mock spills are utilized from time to time to provide some practical experience.

Refresher training is conducted periodically according to legal requirements or at appropriate intervals, or at least once every year. A job-specific overview of the program shall be included in the standard training for new and transferred employees.

The site operator will regularly reminds its employees of the importance of taking preventative actions to avoid spills, immediate reporting in the event of a spill and the need for quick response.

2.2 Management and Procedures

2.2.1 Petroleum Products

Petroleum products are effectively managed and losses due to spills or leaks are avoided through the following inspection activities:

1. Fuel tanks are manually dipped before and after fuel delivery. After adding product to the tank, a site operations representative will inspect the site to verify valves are properly shut off and any small leaks or spills during filling have been appropriately cleaned up.

2. Storage area inspections are conducted daily by site operations personnel and during the tank measurements, to detect any abnormal situations and determine the need to pump water from the secondary containment of the storage tanks.

3. During winter periods, inspection of the fuel storage areas is included on the weekend on-call checklist.

4. On a quarterly basis, secondary containment of double walled tanks are inspected to determine if any leakage into the secondary containment area has occurred. This is included on the routine quarterly checklist.

Fuelling of heavy equipment by the site fuel truck is conducted well away from freshwater systems (minimum 30 meters) such that any potential spills can be isolated and cleaned up well before it enters freshwater. This principle is re-enforced with operating personnel through mechanisms such as Tool Box meetings. Special measures are taken for stationary equipment operating close to water to contain spills and facilitate immediate and effective clean up in the event of a loss of fuel (e.g. location must provide some protection to ensure a potential spill will not report directly to a waterbody). An inventory of spill response materials is maintained to effectively deal with fuel spills up to 1,000 litres.

2.2.2 Contaminated Water

The potential for contaminated water escaping to freshwater systems constitutes a spill risk at the FMC as the site is comprised of several water management structures. Over the years a number of actions have been undertaken at the site to prevent and reduce the likelihood of a spill. Some examples of these include:

- The pipeline from Vangorda Pit to the Vangorda Water Treatment Plant was placed within a secondary flow control ditch which would route a potential loss of water back to the pit.
- A pressure sensitive safety shutoff, which would terminate the pumping in the event of a line break, was installed S wells pumping system.
- A containment ditch, draining back to the dam, was constructed from the point where the Little Creek Dam Dewatering pipeline rises above the crest of the Dam to the point where it joins the Vangorda Haul Road.

As per Canadian Dam Association Dam Safety Guidelines (2007), an Emergency Response and Preparedness Plan (ERPP) and an Operations, Maintenance and Surveillance Manual (OMSM) are required for retaining structures. These documents provide detailed descriptions of measures taken at site to prevent and respond to emergencies at the site. A brief description of the ERPP and OMSM is provided below, although for further information these documents should be referred to.

Emergency Response and Preparedness Plan

The purpose of the ERPP is to provide a plan that includes mechanisms and processes for addressing potential failures of structures and equipment at the Faro Mine Complex. This ERPP describes the internal processes and procedures of a response to a failure or potential failure at the site. Having an ERPP in place enables site personnel to be prepared in the event of an emergency. It also provides one component of a comprehensive facility management system for the tailings facility and associated structures. The goals of the ERPP are to firstly prevent the occurrences of emergencies and secondly to reduce the impact of emergencies. In both cases the goal is to protect human health and safety, and the environment.

Operations, Maintenance and Surveillance Manual

This OMSM provides a documented framework for actions in order to ensure the safe operation, maintenance, and surveillance of the facility. The OMSM is a live document in that it will regularly requires updating; information is updated at a minimum of once per year, as well as at every change in critical personnel or contractors, and changes in procedures or conditions on-site.

3 Spill Response

3.1 Spill Response Procedure

Upon discovery of a spill, all personnel will take immediate action to notify others on site and, when appropriate, control and remediate the spill. Below are the general steps that will be followed in the event of a spill. Refer to Figure 1 for further detail on the process of responding to a spill as well as the roles and responsibilities of each party.

Identification

1. Identify hazards, secure the area (i.e. extinguish fire or spark) and restrict access if necessary.

    a. Refer to Appendix E spill response measures should the spilled substance be Sodium Hypochlorite.

2. Contact Site Security; inform them of situation and request medical or fire assistance if necessary. This initiates the communication procedures as identified in Figure 1.

3. Identify the spilled material and if it is safe to approach.

Response

4. Stop or minimize product flow, if safe to do so.

5. Assess the severity of the spill and personal protective equipment (PPE) needs; if necessary refer to the MSDS for information appropriate handling requirements.

Containment

6. Initiate product containment. Contain spill by:

    a. Damming or diverting the spilled material;

    b. Preventing wind dispersion or erosion by water; and/or

    c. Apply absorbent materials (in spill kit).

7. Site Manager verifies provisions for personal safety, stoppage of product flow, and containment.

Remediation

8. Notify site environmental coordinator to collect samples required. A spill sampling kit is available at the Faro Guardhouse (with Security); Appendix E identifies the contents of the kit and the sampling procedures. To assess the impact of the spill:

    a. If spill in water, water samples should be taken during the spill and throughout the remediation process (refer to Appendix F for sampling instructions); and

b. If spill on land, take soil samples following remediation of the spill site (refer to Appendix
F for sampling instructions).

9. Develop a remediation plan to restore the site, to the extent possible, to the same condition that it was in before the spill, in accordance with the *Contaminated Sites Regulation* (see Appendix C and refer to complete *Contaminated Sites Regulation*). Steps that may be included in the remediation plan include:

    a. Site assessment to identify the areas, depths and concentrations of contaminants on the site.

    b. Selecting a restoration strategy (e.g. ex-situ or in-situ remediation).

    c. Applying for and receiving necessary permits (e.g. Relocation Permit, Land Treatment Facility Permit).

    d. Confirmatory Sampling to show that all contaminants have been removed or remediated.

10. Implement remediation plan as approved by the Project Manager and/or Site Manager.

Report

11. The Mine Manager reports the spill as soon as possible to the Yukon Spill Report Line, at **867-667-7244** (i.e. should the volume meet or exceed reporting thresholds found in the Yukon *Spill Regulations* (Appendix B)). Be prepared to provide the following information:

    a. The location and time of the spill;

    b. The circumstances leading up to the spill;

    c. The type and quantity of material spilled;

    d. The details of any action taken at the spill site; and

    e. A description of the environment at the location of the spill (e.g. terrain, watercourses, etc.)

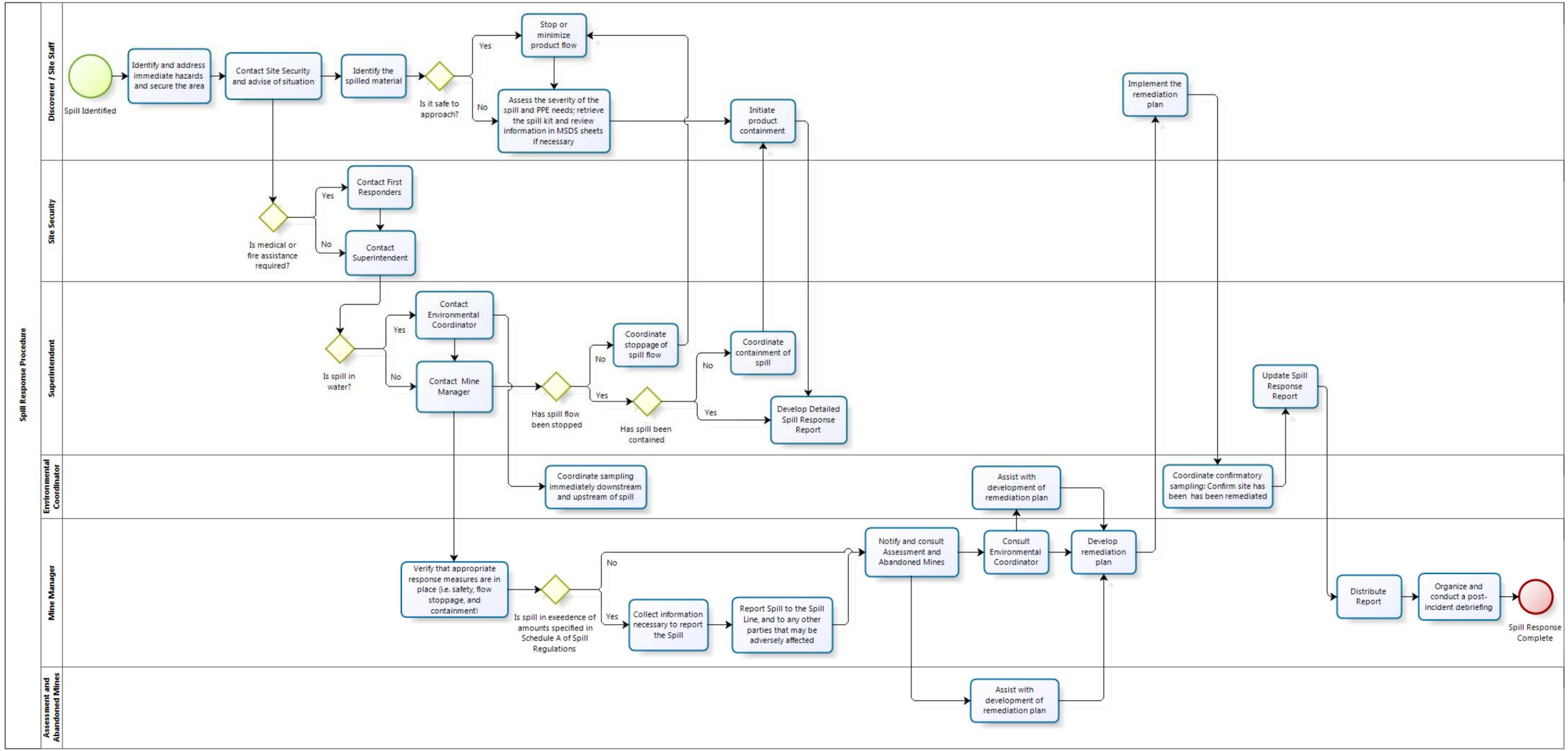
12. Notify as soon as possible other parties or members of the public who may be adversely affected by the spill.

13. Develop a detailed Spill Response Report including but not limited to the information indicated above and other relevant details and explanations. See Spill Report Form in Appendix G for further detail.

Debrief

14. Organize and conduct a post-incident debriefing and implement any required procedural changes.

Figure 1: Spill Response Procedure Flow Diagram



3.2 Spill Kits and Material Safety Data Sheets

Material Safety Data Sheets (MSDS) contain detailed information about a specific product, including the risks of exposure, methods of storage and disposal, protective measures for exposed workers and emergency first aid procedures. Current MSDS must be maintained and accessible to all employees. The MSDS must be current (within 3 years) on all products in the workplace. The MSDS sheets for hazardous materials present at the FMC are provided in Appendix H. This Spill Contingency Plan (along with the appendices) is included in all spill kits and is available in the FMC guardhouse.

Spill response materials and supplies to effectively deal with spills are available at the following locations on site:

- Diesel Fuel Station
- Gas Fuel Station
- Guardhouse Lab

The spill kits at those locations contain response materials specific to the hazardous materials located in those areas. The Warehouse contains a larger quantity and variety of spill response materials. Refer to Appendix I for an inventory of spill response materials and supplies at the FMC.

Appendices

Appendix A – Environment Act - Part 11: Spills

PART 11

SPILLS

Definition

132 In this Part,

"spill" means a release of a substance

(a) into the natural environment;

(b) from or out of a structure, vehicle, or other container; and

(c) that is abnormal in quantity or quality in light of all the circumstances of the release; or

(d) in excess of an amount specified in the regulations. *« déversement »*

"substance" means a hazardous substance, pesticide, contaminant, or special waste. *« substance » S.Y. 1991, c.5, s.132.*

Report of spill

133 A person in control of a substance at the time of a spill or who causes a spill shall report the spill, as soon as possible under the circumstances, to an environmental protection officer and shall make a reasonable effort to notify the owner or person in charge of the spilled substance and any members of the public who may be adversely affected by the spill. *S.Y. 1991, c.5, s.133.*

Contents of report

134 The person who is required to report pursuant to section 133 shall report in person or by telephone, and shall, if they have knowledge of the information or can readily obtain it, provide the following information

(a) the location and time of the spill;

(b) a description of the circumstances leading up to the spill;

(c) the type and quantity of the material or

PARTIE 11

DÉVERSEMENTS

Définition

132 Les définitions suivantes s'appliquent à la présente partie.

« déversement » Rejet dans l'environnement naturel d'une substance dont l'évacuation hors d'un ouvrage, véhicule ou autre contenant présente des caractéristiques quantitatives ou qualitatives anormales, compte tenu des circonstances s'y rapportant, ou se fait en quantité excédant les maximums réglementaires. *"spill"*

« substance » Substance dangereuse, pesticide, polluant ou déchets spéciaux. "*substance*" *L.Y. 1991, ch. 5, art. 132*

Signalement des déversements

133 Quiconque a le contrôle d'une substance au moment de son déversement ou en cause le déversement est tenu de le signaler dans les meilleurs délais possible, à un agent de protection de l'environnement et de s'efforcer raisonnablement de le notifier au propriétaire ou au responsable de la substance déversée et à toute personne à qui le déversement pourrait causer un préjudice. *L.Y. 1991, ch. 5, art. 133*

Teneur du rapport

134 La personne visée à l'article 133 signale l'incident, en personne ou par téléphone, et mentionne les renseignements suivants, lorsqu'elle les détient ou peut les obtenir sans difficulté :

a) le lieu et le moment du déversement;

b) les circonstances s'y rapportant;

c) le type et la quantité de la matière ou de la

substance which has spilled;

(d) the details of any action taken at the site of the spill;

(e) a description of the location of the spill and the immediately surrounding area; and

(f) any additional information in respect of the spill that the Minister, environmental protection officer, or person designated by the regulations requires. *S.Y. 1991, c.5, s.134.*

Duty to mitigate

135 If a spill occurs, the person who owns or has possession, charge, or control of the spilled substance at the time of the spill shall, when they have knowledge of the spill,

(a) take all reasonable measures

(i) to confine, repair, and remedy the effects of the spill; and

(ii) to remove the substance spilled in such a manner as to reduce or mitigate any danger to human life, health, and the natural environment; and

(b) restore or rehabilitate the natural environment to a condition reasonably equivalent to the condition that existed immediately before the spill occurred. *S.Y. 1991, c.5, s.135.*

Environmental protection orders relating to spills

136 If there has been a spill, the Minister or an environmental protection officer may issue an environmental protection order to the person who owns or who had possession, charge, or control of the spilled substance at the time it was spilled ordering that person to take any measures that the Minister or the environmental protection officer considers necessary to protect, restore, or rehabilitate the natural environment, including any or all of the

substance déversée;

d) le détail des mesures correctives prises sur place;

e) une description du lieu où s'est produit le déversement et des environs immédiats;

f) toute autre donnée exigée par le ministre, l'agent de protection de l'environnement ou la personne désignée par règlement. *L.Y. 1991, ch. 5, art. 134*

Obligation d'atténuer les effets

135 Quiconque est propriétaire, a possession, ou a la responsabilité ou le contrôle de la substance déversée en question au moment de son déversement est tenu, lorsqu'il a connaissance du déversement :

a) de prendre toutes les mesures appropriées pour :

(i) limiter, réparer et corriger les conséquences du déversement,

(ii) récupérer la substance déversée de manière à réduire ou à atténuer le danger pour la vie ou la santé humaine et l'environnement naturel;

b) de restaurer l'environnement naturel ou de le remettre dans un état raisonnablement comparable à celui dans lequel il était immédiatement avant le déversement. *L.Y. 1991, ch. 5, art. 135*

Ordonnances de protection de l'environnement concernant les déversements

136 En cas de déversement, le ministre ou un agent de protection de l'environnement peut prendre une ordonnance de protection de l'environnement enjoignant à la personne qui est propriétaire, a possession ou a la responsabilité ou le contrôle de la substance déversée au moment de son déversement de prendre toutes les mesures qu'il juge nécessaires pour protéger et restaurer l'environnement

following measures

(a) to investigate the spill;

(b) to minimize or remedy the effects of the spill;

(c) to restore the area affected by the spill to a condition reasonably equivalent to the condition that existed immediately before the spill occurred;

(d) to measure the rate of release or the ambient concentration of the substance spilled;

(e) to install, repair, or alter any equipment or thing designed to control or eliminate the release of the substance spilled;

(f) to monitor, measure, contain, remove, store, destroy, or otherwise dispose of the substance spilled, or to lessen or prevent further spills of or control the rate of release of the substance spilled; and

(g) to report on any matter ordered to be done in accordance with directions set out in the order. *S.Y. 1991, c.5, s.136.*

Failure to mitigate

137 If any person fails to take the measures required under paragraph 135(a), and an environmental protection officer is of the opinion that danger to human life or health or to the natural environment is occurring or may occur, an environmental protection officer may take the measures, described under paragraph 135(a), cause them to be taken or direct any person referred to in section 135 to take them. *S.Y. 1991, c.5, s.137.*

Inconsistency with another act

138 Any direction of an environmental protection officer under section 137 that is inconsistent with any other enactment is void to the extent of the inconsistency. *S.Y. 1991, c.5, s.138.*

naturel ou le remettre en état, notamment :

a) faire enquête sur le déversement;

b) limiter le plus possible ou corriger les conséquences du déversement;

c) remettre la zone touchée dans un état raisonnablement comparable à celui dans lequel elle était immédiatement avant le déversement;

d) mesurer le taux de rejet ou la concentration de la substance déversée dans le milieu ambiant;

e) installer, réparer ou modifier tout matériel ou dispositif destiné à contrôler ou à empêcher le rejet de la substance déversée;

f) surveiller, mesurer, contenir, enlever, entreposer, détruire ou, de quelque autre façon, éliminer la substance déversée, diminuer ou empêcher tout autre déversement ou contrôler le taux de rejet de la substance en question;

g) signaler tout autre aspect visé par l'ordonnance. *L.Y. 1991, ch. 5, art. 136*

Manquement à atténuer les conséquences

137 Si le destinataire de l'ordonnance prévue à l'article 135 ne prend pas les mesures exigées à l'alinéa 135a), l'agent de protection de l'environnement peut les prendre lui-même, les faire prendre ou ordonner au destinataire de les prendre, s'il estime que l'omission compromet ou risque de compromettre la vie ou la santé humaine. *L.Y. 1991, ch. 5, art. 137*

Incompatibilité avec une autre loi

138 Les dispositions d'un autre texte l'emportent sur les directives incompatibles données par l'agent de protection de l'environnement en vertu de l'article 137. *L.Y. 1991, ch. 5, art. 138*

Right of access

139(1) When it is necessary to prevent serious imminent harm to a person or the natural environment, an environmental protection officer authorized or other person directed to take any measures under section 137 may subject to section 152 enter and have access to any place or property and may do any reasonable things necessary in the circumstances.

(2) Subject to subsection (3) a person who provides assistance or advice in taking the measures required by sections 135, 136 or 137, is not personally liable in respect of anything done or omitted in good faith in the course of providing the assistance or advice.

(3) Subsection (2) does not exempt from liability a person described in subsection 133. *S.Y. 1991, c.5, s.139.*

Droit d'accès

139(1) L'agent de protection de l'environnement autorisé ou la personne visée à l'article 137 peuvent, sous réserve de l'article 152, pénétrer dans tout lieu ou bien et prendre les mesures nécessaires pour empêcher qu'un grave préjudice imminent ne soit causé à une personne ou à l'environnement naturel.

(2) Sous réserve du paragraphe (3), n'encourt aucune responsabilité personnelle pour les actes ou omissions qu'elle commet de bonne foi à cette occasion, la personne qui fournit aide et conseils pour l'intervention visée aux articles 135, 136 ou 137.

(3) Le paragraphe (2) n'exonère pas de sa responsabilité la personne visée à l'article 133. *L.Y. 1991, ch. 5, art. 139*

PART 12

REGULATIONS

Regulations concerning Parts 1, 2, 4, 5 and 15

140 The Commissioner in Executive Council may make regulations relating to Parts 1, 2, 4, 5 and 15 respecting any matter which the Commissioner in Executive Council considers necessary to carry the purposes and provisions of Parts 1, 2, 4, 5, and 15 into effect. *S.Y. 1991, c.5, s.140.*

Regulations concerning Part 3

141 The Commissioner in Executive Council may make regulations relating to Part 3 including regulations

(a) prescribing the establishment of work place environmental committees and their composition, function, powers, procedures, and related matters;

(b) respecting regulatory, economic, or other incentives to encourage conservation of the natural environment and to promote

PARTIE 12

RÈGLEMENTS

Règlements d'application des parties 1, 2, 4, 5 et 15

140 Le commissaire en conseil exécutif peut, par règlement, prendre les mesures qu'il juge nécessaires pour l'application des parties 1, 2, 4, 5 et 15. *L.Y. 1991, ch. 5, art. 140*

Règlements d'application de la partie 3

141 Le commissaire en conseil exécutif peut, par règlement pris en application de la partie 3 :

a) régir l'établissement de comités de l'environnement en milieu de travail et fixer leur composition, leur mission, leur règlement interne et autres questions connexes;

b) instituer des mesures d'encouragement réglementaires, économiques ou autres pour la conservation de l'environnement naturel

Appendix B – Environment Act - Spills Regulations

ENVIRONMENT ACT

Pursuant to section 147 of the *Environment Act*, the Commissioner in Executive Council orders as follows:

1. The annexed Spills Regulations are established.

2. The annexed Regulations shall come into force with effect from the 1st day of January, 1997.

Dated at Whitehorse, in the Yukon Territory, this 16th day of December, 1996.

_____
Commissioner of the Yukon

LOI SUR L'ENVIRONNEMENT

Le Commissaire en conseil exécutif, conformément à l'article 147 de la *Loi sur l'environnement*, décrète ce qui suit :

1. Le Règlement sur les déversements ci-joint est établi.

2. Ce même règlement entre en vigueur le 1er janvier 1997.

Fait à Whitehorse, dans le territoire du Yukon, ce 16 décembre 1996.

_____
Commissaire du Yukon

SPILLS REGULATIONS

Definitions

1. In these regulations,

"Act" means the *Environment Act*; *«loi»*

"Federal Regulations" means the Transportation of Dangerous Goods Regulations (Canada) SOR/85/77 of January 18, 1985, as amended from time to time; *«règlement fédéral»*

"government officials" means federal, territorial or municipal government representatives responsible for responding to spill reports to the Yukon Spills Report Centre. *«fonctionnaires du gouvernement»*

Application

2.(1) These regulations do not apply to a release of gas without flaring where authorized by a licence issued under the *Yukon Oil and Gas Act.*

(2) These Regulations do not apply to ozone depleting substances listed in Schedule A of the Ozone Depleting Substances Regulations.

Spill thresholds

3. A spill in excess of the amounts specified in Schedule A is a spill under the Act.

Spill reporting

4. For the purposes of section 133 of the Act, a report to the Yukon Spills Report Centre will be considered a report to an environmental protection officer.

RÈGLEMENT SUR LES DÉVERSEMENTS

Définitions

1. Les définitions suivantes s'appliquent au présent règlement :

«fonctionnaires du gouvernement» Les représentants des gouvernements fédéral, provinciaux ou municipaux, responsables d'intervenir suite à un avis de déversement auprès du «Yukon Spills Report Centre»; *"government officials"*

«loi» S'entend de la *Loi sur l'environnement*; *"Act"*

«règlement fédéral» S'entend du Règlement sur le transport des marchandises dangereuses (Canada), DORS/85-77, du 18 janvier 1985, ainsi que ses modifications. *"Federal Regulations"*

Application

2.(1) Le présent règlement ne s'applique pas à un rejet de gaz sans torchage lorsqu'il est autorisé en vertu d'un permis émis conformément à la *Loi du Yukon sur le pétrole et le gaz*.

(2) Le présent règlement ne s'applique pas aux substances appauvrissant la couche d'ozone apparaissant à l'annexe A du Règlement sur les substances appauvrissant la couche d'ozone.

Seuils limites

3. Un déversement qui excède les quantitées indiquées à l'annexe A est assimilé à un déversement en vertu de la Loi.

Rapport de déversement

4. Aux fins de l'article 133 de la Loi, un rapport de déversement au «Yukon Spills Report Centre» est assimilé à un rapport fait à un agent de protection de l'environnement.

SCHEDULE A

ITEM	COLUMN 1 - SUBSTANCE SPILLED	COLUMN 2 - SPECIFIED AMOUNT
1.	Explosives of Class 1 as defined in section 3.9 of the Federal Regulations	any amount
2.	Flammable gases, of Division 1 of Class 2 as defined in section 3.11(a) of the Federal Regulations	Any amount of gas from a container larger than 100L, or where the spill results from equipment failure, error or deliberate action or inaction
3.	Non-flammable gases of Division 2 of Class 2 as defined in section 3.11(d) of the Federal Regulations	Any amount of gas from a container larger than 100L, or where the spill results from equipment failure, error or deliberate action or inaction
4.	Poisonous gases of Division 3 of Class 2 as defined in section 3.11(b) of the Federal Regulations	any amount
5.	Corrosive gases of Division 4 of Class 2 as defined in section 3.11(c) of the Federal Regulations	any amount
6.	Flammable liquids of Class 3 as defined in section 3.12 of the Federal Regulations	200 L
7.	Flammable solids of Class 4 as defined in section 3.15 of the Federal Regulations	25 kg
8.	Products or substances that are oxidizing substances of Division 1 of Class 5 as defined in sections 3.17(a) and 3.18(a) of the Federal Regulations	50 kg or 50 L
9.	Products or substances that are organic compounds that contain the bivalent "-0-0-" structure of Division 2 of Class 5 as defined in sections 3.17(b) and 3.18(b) of the Federal Regulations	1 kg or 1 L
10.	Products or substances that are poisons of Division 1 of Class 6 as defined in sections 3.19(a) to (e) and 3.20(a) of the Federal Regulations	5 kg or 5 L
11.	Organisms that are infectious or that are reasonably believed to be infectious and the toxins of these organisms as defined in sections 3.19(f) and 3.20(b) of the Federal Regulations	any amount
12.	Radioactive materials of Class 7 as defined by section 3.24 of the Federal Regulations	any discharge or a radiation level exceeding 10 mSv/h at the package surface and 200 mSv/h at 1 m from the package surface
13.	Products or substances of Class 8 as defined by section 3.24 of the Federal Regulations	5 kg or 5 L

ITEM	COLUMN 1 - SUBSTANCE SPILLED	COLUMN 2 - SPECIFIED AMOUNT
14.	Miscellaneous products or substances of Division 1 of Class 9 as defined by sections 3.27(1) and 2(a) of the Federal Regulations	50 kg or 50 L
15.	Miscellaneous products or substances of Division 2 of Class 9 as defined in section 3.27(1) and 2(b) of the Federal Regulations	1 kg or 1 L
16.	Miscellaneous products or substances of Division 3 of Class 9 as defined in section 3.27(1) and 2(c) of the Federal Regulations	5 kg or 5 L
17.	Special waste as defined in section 1 of the Special Waste Regulations	amounts specified in s. 3(1)(b) of Special Waste Regulations
18.	A pesticide as defined in section 2 of the *Environment Act*, but not including those pesticides and fertilizers listed in Schedule 4 of the Pesticide Regulations	5 kg or 5L
19.	Pesticides and fertilizers listed in Schedule 4 of the Pesticide Regulations	any amount

ANNEXE A

ITEM	1ière COLONNE - SUBSTANCE DÉVERSÉE	2ième COLONNE - QUANTITÉ DÉTERMINÉE
1.	Explosifs de classe 1, tels que décrits à l'article 3.9 du règlement fédéral	Toute quantité
2.	Gaz inflammables de la division 1, classe 2, tels que décrits à l'alinéa 3.11 a) du règlement fédéral	Toute quantité de gaz à l'intérieur d'un récipient pouvant contenir plus de 100 litres, ou lorsque le déversement est le résultat d'une défectuosité de l'équipement, d'une erreur ou d'un acte ou d'une omission délibéré
3.	Gaz ininflammables de la division 2, classe 2, tels que décrits au règlement fédéral	Toute quantité de gaz à l'intérieur d'un récipient pouvant contenir plus de 100 litres, ou lorsque le déversement est le résultat d'une défectuosité de l'équipement, d'une erreur ou d'un acte ou d'une omission délibéré
4.	Gaz toxiques de la division 3, classe 2, tels que décrits à l'alinéa 3.11 b) du règlement fédéral.	Toute quantité
5.	Gaz corrosifs de la division 4, classe 2, tels que décrits au règlement fédéral	Toute quantité
6.	Liquides inflammables de la classe 3, tels que décrits à l'article 3.12 du règlement fédéral.	200 L
7.	Solides inflammables de la classe 4, tels que décrits à l'article 3.15 du règlement fédéral	25 kg
8.	Produits ou substances qui sont des matières comburantes de la division 1, classe 5, tels que décrits aux alinéas 3.17 a) et 3.18 a) du règlement fédéral	50 kg ou 50 L
9.	Des produits ou des substances qui sont des composés organiques qui contiennent la structure bivalente «-0-0-», de la division 2, classe 5, tels que décrits aux alinéas 3.17 b) et 3.18 b) du règlement fédéral	1 kg ou 1 L
10.	Produits ou substances toxiques de la division 1, classe 6, tels que décrits aux alinéas 3.19 a) à e) et 3.20 a) du règlement fédéral	5 kg ou 5 L
11.	Organismes infectieux ou dont il est raisonnable de croire qu'ils sont infectieux ainsi que leurs toxines, tels que décrits aux alinéas 3.19 f) et 3.20 b) du règlement fédéral	Toute quantité

ITEM	1ière COLONNE - SUBSTANCE DÉVERSÉE	2ième COLONNE - QUANTITÉ DÉTERMINÉE
12.	Matières radioactives, de la classe 7, telles que décrites à l'article 3.24 du règlement fédéral	Toute quantité d'un rejet ou de l'intensité de rayonnement radioactif supérieur à 10 millisievert par heure à la surface du colis et de 200 miilisievert par heure à 1 m de la surface du colis
13.	Produits ou substances de la classe 8, tels que décrits à l'article 3.24 du règlement fédéral	5 kg ou 5 L
14.	Matières ou produits divers de la division 1, classe 9, tels que décrits au paragraphe 3.27(1) et à l'alinéa 2 a) du règlement fédéral	50 kg ou 50 L
15.	Matières ou produits divers de la division 2, classe 9, tels que décrits au paragraphe 3.27(1) et à l'alinéa 2 b) du règlement fédéral	5 kg ou 5 L
16.	Matières ou produits divers de la division 3, classe 9, tels que décrits au paragraphe 3.27(1) et à l'alinéa 2 c) du règlement fédéral	5 kg ou 5 L
17.	Déchets spéciaux, tels que décrits à l'article 1 du Règlement sur les déchets spéciaux.	Quantité déterminée à l'alinéa 3(1) b) du Règlement sur les déchets spéciaux
18.	Un pesticide tel que décrit à l'article 2 de la *Loi sur l'environnement*, à l'exception des pesticides et des engrais chimiques énumérés à l'annexe 4 du Règlement sur les pesticides.	5 kg ou 5L
19.	Les pesticides et les engrais chimiques énumérés à l'annexe 4 du Règlement sur les pesticides.	Toute quantité

Appendix C – Guide to the Contaminated Sites Regulation

Environmental Programs

Contaminated Sites Regulation

Guide to the Contaminated Sites Regulation

The Contaminated Site Regulation establishes cleanup standards, processes for identifying and investigating contaminated sites, and permits for managing contaminated material within Yukon. This fact sheet gives a brief overview of some aspects of the regulation. To view the regulation and access other resources, visit our website at http://environmentyukon.gov.yk.ca/contaminatedsites.

Site Assessment Processes

A two step process is normally used to determine whether contamination exists at a site:

1. During a **Site Investigation** (or "Phase I Assessment"), information about the site – such as past and current activities, spills and material handling practices – is compiled. A list is then developed of possible contaminants that may be found on the site and areas where they might be located.

2. If potential areas of contamination are identified, a **Site Assessment** (or "Phase II Assessment") may be carried out. This involves sampling the soil or water in those areas and analyzing the samples for the possible contaminants identified in the Site Investigation. The goal of a Site Assessment is to identify the areas, depths and concentrations of contaminants on the site.

The Contaminated Sites Regulation contains soil and water standards that set out allowable levels of contaminants based on the risks they pose to human and environmental health. If concentrations of contaminants at a site exceed any of these standards, the site is considered a contaminated site.

If you have prepared or received a Site Investigation or Site Assessment report, you can submit it to Environment Yukon for review. We will evaluate the report and tell you if the work was conducted properly, and whether we agree with the report's recommendations.

Cleaning Up Contaminated Sites

Once a site is determined to be contaminated, the contaminants should be removed or contained to reduce the risk to human health and the environment. This process is called remediation or restoration.

A **Plan of Restoration** (or "Remedial Action Plan") is often developed to establish how contamination at a site will be cleaned up. The process of preparing this plan provides an opportunity to determine what cleanup standards are most appropriate and which method should be used to remediate the site.

May 2010

Yukon Environment

Selecting Restoration Standards

Most sites are simply remediated until they meet the **numerical standards** listed in the Contaminated Sites Regulation. For typical sites, this approach is simple, fast, and relatively inexpensive.
For some sites, however, it may not be practical to meet the standards established for typical sites. In such cases, there are a few other options.

1. **Site-specific numerical standards** can be developed by adjusting the generic standards to fit site-specific conditions.

2. In some cases, such as where soil has naturally high concentrations of heavy metals, the site can be cleaned up to meet the natural **background concentrations** of contaminants.

3. When the existing models can't sufficiently address the complexity of the site, **risk assessment** can be used to determine what actual hazards are created by the contamination, and what actions can be taken to reduce those hazards to acceptable levels.

Selecting a Restoration Strategy

Once the appropriate standards have been chosen, a strategy must be selected to clean up the site so that it meets those standards. Remedial strategies generally fall into one of three categories: ex-situ remediation, in-situ remediation, and risk management.

1. **Ex-situ remediation** refers to the removal of contaminants from the site so that they can be treated or disposed of at a facility designed for that purpose. The most common type of ex-situ treatment is removing contaminated soil to a land treatment facility, where it is contained and treated by encouraging bacteria in the soil to break down the contaminants.

2. **In-situ remediation** means treating contaminated soil or water without removing it from the environment. This option is often selected when removing all of the contaminated material would be unreasonably expensive or impractical. It often takes longer than ex-situ treatment, but can be more efficient for certain types of sites.

3. **Risk management** is a method of reducing the risk to human and environmental receptors without removing the contaminants. This may be done by constructing a barrier to stop the spread of contaminants, installing a ventilation system to remove harmful vapours, placing restrictions on land use to prevent exposure to the most sensitive receptors, or a variety of other approaches.

Confirmatory Sampling and Reporting

When remediation is complete, confirmatory sampling must be conducted to show that all contaminants have been removed or remediated. Depending on the nature of the site and the contamination, follow-up monitoring may also be required.

Once your site has been remediated, be sure to submit a final report to Environment Yukon so that the public registry of contaminated sites can be updated to show that your site is no longer contaminated.

Public Registry of Contaminated Sites

Environment Yukon maintains information on reported contaminated sites and spills in the Yukon. Contact the Environmental Programs Branch for information on a specific site.

Reporting Contaminated Sites

The Contaminated Sites Regulation does not require landowners to advise Environment Yukon if they find historical contamination, but many people choose to do so. Once you have reported the contamination, Environment Yukon can provide advice on how to deal with it appropriately, including site assessment procedures and disposal options. Also, many real estate transactions, financing institutions, and insurance companies now require confirmation that properties have been cleaned up to the appropriate standards.

The Environmental Programs Branch can assist landowners, vendors and purchasers in reviewing reports of contamination or cleanup and determining how the CSR applies to the site.

If you would like to report a suspected contaminated site, please contact your local Conservation Officer or the Environmental Programs Branch.

Permits and Protocols

Under the Contaminated Sites Regulation, permits are required to do any of the following:

- A **Relocation Permit** is required to move contaminated material from one site to another.
- A **Land Treatment Facility Permit** is required to construct or operate a facility to treat contaminated materials.
- A **Risk-based Restoration Permit** is required to implement the site-specific cleanup standards developed through the risk assessment process.

To apply for a permit, please download the appropriate application form from our website, and submit it to the Environmental Programs Branch for processing.

Even when a permit is not required, all work related to contaminated sites in the Yukon must adhere to the protocols adopted by Environment Yukon under the authority of the Contaminated Sites Regulation. For more information on these protocols and how they apply to your site, contact the Environmental Programs Branch or visit our website.

For more information on the Contaminated Sites Regulation, please contact:

Environmental Programs Branch
Environment Yukon
Box 2703 (V-8)
Whitehorse, Yukon Y1A 2C6

Phone: (867) 667-5683
Toll-free: 1-800-661-0408 ext. 5683
Fax: (867) 393-6205
Email: envprot@gov.yk.ca

Website: http://environmentyukon.gov.yk.ca/contaminatedsites

Appendix D – Storage Tank Regulations

ENVIRONMENT ACT

Pursuant to section 146 of the *Environment Act*, the Commissioner in Executive Council orders as follows:

1. The annexed Storage Tank Regulations are established.

2. The annexed Regulations shall come into force with effect from the 1st day of January, 1997.

Dated at Whitehorse, in the Yukon Territory, this 16th day of December, 1995.

_____
Commissioner of the Yukon

LOI SUR L'ENVIRONNEMENT

Le Commissaire en conseil exécutif, conformément à l'article 146 de la *Loi sur l'environnement*, décrète ce qui suit :

1. Le Règlement sur les réservoirs de stockage ci-joint est établi.

2. Ce même règlement entre en vigueur le 1er janvier 1997.

Fait à Whitehorse, dans le territoire du Yukon, ce 16 décembre 1996.

_____
Commissaire du Yukon

STORAGE TANK REGULATIONS

Interpretation

1. In these regulations,

"aboveground storage tank" means a storage tank with more than 90% of the storage tank volume above surface grade and that operates at atmospheric pressure plus or minus 10 kPa; *«réservoir de stockage hors sol»*

"aboveground storage tank system" means one or more aboveground storage tanks with any connecting piping, both aboveground or underground, and including pumps on product transfer apparatus, dyking, overfill protection equipment and associated spill containment and collection apparatus; *«système de stockage hors sol»*

"Act" means the *Environment Act*; *«loi»*

"alter" means to enlarge, reduce, upgrade or remove a storage tank system, change the configuration of the piping, tanks, dyking of a storage tank system or replace any tank, but does not include carrying out minor maintenance activities or replacements that do not affect the integrity of the system; *«modifier»*

"Code of Practice for Aboveground Storage Tanks" means the Environmental Code of Practice for Aboveground Storage Tank Systems Containing Petroleum Products (CCME-EPC-LST-71E), published in August 1994, by Canadian Council of Ministers of the Environment, as amended from time to time; *«Code de recommandations applicable aux réservoirs de stockage hors sol»*

"Code of Practice for Underground Storage Tanks" means the Environmental Code of Practice for Underground Storage Tank Systems Containing Petroleum Products and Allied Petroleum Products (CCME-EPC-LST-61E), published in March, 1993 by the Canadian Council of Ministers of the Environment, as amended from time to time; *«Code de recommandations applicable aux réservoirs de stockage souterrains»*

"comfort heating systems" means heating systems with storage tank systems for petroleum products having a capacity of 4,000 litres or less used to supply heat to buildings; *«systèmes de chauffage des locaux»*

RÈGLEMENT SUR LES RÉSERVOIRS DE STOCKAGE

Définitions

1. Les définitions qui suivent s'appliquent au présent règlement :

«carburant moteur» Tout produit pétrolier utilisé afin de propulser un véhicule, un aéronef ou un vaisseau; *"motive fuel"*

«Code de recommandations applicable aux réservoirs de stockage hors sol» S'entend du Code de recommandations techniques pour la protection de l'environnement applicable aux systèmes de stockage hors sol de produits pétroliers (CCME-EPC-LST-71E) et ses modifications, publié au mois d'août 1994 par le Conseil canadien des ministres de l'environnement; *"Code of Practice for Aboveground Storage Tanks"*

«Code de recommandations applicable aux réservoirs de stockage souterrains» S'entend du Code de recommandations techniques pour la protection de l'environnement applicable aux systèmes de stockage souterrains de produits pétroliers et de produits apparentés (CCME-EPC-LST-61E) et ses modifications, publié au mois de mars 1994 par le Conseil canadien des ministres de l'environnement; *"Code of Practice for Underground Storage Tanks"*

«Code national de prévention des incendies» Code national de prévention des incendies du Canada, 1995, publié par la Commission canadienne des codes du bâtiment et de prévention des incendies, Conseil national de recherche, et ses modifications; *"National Fire Code"*

«construire» Bâtir, poser, assembler, positionner, raccorder ou brancher; *"construct"*

«huile de chauffage» Tout produit pétrolier utilisé pour le chauffage de locaux, comprenant, entre autres, le pétrole de chauffage ou le mazout domestique; *"heating fuel"*

«loi» La *Loi sur l'environnement*; *"Act"*

«modifier» Signifie agrandir, réduire, améliorer ou enlever un système de stockage, changer la configuration de la tuyauterie, des réservoirs, de l'endiguement d'un système de stockage ou remplacer tout réservoir, à l'exclusion de la mise en oeuvre

"construct" means to build, install, assemble, position or connect; *«construire»*

"heating fuel" means any petroleum product used for comfort heating, including stove oil or furnace oil; *«huile de chauffage»*

"motive fuel" means any petroleum product used to power a vehicle, aircraft or vessel; *«carburant moteur»*

"National Fire Code" means the National Fire Code of Canada, 1995, issued by the Canadian Commission on Building and Fire Codes, National Research Council, as amended from time to time; *«Code national de prévention des incendies»*

"petroleum product" means a single product or mixture of at least 70% hydrocarbons refined from crude oil, with or without additives, that is used or could be used as a fuel, lubricant or power transmitter and without restricting the foregoing, includes gasoline, diesel fuel, aviation fuel, kerosene, naphtha, lubricating oil, fuel oil and engine oil, but excludes propane, paint and solvents; *«produit pétrolier»*

"piping" means all pipes, fittings and valves necessary for the safe handling and storage of a petroleum product or hazardous substance; *«tuyauterie»*

"storage tank" means a closed container with a capacity of more than 230 litres that is designed to be installed in a fixed location, and includes either an aboveground storage tank or an underground storage tank; *«réservoir de stockage»*

"storage tank system" means one or more storage tanks together with all underground or aboveground connections, piping, pumps and dispensers; *«système de stockage»*

"underground storage tank" means a storage tank with 10% or more of the storage tank volume covered with material such as earth, backfill or concrete; *«réservoir de stockage souterrain»*

"underground storage tank system" means one or more underground storage tanks with all underground or aboveground connections, piping, pumps and dispensers. *«système de stockage souterrain»*

d'activités mineures d'entretien ou de remplacement, ne modifiant pas l'intégrité du système; *"alter"*

«produit pétrolier» Un produit unique ou un mélange contenant au moins 70% d'hydrocarbures, raffiné à partir de pétrole brut, avec ou sans additifs, utilisé ou qui pourrait l'être à titre de carburant, de lubrifiant ou d'émetteur de puissance et, notamment, comme essence, carburant diesel ou d'aviation, kérosène, naphte, huile lubrifiante, mazout, huile pour moteur, à l'exclusion du propane, de la peinture et des solvants; *"petroleum product"*

«réservoir de stockage» Un contenant fermé d'une capacité supérieure à 230 litres, conçu pour être installé à un emplacement fixe, et comprend aussi bien un réservoir hors sol que souterrain; *"storage tank"*

«réservoir de stockage hors sol» Un réservoir de stockage dont plus de 10% de son volume est au-dessus du niveau de la surface et qui fonctionne à une pression atmosphérique de plus ou moins 10 kPa; *"aboveground storage tank"*

«réservoir de stockage souterrain» Un réservoir de stockage dont au moins 10% de son volume est recouvert de matériaux, tels que de la terre, du remblai ou du béton; *"underground storage tank"*

«systèmes de chauffage des locaux» Systèmes de chauffage comprenant des réservoirs de stockage pour les produits pétroliers dont la capacité est de moins de 4 000 litres, utilisés pour fournir du chauffage à des locaux; *"comfort heating systems"*

«système de stockage» Un ou plusieurs réservoirs de stockage, incluant les pièces de jonction, la tuyauterie, les pompes et les distributeurs, aussi bien hors sol que souterrains; *"storage tank system"*

«système de stockage hors sol» Un ou plusieurs réservoirs de stockage hors sol, incluant la tuyauterie de raccordement, aussi bien hors sol que souterraine, y compris les pompes faisant partie des appareils pour le transversement des produits, les endiguements, les dispositifs de protection contre les débordements, et tout autre appareil relié à la retenue et à la collecte des déversements; *"aboveground storage tank system"*

«système de stockage souterrain» Un ou plusieurs réservoirs de stockage souterrains, incluant les pièces

de jonction, la tuyauterie, les pompes et les distributeurs, aussi bien hors sol que souterrains; *"underground storage tank system"*

«tuyauterie» Comprend les tuyaux, les raccords et les soupapes nécessaires pour le maniement sécuritaire et le stockage d'un produit pétrolier ou d'une substance dangereuse. *"piping"*

Application

2.(1) These regulations apply to new storage tank systems and to storage tank systems that are to be altered.

(2) These regulations do not apply to storage tanks used to supply comfort heating systems.

(3) These regulations do not apply to storage tanks used for storing crude oil.

Application

2.(1) Le présent règlement s'applique aux nouveaux systèmes de stockage ainsi qu'à ceux qui sont modifiés.

(2) Le présent règlement ne s'applique pas aux réservoirs de stockage utilisés dans les systèmes de chauffage des locaux.

(3) Le présent règlement ne s'applique pas aux réservoirs de stockage utilisés pour emmagasiner le pétrole brut.

Hazardous Substances

3. For the purposes of section 118 of the Act, a hazardous substance has the same meaning as a dangerous good in the *Dangerous Goods Transportation Act* (Yukon).

Substances dangereuses

3. Pour les fins de l'article 118 de la Loi, une substance dangereuse a la même signification qu'une marchandise dangereuse en vertu de la *Loi sur le transport des marchandises dangereuses* (Yukon).

Petroleum Products in Underground Storage Tanks

4. No person shall alter, construct, cause to construct or operate an underground storage tank system for petroleum products, except as authorized by a permit issued under these regulations.

Produits pétroliers dans des réservoirs de stockage souterrains

4. Nul ne doit modifier, construire, faire en sorte que soit construit ou exploiter un système de stockage souterrain pour des produits pétroliers, à moins d'obtenir un permis en vertu du présent règlement.

Petroleum Products in Aboveground Storage Tanks

5. No person shall alter, construct, cause to construct or operate an aboveground storage tank system for petroleum products having a capacity greater than 4,000 litres, except as authorized by a permit issued under these regulations.

Produits pétroliers dans des réservoirs de stockage hors sol

5. Nul ne doit modifier, construire, faire en sorte que soit construit ou exploiter un système de stockage hors sol pour des produits pétroliers, ayant une capacité de plus de 4 000 litres, à moins d'obtenir un permis en vertu du présent règlement.

Hazardous Substances in Underground Storage Tanks

6. No person shall alter, construct or cause to construct an underground storage tank system for hazardous substances other than petroleum products.

Substances dangereuses dans des réservoirs de stockage souterrains

6. Nul ne doit modifier, construire ou faire en sorte que soit construit un système de stockage souterrain pour des substances dangereuses, autres que des produits pétroliers.

Hazardous Substances in Aboveground Storage Tanks

7.(1) This section applies to aboveground storage tank systems for hazardous substances other than petroleum products having a capacity of 2,000 litres or greater.

(2) No person shall alter, construct, cause to construct or operate an aboveground storage tank system described in subsection (1), except as authorized by a permit issued under these regulations.

Removal of Storage Tank Systems

8.(1) When a storage tank system has no further use or has been out of service for one year, the storage tank system shall be removed, unless decommissioning or abandonment in place is authorized by the Minister.

(2) No person shall remove, decommission or abandon a storage tank system, except as authorized by a permit issued under these regulations.

Public Register

9.(1) The Minister shall establish a register for the purpose of recording the names of persons who have applied for and received a permit under these regulations.

(2) The Minister shall provide public access during normal office hours to the public register established pursuant to subsection (1).

Permits

10.(1) A person applying for a permit or a renewal of a permit under these regulations shall make the application in a form provided by the Minister, and submit the information specified by the Minister, including without limitation,

(a) identification of the applicant;

(b) identification of the owner and operator of the storage tank, if different than the person identified in (a);

(c) any plans related to the activity to be undertaken, including storage tank system design plans, safety and inspection plans and closure and reclamation plans;

(d) identification of on-site and adjacent groundwater and surface water sources; and

Substances dangereuses dans des réservoirs de stockage hors sol

7.(1) Le présent article ne s'applique qu'aux réservoirs de stockage hors sol pour des substances dangereuses, autres que des produits pétroliers, ayant une capacité de 2 000 litres ou plus.

(2) Nul ne doit modifier, construire, faire en sorte que soit construit ou exploiter un système de stockage hors sol, tel que décrit au paragraphe (1), à moins d'obtenir un permis en vertu du présent règlement.

Enlèvement d'un système de stockage

8.(1) Lorsqu'un système de stockage ne sert plus ou est hors service pour une période d'un an, il doit être enlevé, à moins que sa désaffection ou son abandon sur place soit autorisé par le ministre.

(2) Nul ne doit enlever, mettre hors service ou abandonner un système de stockage, à moins d'y être autorisé par un permis émis en vertu du présent règlement.

Registre public

9.(1) Le ministre doit constituer un registre public dans le but d'y inscrire le nom des personnes à qui un permis a été émis en vertu du présent règlement.

(2) Le ministre doit s'assurer que le public puisse avoir accès au registre public constitué en vertu du paragraphe (1) et ce, pendant les heures normales de bureau.

Permis

10.(1) En vertu du présent règlement, une personne qui soumet une demande de permis ou une demande pour le renouvellement de ce dernier doit le faire en utilisant un formulaire prévu par le ministre et y inclure les renseignements demandés, entre autres :

a) l'identité du demandeur;

b) l'identité du propriétaire ainsi que de l'exploitant du réservoir de stockage, si leur identité diffère de celle mentionnée à l'alinéa a);

c) tout projet relié à l'activité à être entreprise, y compris la conception des plans pour un système de stockage, la sécurité, l'inspection, la fermeture et la remise en état;

d) l'identification des nappes d'eau souterraines et de surface, à l'emplacement et dans son voisinage

(e) the proposed dates and timing of work to be undertaken in relation to the permitted activity.

(2) The Minister may issue a permit to the applicant subject to any terms and conditions that the Minister considers appropriate, or may refuse to issue a permit to the applicant.

(3) In issuing a permit under these regulations, the Minister shall consider the Code of Practice for Aboveground Storage Tanks, the Code of Practice for Underground Storage Tanks, and the National Fire Code.

(4) A permit may be issued for a period of up to three years.

(5) The Minister may renew a permit subject to any terms and conditions that the Minister considers appropriate or may refuse to renew a permit.

(6) An environmental protection officer may from time to time conduct an inspection of a site for which a permit issued under these regulations applies to determine whether any of the activities at the site contravene a term or condition of the permit.

(7) It is a condition of every permit to operate a storage tank system that a permittee shall provide notice to the Minister, in writing and as soon as is reasonably practicable, of any significant changes of circumstances involving a permitted storage tank system, including without limitation,

(a) plans to close or remove a storage tank or storage tank system, or

(b) the ownership of the storage tank or storage tank system.

Motive Fuel Records

11.(1) The operator of an underground storage tank system for motive fuel shall maintain and reconcile inventory records each day that motive fuel is added or removed from the storage tank, and shall maintain monthly summaries for each month or part thereof that the storage tank system is operated.

immédiat;

e) les dates prévues ainsi que l'échéancier des travaux à être entrepris, reliés à l'activité permise.

2) Le ministre peut émettre ou non un permis au demandeur, sous réserve des conditions qu'il juge pertinentes.

(3) Lorsqu'il émet un permis en vertu du présent règlement, le ministre doit tenir compte du Code de recommandations applicable aux réservoirs de stockage hors sol, du Code de recommandations applicable aux réservoirs de stockage souterrains, et du Code national de prévention des incendies.

(4) Un permis peut être émis pour une période pouvant aller jusqu'à trois ans.

(5) Le ministre peut renouveler ou non un permis, sous réserve des conditions qu'il juge pertinentes.

(6) Un agent de protection de l'environnement peut, selon les besoins, entreprendre une inspection d'un emplacement pour lequel un permis a été émis en vertu du présent règlement afin de déterminer si l'une des activités entreprises sur cet emplacement enfreint une condition du permis.

(7) Tout titulaire d'un permis permettant d'assurer l'exploitation d'un système de stockage doit, dès que possible, en vertu d'une condition du permis, aviser le ministre par écrit de tout changement important relié au système de stockage, y compris, entre autres :

a) tout projet de fermer ou d'enlever un réservoir de stockage ou un système de stockage;

b) un changement au niveau de la propriété d'un réservoir de stockage ou d'un système de stockage.

Fichiers pour les carburants moteurs

11.(1) L'exploitant d'un système de stockage souterrain pour les carburants moteurs doit tenir à jour et faire concorder les fichiers de stocks pour chaque jour que du carburant moteur est ajouté ou enlevé du réservoir de stockage, et doit également tenir à jour un sommaire mensuel pour chaque mois ou partie de mois au cours duquel le système de stockage est en exploitation.

(2) For the purposes of subsection (1), the operator shall obtain measurements of motive fuel levels and water levels as a part of reconciling inventory records.

(3) Where the inventory records referred to in subsection (1) indicate,

(a) 18 losses in 30 days;

(b) 5 consecutive losses; or

(c) a cumulative gain or loss greater than 0.5% monthly tank throughput or 2.5% of tank capacity

the operator shall immediately report the discrepancy to an environmental protection officer.

(4) The operator of an aboveground storage tank system for motive fuel having a capacity greater than 4,000 litres shall maintain and reconcile inventory records each time motive fuel is added to the storage tank, and shall maintain monthly summaries for each month or part thereof that the storage tank system is in operation.

(5) Where the inventory records referred to in subsection (4) indicate,

(a) a 1.0% shortage of monthly tank throughput or tank capacity, whichever is greater;

(b) 4 consecutive shortages of 50 litres or more; or

(c) consecutive losses totalling 200 litres or more,

the operator shall immediately report the discrepancy to an environmental protection officer.

Heating fuel Records

12.(1) The operator of a storage tank system for heating fuel with a capacity greater than 4000 litres, shall maintain and reconcile inventory records each time heating fuel is added to the storage tank and maintain monthly summaries for each month or part thereof that the storage tank system is operated.

(2) Where the inventory records referred to in subsection (1) indicate,

(2) Pour les fins du paragraphe (1), l'exploitant doit obtenir les lectures du niveau d'eau et de carburant moteur afin de compléter les fichiers de rapprochement des stocks.

(3) L'exploitant doit, dès que possible, faire rapport à un agent de protection de l'environnement de toute anomalie lorsque les fichiers de stocks mentionnés au paragraphe (1) indiquent :

a) 18 pertes en 30 jours;

b) 5 pertes consécutives;

c) une perte ou un gain cumulatif représentant plus de 0,5% du débit mensuel du réservoir ou 2,5% de la capacité de ce dernier.

(4) L'exploitant d'un système de stockage hors sol pour les carburants moteurs, dont la capacité est de plus de 4 000 litres, doit tenir à jour et faire concorder les fichiers de stocks chaque fois que du carburant moteur est ajouté au réservoir de stockage, et doit également tenir à jour un sommaire mensuel pour chaque mois ou partie de mois au cours duquel le système de stockage est en exploitation.

(5) L'exploitant doit, dès que possible, faire rapport à un agent de protection de l'environnement de toute anomalie lorsque les fichiers de stocks mentionnés au paragraphe (4) indiquent :

a) un déficit de 1,0% du débit mensuel du réservoir ou de la capacité de ce dernier, selon le plus élevé des deux;

b) 4 déficits consécutifs de 50 litres ou plus;

c) des pertes consécutives totalisant 200 litres ou plus.

Fichiers de l'huile de chauffage

12.(1) L'exploitant d'un système de stockage pour l'huile de chauffage dont la capacité est de plus de 4 000 litres doit tenir à jour et faire concorder les fichiers de stocks chaque fois que de l'huile de chauffage est ajoutée au réservoir de stockage, et doit également tenir à jour un sommaire mensuel pour chaque mois ou partie de mois au cours duquel le système de stockage est en exploitation.

(2) L'exploitant doit, dès que possible, faire rapport à un agent de protection de l'environnement de toute anomalie lorsque les fichiers de stocks mentionnés au

(a) 4 consecutive shortages of 50 litres or more; or

(b) consecutive losses totalling 200 litres or more

the operator shall immediately report the discrepancy to an environmental protection officer.

Continuous Leakage Detection

13. Sections 11 and 12 do not apply where the Minister has approved in a permit the installation and operation of a continuous leakage detection device in a storage tank system.

Maintenance of Records

14.(1) The operator shall maintain inventory records and monthly summaries collected pursuant to sections 11 and 12 on forms approved by the Minister.

(2) The operator shall retain inventory records and monthly summaries collected pursuant to section 11 and 12 at the site of the storage tank system or at a location specified in a permit for a minimum of two years and shall make them available for inspection upon the request of an environmental protection officer.

Leak Test

15. If any storage tank system fails a leak test, the operator shall immediately report the results of the test to an environmental protection officer.

Fees

16.(1) A person applying for a permit, or an amendment or renewal to a permit shall submit the fee prescribed in Schedule A to the Minister with the application for the permit.

(2) A fee is not refundable.

(3) The Minister may waive fees if the Minister considers it appropriate in the circumstances.

paragraphe (1) indiquent :

a) 4 déficits consécutifs de 50 litres ou plus;

b) des pertes consécutives qui totalisent 200 litres ou plus.

Mécanisme permanent de détection des fuites

13. Les articles 11 et 12 ne s'appliquent pas lorsque le ministre a donné son approbation, dans un permis, pour l'installation et l'exploitation d'un mécanisme permanent de détection des fuites dans un système de stockage.

Mise à jour des fichiers

14.(1) L'exploitant doit tenir à jour les fichiers de stocks ainsi que les sommaires mensuels recueillis conformément aux articles 11 et 12, sur des formulaires approuvés par le ministre.

(2) L'exploitant doit conserver les fichiers de stocks ainsi que les sommaires mensuels recueillis conformément aux articles 11 et 12 à l'emplacement du système de stockage ou dans un lieu mentionné dans un permis et ce, pour une période de deux ans. Il doit les rendre disponibles pour examen suite à la demande d'un agent de protection de l'environnement.

Épreuve d'étanchéité

15. Un exploitant doit dès que possible aviser un agent de protection de l'environnement lorsqu'un fuite est détectée à partir d'un système de stockage, suite à une épreuve d'étanchéité.

Frais

16.(1) La personne qui soumet une demande de permis, ou une demande de modification ou de renouvellement de ce dernier, doit joindre à cette demande, à l'intention du ministre, les frais indiqués à l'annexe A.

(2) Les frais ne sont pas remboursables.

(3) Le ministre peut renoncer aux frais, s'il le juge à propos, compte tenu des circonstances.

SCHEDULE A - PERMIT FEES

ITEM	DESCRIPTION	FEE
1.	Construct, alter or operate storage tank system	
(a)	**underground storage tanks**	
	tanks up to 5,000 litres	$100.00
	tanks 5,001 litres to 20,000 litres	$5.00/ additional 1,000 litres
	tanks 20,001 litres and greater	$2.00/ additional 1,000 litres
(b)	**aboveground storage tanks**	
	tanks up to 10,000 litres	$25.00
	tanks 10,001 litres to 100,000 litres	$1.00/ additional 1,000 litres
	tanks 100,001 to 500,000 litres	$0.50/ additional 1,000 litres
	tanks 500,001 litres and greater	$0.20/ additional 1,000 litres
2.	Closure, decommissioning or a bandonment in place of storage tank system	Free
3.	Amendments of renewals	Free

ANNEXE A - FRAIS DE PERMIS

NUMÉRO	DESCRIPTION	FRAIS
1.	Construction, modification ou exploitation d'un système de stockage	
a)	**réservoirs de stockage souterrain**	
	réservoirs jusqu'à 5 000 litres	100 $
	réservoirs de 5 001 litres à 20 000 litres	5$ par 1 000 litres additionnels
	réservoirs de 20 001 litres ou plus	2 $ par 1 000 litres additionnels
b)	**réservoir de stockage hors sol**	
	réservoirs jusqu'à 10 000 litres	25 $
	réservoirs de 10 001 à 100 000 litres	1 $ par 1 000 litres additionnels
	réservoirs de 100 001 à 500 000 litres	0,50 $ par 1 000 litres additionnels
	réservoirs de 500 001 litres ou plus	0,20 $ par 1 000 litres additionnels
2.	Fermeture, désaffection ou abandon sur place d'un système de stockage	Aucun
3.	Révisions ou renouvellements	Aucun

Appendix E – Spill Response for Sodium Hypochlorite

Spills Response : Sodium Hypochlorite

Faro Mine Complex Guardhouse and area water supply chlorine source for water treatment: Advance 12-A, a 12% solution of sodium hypochlorite

Sodium Hypochlorite (Industrial Bleach)

WHMIS Classification:

Class C, Oxidizing Material

Class D, Div. 2, Toxic Liquid, Skin Sensitizer

Class E, Corrosive Liquids

TDG Classification:

Hypochloride Solutions

UN 1791, Class 8, Packing Group III - Corrosive

Not considered flammable. Polymerization will not occur.

Storage:

- Store upright in a cool, dry, well ventilated area away from incompatible materials;
- Keep container tightly closed when not in use;
- Wash hands thoroughly after handling container;
- Do not cut, grind, weld or drill in, on or near the container;
- Keep away from sources of heat and open flame;
- Empty containers can have residues, gases and mists and are subject to precautionary procedures as well;

Thermal stability:

- Product decomposes thermally above 40°C. Hazardous and toxic decomposition products may include chlorine gas, oxygen and sodium chlorate. Unvented containers will build up internal pressure and may rupture causing a product leak.

Incompatible Substances to Sodium Hypochlorite

All acids, ammonium salts and aqueous ammonium hydroxide solutions, metals, oxidizers, nitrogen compounds, and methanol.

Advance 12A Sodium Hypochlorite Spill Response Plan:

1) Ensure all persons have the required personal protective equipment prior to assessing incident.
2) Assess incident and size of spill;
3) Contact appropriate personel as per company policy
4) Respond with appropriate action plan;
5) Complete and submit incident report.

Spill Response:

Assess size of spill and respond accordingly.

Small Spills – Under 5 kg

- Keep all unauthorized personnel away from the area (50-100 m in all directions).
- Do not touch damaged containers or spilled material unless wearing impermeable protective clothing;
- Attempt to catch or prevent spilled material from contacting surface;
- Cover with DRY san, or other non-combustible material followed with plastic sheet to minimize spreading or contact with rain;
- Use clean tools, preferably non-metallic, to collect materials and place into loosely covered plastic containers for later disposal.

Large Spills – Over 5 kg

- Eliminate all ignition sources;
- Keep all unauthorized personnel away from the area (160 to 330 m in all directions);
- Do not touch damaged containers or spilled material unless wearing impermeable protective clothing;
- Stop leak if you can do it without risk;
- Confine spill to smallest possible area, prevent entry into waterways, sewers, etc.
- Use water spray to reduce vapours or divert cloud drift. Avoid allowing water runoff to contact material.
- Neutralise spilled product with sodium thiosulphate:
    - For spills where product is visible, sodium thiosulphate can be used undiluted.
    - For spills that have been saturated into the surface, sodium thiosulphate should be diluted using potable water.
    - In all cases – ADD SLOWLY, starting at the perimeter of the spill.
        - Adding sodium thiosulphate neutralises the available chlorine content while reducing the pH to about pH 4. Check with a pH meter or test strip. In all cases, depending on the strength of Sodium Hypochlorite, chlorine gas is a dangerous by-product of this reaction procedure.
        - Increase the pH of the contained spill to about pH 7 by slowly adding soda ash. Check pH frequently.

        - The spill should be neutral, with a pH of 7. Check with the appropriate local, provincial or federal agencies for proper and correct disposal methods for this product. If available, use a field test kit to check for levels of residual chlorine in the treated waste water.
    - Ensure proper protective clothing and equipment is worn when handling the sodium thiosulphate.
        - Small spills: Sodium thiosulphate can be dispersed by hand, plastic shovel, or broom.
        - Large spills: if the product has been dyked and contained a circulation pump can be used to move the product to spread the sodium thiosulphate through the contained area.
    - Theoretical amount of sodium thiosulphate required to completely neutralize sodium hypochlorite:

Concentration of Sodium Hypochlorite Bleach Solution	Litres of Sodium Hypochlorite Bleach Solution	Kg of Sodium Hypochlorite Bleach Solution	Kg Sodium Thiosulphate required to completely neutralise chlorine (theoretical)
12%	0.86	1	0.21
12%	1	1.165	0.24
12%	10	11.65	2.41
12%	20	23.23	4.82

- Transfer remaining product from damaged container into approved containers.

Appendix F – Sampling Instructions

SAMPLING INSTRUCTIONS

The following sampling containers are enclosed.

Remember to fill out label on container with a water proof pen – the most important areas are:

Sample ID

Date sample collected

Required Analysis.

General Water Analysis:

- Inorganic/Dissolved Metals – Fill 2 litre plastic bottle
- Total Metals – Fill 250 ml AW (Acid Washed) bottle – add one vial of Nitric Acid.
- Cyanide: Fill 1 litre plastic bottle – Sodium Hydroxide pellets (NaOH) in bottle.

Hydrocarbon Water Analysis:

- Diesel fuel/oil analysis – Fill 1 litre amber glass bottle, ensure Aluminum foil is still in bottle cap
- Gasoline – Fill two 40 ml clear glass vials (HCL Preservative), there must be no headspace in the vial. Use 150 ml glass beaker to collect water and then pour into the glass vial
- Glycol – Fill 125 ml amber glass bottle.

Hydrocarbon Soil Analysis:

- Fill two 125 ml pre-cleaned glass jars – Jars also have a piece Teflon in the lid. All hydrocarbon analysis can be performed from the sample in the two jars.

Samples must be kept cool prior to and when transporting the off-site laboratory for analysis. Samples will be flagged at the laboratory if the temperature is greater than 10 degrees Celsius. This is especially important for Hydrocarbon type samples

Appendix G – Spill Report Form

SPILL REPORT FORM

1. **IDENTIFICATION**

Date of Incident: Date: _____ Time: _____
Date of Discovery: Date: _____ Time: _____
Name of Product: (Attach copy of MSDS) _____
_____
Location of Incident: (Attach Sketch, if helpful) _____
_____
Type of Spill: (Check one)

1. Point Spill: _____ Approx. Area affected: _____ sq. ft/sq. m.

2. Linear Spill: _____ Length of area affected: _____ ft./m.

Volume of Spill: _____ (Estimate volume and identify units, i.e. Imperial gallons, litres, etc.)

Estimated rate of release: _____

Concentration: _____

Expressed in estimated % strength – 100% is not diluted.

2. **DETAILS OF DISCOVERY**

(Prepare, in point form, a chronological sequence of events leading up to the spill or its discovery. Include name, job titles of individuals complete with dates and times with each point)

A. _____
_____
_____

B. _____
_____
_____

C. _____
_____
_____

D. _____
_____
_____

E. _____
_____
_____

3. RISK ASSESSMENT

A) Was MSDS consulted? Yes: _____ No: _____

B) Personal Protective Equipment Required:

_____
_____
_____

Is Employee Safety at Risk? Yes: _____ No: _____

C) Can Material enter a Water Course? Yes: _____ No: _____

D) Is Spill Easily Contained? Yes: _____ No: _____

CHECK ONE:

Spill is considered high-risk immediate action required _____

Call Emergency Response Team for initial response.

OR

Spill is considered low risk, no imminent danger: _____

Proceed with clean-up.

4. ACTION TAKEN UPON DISCOVERY

A) Initial Containment: Date: _____ Time: _____

Describe Methods:

_____
_____
_____

Final Containment: Date: _____Time: _____
Describe methods, if different than above:
_____
_____
_____
Samples taken for analysis: Yes ___ No ___ Date _____ Time _____

5. **DISPOSAL**

Temporary Storage: Date: _____ Time: _____
_____
_____
Final Storage: Date: _____ Time: _____
_____
_____
Ultimate Disposal: Date: _____ Time: _____
_____
_____

6. **REPORTING**

Did the spill quantity exceed the spill reporting threshold as per the Yukon Spill Regulations? (copy attached): Yes _____ No _____
If the spill was of contaminated water, is there a potential that contaminant levels may exceed release criteria?: Yes _____ No _____
If the spill material entered a waterbody, did it occur to an unauthorized release point? (only the Cross Valley Dam, the Sheep Pad Outflow and the Moose Pond Outflow are authorized discharge points): Yes _____ No _____
If answers to any of the above questions is yes, the event is a reportable spill. The Site Manager or his designate must report to the Yukon Spill Report Centre at (867) 667-7244.
Was the spill reported to the above number? Yes _____ No _____
The Site Manager should discuss the incident with the Faro Mine Closure Office to determine if it should also be reported to local and First Nations stakeholders.

7. **RECOMMENDED ACTION**

Short Term: (To solve immediate problem) _____
_____
_____
Long Term: (To prevent a recurrence) _____
_____
_____

8. PERSONS INVOLVED

Name	Position	Organization (AR, other)

9. REPORT CIRCULATION: (In Order – Please Sign)

Shift Supervisor: Date: _____ Time: _____
Comments: _____
_____
_____

Site Superintendent: Date: _____Time: _____
Comments: _____
_____
_____

Site Manager: Date: _____ Time: _____
Comments: _____
_____
_____

Appendix H – FMC Material Safety Data Sheets

Safety Data Sheet

Material Name: Fuel Oil No. 2

SDS No. 0088
US GHS

Synonyms: #2 Heating Oil; 2 Oil; Off-road Diesel Fuel

* * * Section 1 - Product and Company Identification * * *

Manufacturer Information

Hess Corporation
1 Hess Plaza
Woodbridge, NJ 07095-0961

Phone: 732-750-6000 Corporate EHS
Emergency # 800-424-9300 CHEMTREC
www.hess.com (Environment, Health, Safety Internet Website)

* * * Section 2 - Hazards Identification * * *

GHS Classification:

Flammable Liquids - Category 3
Acute Toxicity, Inhalation - Category 4
Skin Corrosion/Irritation – Category 2
Eye Damage/Irritation – Category 2B
Carcinogenicity - Category 2
Specific Target Organ Toxicity (Single Exposure) – Category 3 (respiratory irritation, narcosis)
Aspiration Hazard – Category 1
Hazardous to the Aquatic Environment, Acute Hazard – Category 3

GHS LABEL ELEMENTS

Symbol(s)



Signal Word

DANGER

Hazard Statements

Flammable liquid and vapor.
Harmful if inhaled.
Causes skin irritation.
Causes eye irritation.
Suspected of causing cancer.
Suspected of causing genetic defects.
May cause respiratory irritation.
May cause drowsiness or dizziness.
May be fatal if swallowed and enters airways.
Harmful to aquatic life.

Precautionary Statements

Prevention

Keep away from heat/sparks/open flames/hot surfaces. No smoking

Keep container tightly closed.
Ground/bond container and receiving equipment.
Use explosion-proof electrical/ventilating/lighting/equipment.
Use only non-sparking tools.
Take precautionary measures against static discharge.
Wear protective gloves/protective clothing/eye protection/face protection.
Avoid breathing fume/mist/vapors/spray.
Use only outdoors or in a well-ventilated area.
Wash hands and forearms thoroughly after handling.
Obtain special instructions before use.
Do not handle until all safety precautions have been read and understood.
Avoid release to the environment.

Response
In case of fire: Use water spray, fog or foam.
If on skin (or hair): Wash with plenty of soap and water. Take off immediately all contaminated clothing and wash it before reuse. If skin irritation occurs, get medical advice/attention.
If inhaled: Remove person to fresh air and keep comfortable for breathing. Call a poison center or doctor if you feel unwell.
If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If eye irritation persists: Get medical advice/attention.
If exposed or concerned: Get medical advice/attention.
If swallowed: Immediately all a poison center or doctor/physician if you feel unwell. Do NOT induce vomiting.

Storage
Store in a well-ventilated place.
Keep cool. Store locked up.
Keep container tightly closed.

Disposal
Dispose of contents/container in accordance with local/regional/national/international regulations.

* * * Section 3 - Composition / Information on Ingredients * * *

CAS #	Component	Percent
68476-30-2	Fuel oil No. 2	100
91-20-3	Naphthalene	<0.1

A complex combination of hydrocarbons with carbon numbers in the range C9 and higher produced from the distillation of petroleum crude oil.

* * * Section 4 - First Aid Measures * * *

First Aid: Eyes

In case of contact with eyes, immediately flush with clean, low-pressure water for at least 15 min. Hold eyelids open to ensure adequate flushing. Seek medical attention.

First Aid: Skin

Remove contaminated clothing. Wash contaminated areas thoroughly with soap and water or with waterless hand cleanser. Obtain medical attention if irritation or redness develops.

First Aid: Ingestion

DO NOT INDUCE VOMITING. Do not give liquids. Obtain immediate medical attention. If spontaneous vomiting occurs, lean victim forward to reduce the risk of aspiration. Monitor for breathing difficulties. Small amounts of material which enter the mouth should be rinsed out until the taste is dissipated.

First Aid: Inhalation

Remove person to fresh air. If person is not breathing, provide artificial respiration. If necessary, provide additional oxygen once breathing is restored if trained to do so. Seek medical attention immediately.

* * * Section 5 - Fire Fighting Measures * * *

General Fire Hazards

See Section 9 for Flammability Properties.

Vapors may be ignited rapidly when exposed to heat, spark, open flame or other source of ignition. When mixed with air and exposed to an ignition source, flammable vapors can burn in the open or explode in confined spaces. Being heavier than air, vapors may travel long distances to an ignition source and flash back. Runoff to sewer may cause fire or explosion hazard.

Hazardous Combustion Products

Carbon monoxide, carbon dioxide and non-combusted hydrocarbons (smoke).

Extinguishing Media

SMALL FIRES: Any extinguisher suitable for Class B fires, dry chemical, CO2, water spray, fire fighting foam, or gaseous extinguishing agent.

LARGE FIRES: Water spray, fog or fire fighting foam. Water may be ineffective for fighting the fire, but may be used to cool fire-exposed containers.

Unsuitable Extinguishing Media

None

Fire Fighting Equipment/Instructions

Small fires in the incipient (beginning) stage may typically be extinguished using handheld portable fire extinguishers and other fire fighting equipment. Firefighting activities that may result in potential exposure to high heat, smoke or toxic by-products of combustion should require NIOSH/MSHA- approved pressure-demand self-contained breathing apparatus with full facepiece and full protective clothing. Isolate area around container involved in fire. Cool tanks, shells, and containers exposed to fire and excessive heat with water. For massive fires the use of unmanned hose holders or monitor nozzles may be advantageous to further minimize personnel exposure. Major fires may require withdrawal, allowing the tank to burn. Large storage tank fires typically require specially trained personnel and equipment to extinguish the fire, often including the need for properly applied fire fighting foam.

* * * Section 6 - Accidental Release Measures * * *

Recovery and Neutralization

Carefully contain and stop the source of the spill, if safe to do so.

Materials and Methods for Clean-Up

Take up with sand or other oil absorbing materials. Carefully shovel, scoop or sweep up into a waste container for reclamation or disposal.

Emergency Measures

Evacuate nonessential personnel and remove or secure all ignition sources. Consider wind direction; stay upwind and uphill, if possible. Evaluate the direction of product travel, diking, sewers, etc. to confirm spill areas. Spills may infiltrate subsurface soil and groundwater; professional assistance may be necessary to determine the extent of subsurface impact.

Personal Precautions and Protective Equipment

Response and clean-up crews must be properly trained and must utilize proper protective equipment (see Section 8).

Environmental Precautions

Protect bodies of water by diking, absorbents, or absorbent boom, if possible. Do not flush down sewer or drainage systems, unless system is designed and permitted to handle such material. The use of fire fighting foam may be useful in certain situations to reduce vapors. The proper use of water spray may effectively disperse product vapors or the liquid itself, preventing contact with ignition sources or areas/equipment that require protection.

Prevention of Secondary Hazards

None

* * * Section 7 - Handling and Storage * * *

Handling Procedures

Handle as a combustible liquid. Keep away from heat, sparks, excessive temperatures and open flame! No smoking or open flame in storage, use or handling areas. Bond and ground containers during product transfer to reduce the possibility of static-initiated fire or explosion.

Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when this product is loaded into tanks previously containing low flash point products (such as gasoline) - see API Publication 2003, "Protection Against Ignitions Arising Out Of Static, Lightning and Stray Currents."

Storage Procedures

Keep containers closed and clearly labeled. Use approved vented storage containers. Empty product containers or vessels may contain explosive vapors. Do not pressurize, cut, heat, weld or expose such containers to sources of ignition.

Store in a well-ventilated area. This storage area should comply with NFPA 30 "Flammable and Combustible Liquid Code". Avoid storage near incompatible materials. The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 "Cleaning Mobile Tanks In Flammable and Combustible Liquid Service" and API RP 2015 "Cleaning Petroleum Storage Tanks."

Incompatibilities

Keep away from strong oxidizers; Fluorel ®

* * * Section 8 - Exposure Controls / Personal Protection * * *

Component Exposure Limits

Fuel oil No. 2 (68476-30-2)

ACGIH: 0.2 mg/m3 TWA (inhalable fraction and vapor, as total hydrocarbons, listed under Diesel fuel)
Skin - potential significant contribution to overall exposure by the cutaneous route (listed under Diesel fuel)

Naphthalene (91-20-3)

ACGIH: 10 ppm TWA
15 ppm STEL
Skin - potential significant contribution to overall exposure by the cutaneous route
OSHA: 10 ppm TWA; 50 mg/m3 TWA
NIOSH: 10 ppm TWA; 50 mg/m3 TWA
15 ppm STEL; 75 mg/m3 STEL

Engineering Measures

Use adequate ventilation to keep vapor concentrations of this product below occupational exposure and flammability limits, particularly in confined spaces.

Personal Protective Equipment: Respiratory

A NIOSH/MSHA-approved air-purifying respirator with organic vapor cartridges or canister may be permissible under certain circumstances where airborne concentrations are or may be expected to exceed exposure limits or for odor or irritation. Protection provided by air-purifying respirators is limited.

Use a positive pressure, air-supplied respirator if there is a potential for uncontrolled release, exposure levels are not known, in oxygen-deficient atmospheres, or any other circumstance where an air-purifying respirator may not provide adequate protection.

Personal Protective Equipment: Hands

Gloves constructed of nitrile, neoprene, or PVC are recommended.

Personal Protective Equipment: Eyes

Safety glasses or goggles are recommended where there is a possibility of splashing or spraying.

Personal Protective Equipment: Skin and Body

Chemical protective clothing such as of E.I. DuPont TyChem®, Saranex® or equivalent recommended based on degree of exposure. Note: The resistance of specific material may vary from product to product as well as with degree of exposure. Consult manufacturer specifications for further information.

* * * Section 9 - Physical & Chemical Properties * * *

Appearance:	Red or reddish/orange colored (dyed)	**Odor:**	Mild, petroleum distillate odor
Physical State:	Liquid	**pH:**	ND
Vapor Pressure:	0.009 psia @ 70 °F (21 °C)	**Vapor Density:**	>1.0
Boiling Point:	340 to 700 °F (171 to 371 °C)	**Melting Point:**	ND
Solubility (H2O):	Negligible	**Specific Gravity:**	AP 0.823-0871
Evaporation Rate:	Slow; varies with conditions	**VOC:**	ND
Octanol/H2O Coeff.:	ND	**Flash Point:**	100 °F (38 °C) minimum
Flash Point Method:	PMCC	**Upper Flammability Limit (UFL):**	7.5
Lower Flammability Limit (LFL):	0.6	**Burning Rate:**	ND
Auto Ignition:	494°F (257°C)		

* * * Section 10 - Chemical Stability & Reactivity Information * * *

Chemical Stability

This is a stable material.

Hazardous Reaction Potential

Will not occur.

Conditions to Avoid

Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources.

Incompatible Products

Keep away from strong oxidizers; Fluorel ®

Hazardous Decomposition Products

Carbon monoxide, carbon dioxide and non-combusted hydrocarbons (smoke).

* * * Section 11 - Toxicological Information * * *

Acute Toxicity

A: General Product Information

Harmful if swallowed.

B: Component Analysis - LD50/LC50

Fuel oil No. 2 (68476-30-2)

Oral LD50 Rat 12 g/kg; Dermal LD50 Rabbit 4720 µL/kg; Dermal LD50 Rabbit >2000 mg/kg; Inhalation LC50 Rat 4.6 mg/L 4 h

Naphthalene (91-20-3)

Inhalation LC50 Rat >340 mg/m3 1 h; Oral LD50 Rat 490 mg/kg; Dermal LD50 Rat >2500 mg/kg; Dermal LD50 Rabbit >20 g/kg

Product Mixture

Oral LD50 Rat 14.5 ml/kg; Dermal LD50 Rabbit >5 mL/kg; Guinea Pig Sensitization: negative; Primary dermal irritation: moderately irritating (Draize mean irritation score - 3.98 rabbits); Draize eye irritation: mildly irritating (Draize score, 48 hours, unwashed - 2.0 rabbits)

Potential Health Effects: Skin Corrosion Property/Stimulativeness

Practically non-toxic if absorbed following acute (single) exposure. May cause skin irritation with prolonged or repeated contact. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are repeatedly exposed.

Potential Health Effects: Eye Critical Damage/ Stimulativeness

Contact with eyes may cause mild irritation.

Potential Health Effects: Ingestion

Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous system (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest, and death may occur.

Potential Health Effects: Inhalation

Excessive exposure may cause irritations to the nose, throat, lungs and respiratory tract. Central nervous system (brain) effects may include headache, dizziness, loss of balance and coordination, unconsciousness, coma, respiratory failure, and death.

WARNING: the burning of any hydrocarbon as a fuel in an area without adequate ventilation may result in hazardous levels of combustion products, including carbon monoxide, and inadequate oxygen levels, which may cause unconsciousness, suffocation, and death.

Respiratory Organs Sensitization/Skin Sensitization

This product is not reported to have any skin sensitization effects.

Generative Cell Mutagenicity

This product is not reported to have any mutagenic effects. Material of similar composition has been positive in a mutagenicity study.

Carcinogenicity

A: General Product Information

Suspected of causing cancer.

Dermal carcinogenicity: positive - mice
Studies have shown that similar products produce skin tumors in laboratory animals following repeated applications without washing or removal. The significance of this finding to human exposure has not been determined. Other studies with active skin carcinogens have shown that washing the animal's skin with soap and water between applications reduced tumor formation.

This product is similar to Diesel Fuel. IARC classifies whole diesel fuel exhaust particulates as probably carcinogenic to humans (Group 2A) and NIOSH regards it as a potential cause of occupational lung cancer based on animal studies and limited evidence in humans.

B: Component Carcinogenicity

Fuel oil No. 2 (68476-30-2)

ACGIH: A3 - Confirmed Animal Carcinogen with Unknown Relevance to Humans (listed under Diesel fuel)

Naphthalene (91-20-3)

ACGIH: A4 - Not Classifiable as a Human Carcinogen
NTP: Reasonably Anticipated To Be A Human Carcinogen (Possible Select Carcinogen)
IARC: Monograph 82 [2002] (Group 2B (possibly carcinogenic to humans))

Reproductive Toxicity

This product is not reported to have any reproductive toxicity effects.

Specified Target Organ General Toxicity: Single Exposure

This product is not reported to have any specific target organ general toxicity single exposure effects.

Specified Target Organ General Toxicity: Repeated Exposure

This product is not reported to have any specific target organ general toxicity repeat exposure effects.

Aspiration Respiratory Organs Hazard

The major health threat of ingestion occurs from the danger of aspiration (breathing) of liquid drops into the lungs, particularly from vomiting. Aspiration may result in chemical pneumonia (fluid in the lungs), severe lung damage, respiratory failure and even death.

* * * Section 12 - Ecological Information * * *

Ecotoxicity

A: General Product Information

Very toxic to aquatic life with long lasting effects. Keep out of sewers, drainage areas and waterways. Report spills and releases, as applicable, under Federal and State regulations.

B: Component Analysis - Ecotoxicity - Aquatic Toxicity

Fuel oil No. 2 (68476-30-2)

Test & Species	Conditions
96 Hr LC50 Pimephales promelas	35 mg/L [flow-through]

Naphthalene (91-20-3)

Test & Species	Conditions
96 Hr LC50 Pimephales promelas	5.74-6.44 mg/L [flow-through]
96 Hr LC50 Oncorhynchus mykiss	1.6 mg/L [flow-through]
96 Hr LC50 Oncorhynchus mykiss	0.91-2.82 mg/L [static]
96 Hr LC50 Pimephales promelas	1.99 mg/L [static]
96 Hr LC50 Lepomis macrochirus	31.0265 mg/L [static]
72 Hr EC50 Skeletonema costatum	0.4 mg/L
48 Hr LC50 Daphnia magna	2.16 mg/L
48 Hr EC50 Daphnia magna	1.96 mg/L [Flow through]
48 Hr EC50 Daphnia magna	1.09 - 3.4 mg/L [Static]

Persistence/Degradability

No information available.

Bioaccumulation

No information available.

Mobility in Soil

No information available.

* * * Section 13 - Disposal Considerations * * *

Waste Disposal Instructions

See Section 7 for Handling Procedures. See Section 8 for Personal Protective Equipment recommendations.

Disposal of Contaminated Containers or Packaging

Dispose of contents/container in accordance with local/regional/national/international regulations.

* * * Section 14 - Transportation Information * * *

DOT Information

Shipping Name: Fuel Oil, No. 2

UN #: 1202 **Hazard Class:** 3 **Packing Group:** III

Placard:



* * * Section 15 - Regulatory Information * * *

Regulatory Information

Component Analysis

This material contains one or more of the following chemicals required to be identified under SARA Section 302 (40 CFR 355 Appendix A), SARA Section 313 (40 CFR 372.65) and/or CERCLA (40 CFR 302.4).

Naphthalene (91-20-3)

SARA 313: 0.1 % de minimis concentration
CERCLA: 100 lb final RQ; 45.4 kg final RQ

SARA Section 311/312 – Hazard Classes

Acute Health	Chronic Health	Fire	Sudden Release of Pressure	Reactive
X	X	X	--	--

SARA SECTION 313 - SUPPLIER NOTIFICATION

This product may contain listed chemicals below the de minimis levels which therefore are not subject to the supplier notification requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act (EPCRA) of 1986 and of 40 CFR 372. If you may be required to report releases of chemicals listed in 40 CFR 372.28, you may contact Hess Corporate Safety if you require additional information regarding this product.

State Regulations

Component Analysis - State

The following components appear on one or more of the following state hazardous substances lists:

Component	CAS	CA	MA	MN	NJ	PA	RI
Naphthalene	91-20-3	Yes	Yes	Yes	Yes	Yes	No

The following statement(s) are provided under the California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65):

WARNING! This product contains a chemical known to the state of California to cause cancer.

Component Analysis - WHMIS IDL

No components are listed in the WHMIS IDL.

Additional Regulatory Information

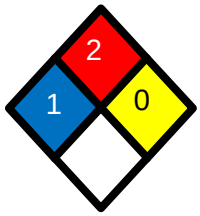
Component Analysis - Inventory

Component	CAS #	TSCA	CAN	EEC
Fuel oil No. 2	68476-30-2	Yes	DSL	EINECS
Naphthalene	91-20-3	Yes	DSL	EINECS

* * * Section 16 - Other Information * * *

NFPA® Hazard Rating

Health	1
Fire	2
Reactivity	0



HMIS® Hazard Rating

Health	1*	Slight
Fire	2	Moderate
Physical	0	Minimal
		*Chronic

Abbreviations:

AP = Approximately; < = Less than > = Greater than; N/A = Not Applicable; N/D = Not Determined; ppm = parts per million

Key/Legend

EPA = Environmental Protection Agency; TSCA = Toxic Substance Control Act; ACGIH = American Conference of Governmental Industrial Hygienists; API = American Petroleum Institute (202) 682-8000; IARC = International Agency for Research on Cancer; MSHA = Mine Safety and Health Administration; NIOSH = National Institute for Occupational Safety and Health; NTP = National Toxicology Program; OSHA = Occupational Safety and Health Administration., NJTSR = New Jersey Trade Secret Registry.

Literature References

None

Other Information

Information presented herein has been compiled from sources considered to be dependable, and is accurate and reliable to the best of our knowledge and belief, but is not guaranteed to be so. Since conditions of use are beyond our control, we make no warranties, expressed or implied, except those that may be contained in our written contract of sale or acknowledgment.

Vendor assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally, vendor assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material, even if reasonable safety procedures are followed. Furthermore, vendee assumes the risk in their use of the material.

End of Sheet

Section 1: PRODUCT AND COMPANY IDENTIFICATION

Product Name: Gasoline (Midgrade Unleaded)
Gasoline (Premium Unleaded)
Gasoline (Regular Unleaded)

Synonyms: CASRN 86290-81-5.

Product Use: Motor Fuel.

Manufacturer/Supplier: Husky Oil Marketing Company
PO Box 6525 Station 'D'
Calgary, Alberta
T2P 3G7

Phone Number: 403-298-6111

Emergency Phone: 403-262-2111

Date of Preparation: March 19, 2012

Section 2: HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
DANGER

EXTREMELY FLAMMABLE LIQUID AND VAPOR - VAPOR MAY CAUSE FLASH FIRE. HARMFUL OR FATAL IF SWALLOWED. CAN ENTER LUNGS AND CAUSE DAMAGE. CANCER HAZARD – CAN CAUSE CANCER. IRRITATING TO EYES AND SKIN.

Colour: Colourless or dyed red or purple.
Physical State: Liquid.
Odour: Petroleum.

WHMIS	Personal Protection Equipment	TDG (Ground)
		

Potential Health Effects: See Section 11 for more information.

Likely Routes of Exposure: Eye contact. Skin contact. Inhalation. Ingestion. Skin absorption.

Eye: Irritating to eyes. Signs/symptoms may include redness, swelling, pain, tearing, and blurred or hazy vision. Product vapours are moderately irritating to the eyes with effects beginning near 200-500 ppm.

Skin: Irritating to skin. Signs/symptoms may include localized redness, swelling, and itching.

Ingestion: Harmful or fatal: may cause lung damage if swallowed. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. May cause gastrointestinal irritation. Signs/symptoms may include abdominal pain, stomach upset, nausea, vomiting and diarrhea.

Inhalation: May cause respiratory tract irritation. Signs/symptoms may include cough, sneezing, nasal discharge, headache, hoarseness, and nose and throat pain. May cause headache, dizziness, confusion, loss of appetite and loss of consciousness. At concentrations near

1000 ppm, central nervous system effects such as headache, blurred vision, dizziness, and loss of coordination may occur. Exposure to vapour concentrations exceeding 5000 ppm may result in loss of consciousness, coma and death.

Chronic Effects: See Section 11 for more information.

Medical Conditions Aggravated By Exposure: Not available.

Target Organs: Skin. Eyes. Gastrointestinal tract. Respiratory system. Blood. Cardiovascular system. Bone marrow. Spleen. Liver. Kidneys. Nervous system. Thymus.

Potential Environmental Effects: See Section 12 for more information.

This material is considered hazardous by the OSHA Hazard Communication Standard, (29 CFR 1910.1200).

Section 3: COMPOSITION / INFORMATION ON INGREDIENTS

Component	CAS No.	Wt. %
Gasoline	86290-81-5	60 - 100

Section 4: FIRST AID MEASURES

Eye Contact: Flush eyes with plenty of water for at least 15 minutes. If signs/symptoms persist, get medical attention.

Skin Contact: Wash skin with soap and water for at least 15 minutes while removing contaminated clothing and shoes. If signs/symptoms develop, get medical attention.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention immediately.

Inhalation: Remove person to fresh air. If breathing has stopped apply artificial respiration. If signs/symptoms develop, get medical attention.

General Advice: In case of accident or if you feel unwell, seek medical advice immediately (show the label or MSDS where possible).

Note to Physicians: Symptoms may not appear immediately.

Section 5: FIRE FIGHTING MEASURES

Flammability: Flammable liquid by WHMIS criteria. Flammable liquid by OSHA criteria. Released vapours may form flammable/explosive mixtures at or above the flash point. Vapours may travel considerable distances to ignition sources and cause a flash fire. Cool containing vessels with water jet in order to prevent pressure build-up, auto-ignition or explosion.

Means of Extinction
Suitable Extinguishing Media: Dry chemical, foam, or carbon dioxide.
Unsuitable Extinguishing Media: Water may not be an effective medium to extinguish fire.

Products of Combustion: Oxides of carbon.

Protection of Firefighters: Keep upwind of fire. Wear full fire fighting turn-out gear (full Bunker gear) and respiratory protection (SCBA).

Explosion Data
Sensitivity to Mechanical Impact: This material is not sensitive to mechanical impact.
Sensitivity to Static Discharge: This material is sensitive to static discharge at temperatures above the flash point.

Section 6: ACCIDENTAL RELEASE MEASURES

Personal Precautions: Evacuate all unnecessary personnel. Stay upwind. Eliminate all ignition sources. Use personal protection recommended in Section 8. Isolate the hazard area and deny entry to unnecessary and unprotected personnel.

Environmental Precautions: Keep out of drains, sewers, ditches, and waterways.

Methods for Containment: Stop leak if without risk. Contain spill and absorb with inert absorbent. Large pools may be covered with foam to prevent vapour evolution. Do not flush to sewer or allow to enter waterways.

Methods for Clean-Up: Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers. Use clean non-sparking tools to collect absorbed material. Large spills should be removed with explosion proof vacuum equipment.

Other Information: Dispose of in accordance with all federal, provincial and local regulations. Comply with federal, provincial, and local requirements for spill and/or release notification.

Section 7: HANDLING AND STORAGE

Handling:
Do not swallow. Do not get in eyes, or on skin. All equipment used when handling the product must be grounded. Handle and open container with care. When using do not eat or drink. Wash hands before eating, drinking, or smoking. See Section 8 for information on Personal Protective Equipment.

Storage:
Store in cool, dry, well-ventilated area away from incompatible materials, heat, and sources of ignition. All storage containers and pumping equipment should be grounded. Keep out of the reach of children.

Section 8: EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Guidelines
Component

Gasoline
(86290-81-5) **ACGIH:** 300 ppm (TWA); 500 ppm (STEL); A3 (1990)
(86290-81-5) **OSHA:** 300 ppm (TWA); 500 ppm (STEL) [Vacated]; For Gasoline

Naphtha (petroleum), catalytic reformed
(68955-35-1) **ACGIH:** 100 ppm (TWA); (1980); For Stoddard solvent
(68955-35-1) **OSHA:** 100 ppm (TWA), 400 mg/m³ (TWA); For Naphtha.

Naphtha (petroleum), light catalytic cracked
(64741-55-5) **ACGIH:** 100 ppm (TWA); (1980); For Stoddard solvent
(64741-55-5) **OSHA:** 100 ppm (TWA), 400 mg/m³ (TWA); For Naphtha.

Naphtha (petroleum), isomerization

(64741-70-4) **ACGIH:** 100 ppm (TWA); (1980); For Stoddard solvent

(64741-70-4) **OSHA:** 100 ppm (TWA), 400 mg/m³ (TWA); For Naphtha.

Hydrocarbons, C1-4, debutanizer fraction

(68527-19-5) **ACGIH:** No TLV established.

(68527-19-5) **OSHA:** No PEL established.

Benzene

(71-43-2) **ACGIH:** 0.5 ppm (TWA); 2.5 ppm (STEL); Skin; A1; BEI (1996)

(71-43-2) **OSHA:** 1 ppm (TWA); 5 ppm (STEL);

Xylenes

(1330-20-7) **ACGIH:** 100 ppm (TWA); 150 ppm (STEL); A4; BEI (1992)
(1330-20-7) **OSHA:** 100 ppm (TWA), 435 mg/m³ (TWA);
150 ppm (STEL) [Vacated]

PEL: Permissible Exposure Limit
TLV: Threshold Limit Value
TWA: Time-Weighted Average
STEL: Short-Term Exposure Limit
C: Ceiling

Engineering Controls:	Use ventilation adequate to keep exposures (airborne levels of dust, fume, vapour, gas, etc.) below recommended exposure limits. Use explosion-proof ventilation equipment.
Personal Protective Equipment	
Eye/Face Protection:	Wear safety glasses. Ensure that eyewash stations are close to the workstation location.
Hand Protection:	Wear impervious gloves. Neoprene or nitrile material is suggested. Consult manufacturer specifications for further information.
Skin and Body Protection:	Wear suitable protective clothing. Flame resistant clothing such as Nomex ® is recommended in areas where material is stored or handled.
Respiratory Protection:	If engineering controls and ventilation are not sufficient to control exposure to below the allowable limits then an appropriate NIOSH/MSHA approved air-purifying respirator or self-contained breathing apparatus (SCBA) should be used. Supplied air breathing apparatus must be used when oxygen concentrations are low or if airborne concentrations exceed the limits of the air-purifying respirators.
General Hygiene Considerations:	Handle according to established industrial hygiene and safety practices.

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Colourless or dyed red or purple liquid.
Colour:	Colourless or dyed red or purple.
Odour:	Petroleum.
Odour Threshold:	0.12 - 0.15 ppm recognition. 0.06 - 0.08 ppm threshold.
Physical State:	Liquid.
pH:	Not available.
Viscosity:	Not available.
Melting Point:	Not available.
Boiling Point:	30 to 215 °C
Flash Point:	-50 °C (TCC)
Evaporation Rate:	Not available.
Lower Flammability Limit:	1.3 %
Upper Flammability Limit:	7.1 %
Vapor Pressure:	Not available.
Vapor Density:	Not available.
Specific Gravity:	0.7 (Water = 1)
Density:	Not available.
Solubility in Water:	Insoluble.
Coefficient of Water/Oil Distribution:	Not available.
Auto-ignition Temperature:	257 °C
Percent Volatile, wt. %:	Not available.
VOC content, wt. %:	Not available.

Section 10: STABILITY AND REACTIVITY

Stability:	Stable under normal storage conditions.
Conditions of Reactivity:	Contact with incompatible materials. Sources of ignition.
Incompatible Materials:	Strong acids. Strong oxidizers. Chlorine.
Hazardous Decomposition Products:	Not available.
Possibility of Hazardous Reactions:	None known.

Section 11: TOXICOLOGICAL INFORMATION

EFFECTS OF ACUTE EXPOSURE

Component Toxicity

Component	CAS No.	LD_{50} oral	LD_{50} dermal	LC_{50}
Gasoline	86290-81-5	60 mL/kg, (mouse)	Not available.	Not available.
Naphtha (petroleum), catalytic reformed	68955-35-1	5400 mg/kg, (rat)	Not available.	Not available.
Naphtha (petroleum), light catalytic cracked	64741-55-5	Not available.	Not available.	Not available.
Naphtha (petroleum), isomerization	64741-70-4	Not available.	Not available.	Not available.
Hydrocarbons, C1-4, debutanizer fraction	68527-19-5	Not available.	Not available.	Not available.
Benzene	71-43-2	930 mg/kg, (rat)	>9400 µl/kg, (rabbit)	10000 ppm, (rat), 7H
Xylenes	1330-20-7	>1700 mg/kg, (rat)	4300 mg/kg, (rabbit)	5000 ppm, (rat), 4H

Eye: Irritating to eyes. Signs/symptoms may include redness, swelling, pain, tearing, and blurred or hazy vision. Product vapours are moderately irritating to the eyes with effects beginning near 200-500 ppm.

Skin: Irritating to skin. Signs/symptoms may include localized redness, swelling, and itching.

Ingestion: Harmful or fatal: may cause lung damage if swallowed. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. May cause gastrointestinal irritation. Signs/symptoms may include abdominal pain, stomach upset, nausea, vomiting and diarrhea.

Inhalation: May cause respiratory tract irritation. Signs/symptoms may include cough, sneezing, nasal discharge, headache, hoarseness, and nose and throat pain. May cause headache, dizziness, confusion, loss of appetite and loss of consciousness. At concentrations near 1000 ppm, central nervous system effects such as headache, blurred vision, dizziness, and loss of coordination may occur. Exposure to vapour concentrations exceeding 5000 ppm may result in loss of consciousness, coma and death.

Skin Sensitization: Not hazardous by OSHA/WHMIS criteria.

Respiratory Sensitization: Not hazardous by OSHA/WHMIS criteria.

EFFECTS OF CHRONIC EXPOSURE

Target Organs: Skin. Eyes. Gastrointestinal tract. Respiratory system. Blood. Cardiovascular system. Bone marrow. Spleen. Liver. Kidneys. Nervous system. Thymus.

Chronic Effects: Hazardous by OSHA/WHMIS criteria. Prolonged or repeated contact may dry skin and cause irritation. Long term inhalation of Benzene or Xylene vapours can result in bone marrow abnormalities with damage to blood forming tissues and may cause anemia and other blood cell abnormalities. Immunodepressive effects have also been reported. Repeated exposure of the eyes to high concentrations of Xylenes vapour may cause reversible eye damage.

Carcinogenicity: Hazardous by OSHA/WHMIS criteria. May cause cancer. Long-term exposure to Gasoline vapors has caused cancer in laboratory animals. Chronic exposure to benzene has been associated with an increased incidence of leukemia and multiple myeloma (tumour composed of cells of the type normally found in the bone marrow).

Component Carcinogenicity

Component	ACGIH	IARC	NTP	OSHA	Prop 65
Gasoline	A3	Group 2B	Not listed.	OSHA Carcinogen.	Listed.
Naphtha (petroleum), catalytic reformed	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Naphtha (petroleum), light catalytic cracked	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Naphtha (petroleum), isomerization	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Hydrocarbons, C1-4, debutanizer fraction	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Benzene	A1	Group 1	List 1	OSHA Carcinogen.	Listed.
Xylenes	A4	Group 3	Not listed.	Not listed.	Not listed.

Mutagenicity: Hazardous by OSHA/WHMIS criteria. May cause heritable genetic damage.

Reproductive Effects: Not hazardous by OSHA/WHMIS criteria.

Developmental Effects

Teratogenicity: Not hazardous by OSHA/WHMIS criteria.

Embryotoxicity: Benzene and Xylene have caused adverse fetal effects in laboratory animals.

Toxicologically Synergistic Materials: Not available.

Section 12: ECOLOGICAL INFORMATION

Ecotoxicity: Not available.

Persistence / Degradability: Not available.

Bioaccumulation / Accumulation: Not available.

Mobility in Environment: Not available.

Section 13: DISPOSAL CONSIDERATIONS

Disposal Instructions: Disposal should be in accordance with applicable regional, national and local laws and regulations. Local regulations may be more stringent than regional or national requirements.

Section 14: TRANSPORTATION INFORMATION

CFR

Proper Shipping Name: UN 1268, PETROLEUM PRODUCTS, N.O.S., 3, PG I

Class: 3

UN Number: 1268

Packing Group: I

Label Code:



TDG

Proper Shipping Name: UN 1268, PETROLEUM PRODUCTS, N.O.S., 3, PG I

Class: 3

UN Number: 1268

Packing Group: I

Label Code:



Section 15: REGULATORY INFORMATION

Chemical Inventories

US (TSCA)
The components of this product are in compliance with the chemical notification requirements of TSCA.

Canada (DSL)
The components of this product are in compliance with the chemical notification requirements of the NSN Regulations under CEPA, 1999.

Federal Regulations

Canada
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.

WHMIS Classification:
Class B2 - Flammable Liquids.
Class D2A - Carcinogenicity.
Class D2A - Mutagenicity.
Class D2A - Chronic toxic effects.
Class D2B - Skin irritant.
Class D2B - Eye irritant.

Hazard Symbols:



United States
This MSDS has been prepared to meet the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200.

SARA Title III

Component	Section 302 (EHS) TPQ (lbs.)	Section 304 EHS RQ (lbs.)	CERCLA RQ (lbs.)	Section 313	RCRA CODE	CAA 112(r) TQ (lbs.)
Gasoline	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Naphtha (petroleum), catalytic reformed	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Naphtha (petroleum), light catalytic cracked	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Naphtha (petroleum), isomerization	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Hydrocarbons, C1-4, debutanizer fraction	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.	Not listed.
Benzene	Not listed.	Not listed.	10	313	U019	Not listed.
Xylenes	Not listed.	Not listed.	100	313	U239	Not listed.

State Regulations
Massachusetts
US Massachusetts Commonwealth's Right-to-Know Law (Appendix A to 105 Code of Massachusetts Regulations Section 670.000)

Component	CAS No.	RTK List
Gasoline	86290-81-5	Not listed.
Naphtha (petroleum), catalytic reformed	68955-35-1	Not listed.
Naphtha (petroleum), light catalytic cracked	64741-55-5	Not listed.
Naphtha (petroleum), isomerization	64741-70-4	Not listed.
Hydrocarbons, C1-4, debutanizer fraction	68527-19-5	Not listed.
Benzene	71-43-2	E
Xylenes	1330-20-7	Listed.

Note: E = Extraordinarily Hazardous Substance

New Jersey
US New Jersey Worker and Community Right-to-Know Act (New Jersey Statute Annotated Section 34:5A-5)

Component	CAS No.	RTK List
Gasoline	86290-81-5	Not listed.
Naphtha (petroleum), catalytic reformed	68955-35-1	Not listed.
Naphtha (petroleum), light catalytic cracked	64741-55-5	Not listed.
Naphtha (petroleum), isomerization	64741-70-4	Not listed.
Hydrocarbons, C1-4, debutanizer fraction	68527-19-5	Not listed.
Benzene	71-43-2	SHHS
Xylenes	1330-20-7	SHHS

Note: SHHS = Special Health Hazard Substance

Pennsylvania

US Pennsylvania Worker and Community Right-to-Know Law (34 Pa. Code Chap. 301-323)

Component	CAS No.	RTK List
Gasoline	86290-81-5	Listed.
Naphtha (petroleum), catalytic reformed	68955-35-1	Not listed.
Naphtha (petroleum), light catalytic cracked	64741-55-5	Not listed.
Naphtha (petroleum), isomerization	64741-70-4	Not listed.
Hydrocarbons, C1-4, debutanizer fraction	68527-19-5	Not listed.
Benzene	71-43-2	ES
Xylenes	1330-20-7	E

Note: E = Environmental Hazard; S = Special Hazardous Substance

California

California Prop 65: WARNING: This product contains chemicals known to the State of California to cause cancer, birth defects or other reproductive harm.

Component	Type of Toxicity
Gasoline	cancer (wholly vaporized)
Benzene	developmental, male & cancer

Section 16: OTHER INFORMATION

Disclaimer:

The information contained in this document applies to this specific material as supplied. It may not be valid for this material if it is used in combination with any other materials. It is the user's responsibility to satisfy oneself as to the suitability and completeness of this information for his own particular use.

Expiry Date: March 18, 2015

Version: 1.0

MSDS Prepared by: **Deerfoot Consulting Inc.**

Phone: (403) 720-3700

Material Safety Data Sheet

FIR No.: 175527 **Level:** 2
Version Number: CA-EN-8 **Release Date:** 2011-07-13

1. Product and Company Identification

Product Name: SAE 75W-90 API GL-4 Gear Oil
Product Code: See Attachment
Application: Gear oil
Supplier: Ford Motor Company of Canada
Oakville, Ontario L6J 5E4
1-800-392-3673
Emergency Telephone: Poison Control Center: 1-800-959-3673
CHEMTREC: U.S. and Canada: 1-800-424-9300
CHEMTREC: International: 1-703-527-3887

2. Composition/Information on Ingredients

This chemical product is a preparation.

Chemical Name	CAS Number	Percent Concentration	Hazard Classification
PETROLEUM DISTILLATES HYDROTREATED HEAVY PARAFFINIC	64742-54-7	40-70	HAZCOM RSMS_P_SOM RSMS_D_ALL DSL LISTED
PETROLEUM DISTILLATES, HYDROTREATED HEAVY NAPHTHENIC	64742-52-5	10-30	RSMS_P_SOM RSMS_D_ALL HAZCOM DSL LISTED
PETROLEUM DISTILLATES, HYDROTREATED LIGHT PARAFFINIC	64742-55-8	3-7	DSL LISTED RSMS_P_SOM HAZCOM RSMS_D_ALL

3. Hazards Identification

Health:

Exposure to oil mist/fume/vapor may cause respiratory tract irritation.
Inhalation of mist and vapors may irritate the nose, throat, and lungs.
Ingestion may cause slight stomach irritation and discomfort.
This product is not expected to cause eye irritation under normal conditions of use. Symptoms of slight eye irritation may result when direct contact occurs, or when exposed to high mist levels in poorly ventilated areas.
No skin irritation can be expected from single short-term exposure to this product. Prolonged or repeated contact may produce some irritation.

4. First-Aid Measures

Inhalation:
If inhalation of gas/fume/vapor/dust/mist from the material is excessive (air concentration is greater than the TLV or health effects are noticed), immediatly remove the affected person(s) to fresh air.
If irritation persists, get medical attention.

Skin Contact:
Immediately take off all contaminated clothing.
Wash skin with soap and water.
If irritation persists, get medical attention.

Eye Contact:
In case of contact with eyes, rinse immediately with plenty of water for at least 15 minutes and seek medical attention.
If irritation persists, get medical attention.

Ingestion:
If the material is swallowed, get immediate medical attention or advice -- Do not induce vomiting.

5. Fire-Fighting Measures

Extinguishing Media:
EXTINGUISHER INFORMATION: Dry chemical, foam, carbon dioxide, water fog.

Specific Methods:
Use water to cool fire-exposed containers, structures, and to protect personnel.
Water may be an ineffective extinguishing medium.

Specific Hazards:
Empty containers may retain product residue including Flammable or Explosive vapors. Do not cut, drill, grind, or weld near full, partially full, or empty product containers.
Irritating and/or toxic fumes and gases may be emitted upon the product's decomposition.
Upon decomposition, this product emits carbon monoxide, carbon dioxide and/or low molecular weight hydrocarbons.

Protection of Firefighters:
Fire fighters should be equipped with NIOSH-approved, self-contained breathing apparatus (SCBA) and full protective clothing.

6. Accidental Release Measures

Personal Precautions:
Avoid inhalation of vapors and contact with skin and eyes.
In case of spills, beware of slippery floors and surfaces.
Wear appropriate protective equipment and clothing during clean-up.

Environmental Precautions:
Do not allow the spilled product to enter public drainage system or open water courses.
WATER SPILL: Remove from surface by skimming or with suitable absorbents. If allowed by local authorities and environmental agencies, sinking and/or suitable dispersants may be used in confined waters.

Methods for Cleaning Up: Contain the discharged material.
Absorb the spilled material with an inert absorbent (nonflammable) material.
In case of large spills, follow all facility Emergency Response Procedures.

7. Handling and Storage

Handling:

Technical Measures: Avoid the generation of oil mists.

Precautions and Advice for Safe Handling: Elevated temperature or mechanical action may form vapors, mist, or fumes which may be irritating to the eyes, nose, throat, and lungs.
Avoid breathing vapors or mist.
Keep the container closed when not in use.

Storage: **Technical Measures:** No special precautions.

Storage Conditions: Keep the container tightly closed and in a cool, well-ventilated place.
Store this product away from strong oxidizing agents.

8. Exposure Controls/Personal Protection

Engineering Measures: Use adequate mechanical ventilation (general and/or local exhaust) ventilation to maintain exposure below PEL(s) and/or TLV(s).

Control Parameters: If oil mist is generated, observe the OSHA exposure limit of 5 mg/m3.
Ford Motor Company recommends an exposure limit of 1.0 mg/m3.

Personal Protective Equipment:

Respiratory Protection: If engineering controls do not maintain airborne concentrations to a level which is adequate to protect worker health, an approved respirator must be worn. Respirator selection, use and maintenance should be in accordance with the requirements of OSHA Respiratory Protection Standard 29 CFR 1910.134 and/or Canadian Standard CSA Z94.4.

Hand Protection: Use of impervious gloves is recommended, such as neoprene.
The use of nitrile-latex gloves is recommended.
The use of polyvinyl chloride gloves is recommended.

Eye Protection: Wear safety glasses with side shields.
Wear chemical goggles; face shield (if splashing is possible).

Skin and Body Protection: Remove contaminated clothing and wash before reuse.

FIR No.:	175527	**Level:**	2
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Hygiene Measures: Wash thoroughly after handling.
When using this material, do not eat, drink or smoke.

9. Physical and Chemical Properties

Specific Gravity: 0.88-0.89 H2O=1 @20-25°C

Physical State: LIQUID

Form: OIL

Odor: HYDROCARBON

Color: BRIGHT AND CLEAR

pH: NA N.AP

Temperature Range During which Changes in Physical State Occur:

Boiling Point: >280 °C

Flash Point: 177 °C COC

Auto-ignition Temperature: >320 °C

Explosion Properties:

UEL: N.AV

LEL: N.AV

Vapor Pressure: <0.5@20°C Pa

Vapor Density: >1 (AIR=1)

Solubility: NEGLIGIBLE IN WATER

Viscosity: > 40 mm2/s @40°C

Evaporation Rate: N.AV

10. Stability and Reactivity

Stability: This is a stable material.

Conditions and Materials to Avoid: This product may react with strong oxidizing agents (bleach--sodium hypochlorite, calcium hypochlorite, hydrogen peroxide, permanganate, nitric acid, concentrated OXYGEN, perchlorates).

Hazardous Decomposition Products: Carbon monoxide, carbon dioxide, and other low molecular weight hydrocarbons.
Irritating and/or toxic gases may be emitted upon the product's decomposition.

FIR No.:	175527	**Level:**	2
Version Number:	CA-EN-8	**Release Date:**	2011-07-13

11. Toxicological Information

Chronic (Long Term) Toxicity:

Base oil severely refined: Not carcinogenic in animal studies.
Representative material passes IP-346, Modified Ames test, and/or other screening tests.
Continuous long term contact with used motor oil has caused skin cancer in animal tests.

12. Ecological Information

No specific aquatic data available for this product.

13. Disposal Considerations

Waste from Residues:

Dispose of waste material according to Local, State, Federal, and Provincial Environmental Regulation.

Contaminated Packaging:

No consideration given when disposed of according to local, state, and Federal regulations.

Material Safety Data Sheet

FIR No.:	175527	**Level:**	2
Version Number:	CA-EN-8	**Release Date:**	2011-07-13

14. Transport Information

U.S. Department of Transportation (DOT) 49 - CFR 172.101
This product is not regulated as a dangerous good.

Canadian Transportation of Dangerous Goods (T.D.G.) - TDGR Schedule II
This product is not regulated as a dangerous good.

Secretary of Communication and Transportation (SCT) - NOM-002-SCT2/1994 (Mexico)
This product is not regulated as a dangerous good.

International and Domestic Air Transportation - ICAO & IATA Section 4.2
This product is not regulated as a dangerous good.

International Water Transportation - IMDG Code Amendment 31-02
This product is not regulated as a dangerous good.

15. Regulatory Information

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.
Don't pollute. Conserve resources. Return used oil to collection centers.
Material contains a chemical which is a Ford Motor Company Material of Concern. Use and release of this material should be minimized to the greatest extent possible.
Not a controlled product.

16. Other Information

Key/Legend: N.AP = Not applicable; N.AV = Not available; ND = Not determined or No data; TLV = Threshold limit value; TWA = Time-weighted average; STEL = Short-term exposure limit; C = Ceiling limit

The following sections contain revisions OR NEW statements.	2 15 16 4 8
Preparation Information:	The chemical identification and properties for this material were provided by the manufacturer. For Canadian locations, a manufacture's MSDS is available upon request. Health and safety information has been evaluated by the Occupational and Environmental Health Sciences Department, Ford Motor Company, Diagnostic Service Center II, 1800 Fairlane Drive, Allen Park, MI 48101, USA.

Material Safety Data Sheet

FIR No.:	175527	**Level:**	2
Version Number:	CA-EN-8	**Release Date:**	2011-07-13

Disclaimer:

The information on this data sheet represents our current data and is accurate to the best of our knowledge as to the proper handling of this product under normal conditions and in accordance with the application specified on the packaging and/or technical guidance literature. Any other use of the product which involves using the product in combination with any other product or any other process is the responsibility of the user.

Material Safety Data Sheet

FIR No.: 175527 **Level:** 2
Version Number: CA-EN-8 **Release Date:** 2011-07-13

Attachment

Product Code	Container Size	Part of Kit	Kit Product Code
XT-4-QGL	1 qt. (946 mL)		
XY-75W90-QGL (Obsolete)	1 qt. (946 mL)		

MATERIAL SAFETY DATA SHEET

1. Product and Company Identification

Material name	**CALCIUM OXIDE**
Version #	01
Revision date	09-19-2011
CAS #	1305-78-8
Product Codes	**J.T.Baker: 1410, 1414** **Macron: 0204, 3530, 4243, 4248, 4268**
Synonym(s)	Lime unslaked; lime burnt; quicklime; calx; lime purified
Manufacturer	Avantor Performance Materials, Inc.
Address	3477 Corporate Parkway Suite #200 Center Valley, PA 18034 US
Customer Service	855-282-6867
24 Hour Emergency	908-859-2151
Chemtrec	800-424-9300

2. Hazards Identification

Emergency overview

DANGER

Corrosive. Causes severe skin and eye burns. Causes digestive tract burns. Mist or vapor extremely irritating to eyes and respiratory tract. Reacts with water.

OSHA regulatory status

This product is considered hazardous under 29 CFR 1910.1200 (Hazard Communication).

Potential health effects

Routes of exposure	Ingestion. Inhalation. Skin contact. Eye contact.
Eyes	Corrosive. Causes severe eye burns. Dust or splashes from the mixture may cause permanent eye damage.
Skin	Corrosive. Causes severe skin burns.
Inhalation	Corrosive. May cause damage to mucous membranes in nose, throat, lungs and bronchial system.
Ingestion	Corrosive. Ingestion may produce burns to the lips, oral cavity, upper airway, esophagus and possibly the digestive tract.

Target organs

Eyes. Skin. Respiratory system.

Chronic effects

Corrosive. Prolonged contact causes serious tissue damage.

Potential environmental effects

The product may affect the acidity (pH-factor) in water with risk of harmful effects to aquatic organisms.

3. Composition / Information on Ingredients

Components	CAS #	Percent
CALCIUM OXIDE	1305-78-8	90 - 100

4. First Aid Measures

First aid procedures

Eye contact

Immediately flush with plenty of water for at least 15 minutes. If easy to do, remove contact lenses. Call a physician or poison control center immediately. In case of irritation from airborne exposure, move to fresh air. Get medical attention immediately.

Skin contact	Immediately flush with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Call a physician or poison control center immediately. Wash clothing separately before reuse. Destroy or thoroughly clean contaminated shoes.
Inhalation	Move to fresh air. If breathing stops, provide artificial respiration. If breathing is difficult, give oxygen. Call a physician or poison control center immediately.
Ingestion	Call a physician or poison control center immediately. Do not induce vomiting. If vomiting occurs, the head should be kept low so that stomach vomit doesn't enter the lungs.
Notes to physician	Keep victim under observation. Treat symptomatically.
General advice	In the case of accident or if you feel unwell, seek medical advice immediately (show the label where possible). Show this safety data sheet to the doctor in attendance. Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves.

5. Fire Fighting Measures

Flammable properties	The product is not flammable. No unusual fire or explosion hazards noted.
Extinguishing media	
Suitable extinguishing media	Carbon dioxide (CO2). Dry chemical powder. Foam.
Unsuitable extinguishing media	The product reacts with water and will generate heat.
Protection of firefighters	
Protective equipment and precautions for firefighters	Use water spray to cool unopened containers. Self-contained breathing apparatus and full protective clothing must be worn in case of fire. Cool containers exposed to flames with water until well after the fire is out.
Special protective equipment for fire-fighters	Wear full protective clothing, including helmet, self-contained positive pressure or pressure demand breathing apparatus, protective clothing and face mask. Wear self-contained breathing apparatus with a full facepiece operated in the positive pressure demand mode when fighting fires.
Specific methods	In the event of fire and/or explosion do not breathe fumes.

6. Accidental Release Measures

Personal precautions	Wear appropriate protective equipment and clothing during clean-up. Keep upwind. Keep out of low areas. Ventilate closed spaces before entering them.
Environmental precautions	Prevent further leakage or spillage if safe to do so. Avoid discharge into drains, water courses or onto the ground.
Methods for cleaning up	Avoid dust formation. Large Spills: Sweep up or vacuum up spillage and collect in suitable container for disposal. Small Spills: Sweep up and place in a clearly labeled container for chemical waste. Clean surface thoroughly to remove residual contamination. Never return spills in original containers for re-use. DO NOT GET WATER on spilled material or inside containers. Collect in a non-combustible container for prompt disposal. Clean up in accordance with all applicable regulations.

7. Handling and Storage

Handling	Do not get in eyes, on skin, on clothing. Do not taste or swallow. Wash thoroughly after handling. Do not eat, drink or smoke when using the product. Considerable heat is generated when water or acid is added, therefore when making solutions always add the caustic to the water or acid with constant stirring.
Storage	Keep tightly closed in a dry, cool and well-ventilated place.

8. Exposure Controls / Personal Protection

ACGIH

Material	Type	Value
CALCIUM OXIDE (1305-78-8)	TWA	2.0000 mg/m3

Occupational exposure limits

U.S. - OSHA

Material	Type	Value
CALCIUM OXIDE (1305-78-8)	PEL	5.0000 mg/m3

Engineering controls Good general ventilation (typically 10 air changes per hour) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

Personal protective equipment

Eye / face protection Wear safety glasses with side shields (or goggles) and a face shield.

Skin protection Wear appropriate chemical resistant clothing. Wear appropriate chemical resistant gloves.

Respiratory protection If engineering controls do not maintain airborne concentrations below recommended exposure limits (where applicable) or to an acceptable level (in countries where exposure limits have not been established), an approved respirator must be worn. Respirator type: High-efficiency particulate respirator with full facepiece.

General hygeine considerations Provide eyewash station and safety shower. Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants.

General Wear chemical protective equipment that is specifically recommended by the manufacturer. Launder contaminated clothing before reuse.

9. Physical & Chemical Properties

Appearance	Granular.
Color	White to yellow.
Odor	Not available.
Odor threshold	Not available.
Physical state	Solid.
Form	Powder.
pH	12.8 (Saturated solution)
Melting point	4661.6 °F (2572 °C)
Freezing point	4661.6 °F (2572 °C)
Boiling point	5162 °F (2850 °C)
Flash point	Not available.
Evaporation rate	Not available.
Flammability limits in air, upper, % by volume	Not available.
Flammability limits in air, lower, % by volume	Not available.
Specific gravity	3.37
Relative density	Not available.
Partition coefficient (n-octanol/water)	Not available
Auto-ignition temperature	Not available.
Molecular weight	56.08 g/mol

Molecular formula	Ca-O

10. Chemical Stability & Reactivity Information

Chemical stability	Material is stable under normal conditions. Material reacts with water.
Conditions to avoid	Exposure to moisture. Reacts violently with strong acids.
Incompatible materials	Moisture. Oxidizing agents. Acids. Halogens. Alcohols.
Hazardous decomposition products	Oxides of calcium.
Possibility of hazardous reactions	Hazardous polymerization does not occur.

11. Toxicological Information

Sensitization	Not a skin sensitizer.
Local effects	Causes severe burns.
Chronic effects	Corrosive. Prolonged contact causes serious tissue damage.
Carcinogenicity	This product is not considered to be a carcinogen by IARC, ACGIH, NTP, or OSHA.
Skin corrosion/irritation	Corrosive to skin and eyes.
Epidemiology	No epidemiological data is available for this product.
Mutagenicity	No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
Neurological effects	No data available for this product.
Reproductive effects	Contains no ingredient listed as toxic to reproduction
Teratogenicity	No data available to indicate product or any components present at greater than 0.1% may cause birth defects.
Symptoms and target organs	Corrosive effects.
Further information	Danger of very serious irreversible effects. Symptoms may be delayed.

12. Ecological Information

Ecotoxicity	The product may affect the acidity (pH-factor) in water with risk of harmful effects to aquatic organisms.
Persistence and degradability	Not available.
Partition coefficient (n-octanol/water)	Not available

13. Disposal Considerations

Disposal instructions	Dispose of this material and its container to hazardous or special waste collection point. Incinerate the material under controlled conditions in an approved incinerator. All wastes must be handled in accordance with local, state and federal regulations.
Contaminated packaging	Since emptied containers retain product residue, follow label warnings even after container is emptied. Offer rinsed packaging material to local recycling facilities.

14. Transport Information

DOT

Basic shipping requirements:

UN number	UN1910
Proper shipping name	Calcium oxide
Hazard class	8
Packing group	III

Additional information:

Special provisions	IB8, IP3, T1, TP33

Basic shipping requirements:

Labels required	8

Additional information:

Packaging exceptions	154
Packaging non bulk	213
Packaging bulk	240
ERG number	157

IATA

Basic shipping requirements:

UN number	1910
Proper shipping name	Calcium oxide
Hazard class	8
Packing group	III

Additional information:

ERG code	8L

IMDG

Basic shipping requirements:

UN number	1910
Proper shipping name	CALCIUM OXIDE
Hazard class	8



DOT



IATA



IMDG

15. Regulatory Information

US federal regulations

This product is a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.
All components are on the U.S. EPA TSCA Inventory List.

CERCLA/SARA Hazardous Substances - Not applicable.

CERCLA (Superfund) reportable quantity

None

Superfund Amendments and Reauthorization Act of 1986 (SARA)

Hazard categories	Immediate Hazard - Yes Delayed Hazard - No Fire Hazard - No Pressure Hazard - No Reactivity Hazard - No
Section 311 hazardous chemical	Yes
Food and Drug Administration (FDA)	Total food additive Direct food additive GRAS food additive

Inventory status

Country(s) or region	Inventory name	On inventory (yes/no)*
Australia	Australian Inventory of Chemical Substances (AICS)	Yes
Canada	Domestic Substances List (DSL)	Yes
Canada	Non-Domestic Substances List (NDSL)	No
China	Inventory of Existing Chemical Substances in China (IECSC)	Yes
Europe	European Inventory of Existing Commercial Chemical Substances (EINECS)	Yes
Europe	European List of Notified Chemical Substances (ELINCS)	No
Japan	Inventory of Existing and New Chemical Substances (ENCS)	Yes
Korea	Existing Chemicals List (ECL)	Yes
New Zealand	New Zealand Inventory	Yes
Philippines	Philippine Inventory of Chemicals and Chemical Substances (PICCS)	Yes
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

*A "Yes" indicates that all components of this product comply with the inventory requirements administered by the governing country(s)

State regulations This product does not contain a chemical known to the State of California to cause cancer, birth defects or other reproductive harm.

US - Pennsylvania RTK - Hazardous Substances: Listed substance

CALCIUM OXIDE (CAS 1305-78-8) Listed.

Saf-T-Data

Health: 2 - Moderate
Flammability: 0 - None
Reactivity: 2 - Moderate
Contact: 3 - Severe (Corrosive)
Lab Protective Equip: D - GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: W - White (Corrosive)

16. Labeling Info

Label Hazard Warning

DANGER

Corrosive. Causes severe skin and eye burns. Causes digestive tract burns. Mist or vapor extremely irritating to eyes and respiratory tract. Material reacts with water.

Label Precautions Use only with adequate ventilation. Do not get in eyes, on skin, or on clothing. Do not breathe dust. Do not taste or swallow. Wash thoroughly after handling.

Label First Aid Immediately flush eyes with plenty of water for at least 15 minutes. Immediately flush skin with plenty of water. If gas/fume/vapor/dust/mist from the material is inhaled, remove the affected person immediately to fresh air. Get medical attention immediately. IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician. Do not induce vomiting without advice from poison control center. If vomiting occurs, keep head low so that stomach content doesn't get into the lungs. Do not use mouth-to-mouth method if victim ingested the substance.

17. Other Information

NFPA ratings

Health: 3
Flammability: 0
Instability: 1
Special hazards: W

Disclaimer

THE INFORMATION PRESENTED IN THIS MATERIAL SAFETY DATA SHEET (MSDS/SDS) WAS PREPARED BY TECHNICAL PERSONNEL BASED ON DATA THAT THEY BELIEVE IN THEIR GOOD FAITH JUDGMENT IS ACCURATE. HOWEVER, THE INFORMATION PROVIDED HEREIN IS PROVIDED “AS IS,” AND AVANTOR PERFORMANCE MATERIALS MAKES AND GIVES NO REPRESENTATIONS OR WARRANTIES WHATSOEVER, AND EXPRESSLY DISCLAIMS ALL WARRANTIES REGARDING SUCH INFORMATION AND THE PRODUCT TO WHICH IT RELATES, WHETHER EXPRESS, IMPLIED, OR STATUTORY, INCLUDING WITHOUT LIMITATION, WARRANTIES OF ACCURACY, COMPLETENESS, MERCHANTABILITY, NON-INFRINGEMENT, PERFORMANCE, SAFETY, SUITABILITY, STABILITY, AND FITNESS FOR A PARTICULAR PURPOSE, AND ANY WARRANTIES ARISING FROM COURSE OF DEALING, COURSE OF PERFORMANCE, OR USAGE OF TRADE. THIS MSDS/SDS IS INTENDED ONLY AS A GUIDE TO THE APPROPRIATE PRECAUTIONARY HANDLING OF THE MATERIAL BY A PROPERLY TRAINED PERSON USING THIS PRODUCT, AND IS NOT INTENDED TO BE COMPREHENSIVE AS TO THE MANNER AND CONDITIONS OF USE, HANDLING, STORAGE, OR DISPOSAL OF THE PRODUCT. INDIVIDUALS RECEIVING THIS MSDS/SDS MUST ALWAYS EXERCISE THEIR OWN INDEPENDENT JUDGMENT IN DETERMINING THE APPROPRIATENESS OF SUCH ISSUES. ACCORDINGLY, AVANTOR PERFORMANCE MATERIALS ASSUMES NO LIABILITY WHATSOEVER FOR THE USE OF OR RELIANCE UPON THIS INFORMATION. NO SUGGESTIONS FOR USE ARE INTENDED AS, AND NOTHING HEREIN SHALL BE CONSTRUED AS, A RECOMMENDATION TO INFRINGE ANY EXISTING PATENTS OR TO VIOLATE ANY FEDERAL, STATE, LOCAL, OR FOREIGN LAWS. AVANTOR PERFORMANCE MATERIALS REMINDS YOU THAT IT IS YOUR LEGAL DUTY TO MAKE ALL INFORMATION IN THIS MSDS/SDS AVAILABLE TO YOUR EMPLOYEES.

Issue date

09-19-2011

Established in 1981 megaloid laboratories limited
2221 Ninth Line | Oakville, ON L6H 7G7
Phone: 905-337-7411 | Fax: 905-337-1686
megaloid.ca

Safety Data Sheet

1. PRODUCT INDENTIFICATION

Name **Diethylene Glycol**
Synonyms **dihydroxydiethyl ether; 2,2-oxydiethanol; 2-hydroxyethyl ether**
CAS# **111-46-6**
Europe EC# **203-872-2**
Product Uses **mfg of resins & polyols; antifreeze, dehydrating agent, component of inks, etc**

2. HAZARDS

Quick Guide: will burn in fire; toxic substances form in fire; may ignite on hot surface; toxic on ingestion

Canada – WHMIS **D 1B**
Key: ***B 2*** *– Flash Point <38°C,* ***B 3*** *– Flash Point >38°C & <93°C*
D 1 *– Immediately Toxic,* ***D 2*** *– Chronic Toxicity*
C *– Oxidising Substance,* ***E*** *– Corrosive,* ***F*** *– Reactive Substance*

U.S.A. – HMIS **Health – 2, Fire – 1, Reactivity – 0**
Key: ***0****=minimal,* ***1****=slight,* ***2****=moderate,* ***3****=serious,* ***4****=severe*

3. COMPOSITION

	%	TWAEV / TLV mg/m^3	LD_{50} (mg/kg) ORAL	LD_{50} (mg/kg) SKIN	LC_{50} ppm INHALATION
2-hydroxyethyl ether	100%	not listed	2300	11,890	1070

4. FIRST AID

SKIN: Wash with water. Remove contaminated clothing and do not reuse until laundered.
EYES: Wash eyes with plenty of water, holding eyelids open. Seek medical assistance promptly if there is irritation.
INHALATION: Remove from contaminated area promptly. ***CAUTION: Rescuer must not endanger himself!*** If breathing stops, administer artificial respiration and seek medical aid promptly.
INGESTION: Give plenty of water to dilute product. Do not induce vomiting (NOTE below). Keep victim quiet. If vomiting occurs, lower victim's head below hips to prevent inhalation of vomited material. Seek medical help promptly.

Inadvertent inhalation of vomited material may seriously damage the lungs. The danger of this is greater than the risk of poisoning through absorption of this relatively low-toxicity substance. The stomach should only be emptied under medical supervision, and after the installation of an airway to protect the lungs.

5. FIRE FIGHTING & FLAMMABILITY

Flash Point	124°C / 255°F (closed cup)
Autoignition Temperature	224°C / 435°F
Flammable Limits	1.6% – 10.8%
Combustion Products	carbon monoxide, nitrogen oxides, smoke, part oxidised hydrocarbon fragments, including (irritating) formaldehyde
Fire Fighting Precautions	foam, dry chemical, water fog, water spray – water jet spreads flames; firefighters must wear SCBA
Static Charge Accumulation	cannot accumulate a static charge

Please ensure that this MSDS is given to, and explained to people using this product.

6. ACCIDENTAL RELEASE MEASURES

Leak Precaution	dyke to control spillage and prevent environmental contamination
Handling Spill	ventilate contaminated area; recover free liquid with suitable pumps; absorb residue on an inert sorbent, sweep, shovel & store in closed containers for recycling or disposal

7. HANDLING & STORAGE

Diethylene glycol absorbs moisture from the air. Store in a dry environment, away from sources of open flame, oxidising agents and substances listed in Part 10.

This product may react with oxygen in the air to form explosive or flammable peroxides. Ensure that containers are full and tightly sealed. If prolonged storage of a part container is anticipated, flush headspace with dry nitrogen gas prior to sealing. Always ensure that containers, whether empty or full, or part full, are tightly sealed unless in use.

Avoid breathing product mist. Use with adequate ventilation. Never cut, drill, weld or grind on or near this container. Avoid contact with skin and wash work clothes frequently. An eye bath and safety shower must be available near the workplace.

Sweet taste makes glycols attractive to pets and children. Keep away from children and clean spills promptly.

8. EXPOSURE CONTROL & PERSONAL PROTECTION

Ontario TWAEV	not listed – *AIHA WEEL is 10 mg/m^3 / 2.3ppm*
ACGIH TLV	not listed
OSHA PEL	not listed
Ventilation	not required; if visible mist is generated, install mechanical ventilation at source
Hands	no special protective gloves required; nitrile or butyl gloves are resistant to diethylene glycol
Eyes	safety glasses with side shields – *always protect the eyes*
Clothing	no special protective clothing required

9. PHYSICAL PROPERTIES

Odour & Appearance	clear, colourless, odourless, viscous, hygroscopic liquid with a sweet taste
Odour Threshold	not known – odourless
Vapour Pressure	0.0057mmHg / 0.00076kPa (25°C / 77°F)
Evaporation Rate (*Butyl Acetate = 1*)	0.001 – *not considered volatile*
Vapour Density (air = 1)	3.7
Boiling Range	246°C / 475°F
Melting Point	-10.5^{o}C / 13°F – *supercools to well below this temperature*
Specific Gravity	1.118 (20/20°C)
Water Solubility	complete
Also soluble in	alcohols, ketones, ethers, esters; limited solubility in hydrocarbons
Viscosity	38centipoise (20°C / 68°F)
pH	none – (*does not liberate hydrogen ions when dissolved*)
Conversion Factor	1ppm = 4.3mg/m^3
Molecular Weight	106grams per mole

10. REACTIVITY

Dangerously Reactive With	strong oxidising agents & hypochlorites; reacts with powdered metals: aluminium, zinc, or alkali metals: sodium, potassium, lithium, or their hydrides releases hydrogen & creates alkali; reacts with boron trichloride & aluminium chloride to produce hydrogen chloride gas
Also Reactive With	epoxides, strong acids & acid anhydrides, carbon disulphide, halogens & isocyanates
Stability	stable; will not polymerize
Decomposes in Presence of	air to form peroxides which may explode; oxidation is faster in the presence of acid & if heated
Decomposition Products	none apart from Hazardous Combustion Products
Sensitive to Mechanical Impact	no

Please ensure that this MSDS is given to, and explained to people using this product.

11. TOXICITY

Effects, Acute Exposure

Skin Contact	little to no effect
Skin Absorption	slight; no toxic effects by this route
Eye Contact	may be slightly irritating
Inhalation	little to no effect; low vapour pressure makes vapour formation unlikely; diethylene glycol is used to create theatrical mist with no reported consequences
Ingestion*	ingestion in amounts similar to those producing intoxication with alcohol cause similar effects; headache, dizziness, drowsiness; *not a route of occupational exposure*

Effects, Chronic Exposure

General	experimental long-term ingestion has produced renal stones & liver damage in rodents
Sensitising	not a sensitiser in humans or animals
Carcinogen/Tumorigen	not considered a tumorigen or a carcinogen in humans or animals
Reproductive Effect	no known effect in humans or animals
Mutagen	no known effect on humans or animals
Synergistic With	consumption of ethyl alcohol
LD_{50} (oral)*	2300 & 28,100mg/kg (mouse), 3300 & 3400mg/kg (cat), 4400 – 44,000mg/kg (rabbit),
(*Note very broad range of oral LD_{50}*)	7800 – 30,000mg/kg (rat), 8000-9900mg/kg (dog), 7800 – 13,200mg/kg (guinea pig)
LD_{50} (skin)	11,890 & 13,300mg/kg (rabbit)
LC_{50} (inhalation)	above 1070ppm (rat)

**** NOTE on oral toxicity:*** *Diethylene glycol is more toxic in humans than to the laboratory animals used in testing (above). Obviously, LD_{50} testing cannot be carried out on humans. In 1937, 105 people (34 children, 71 adults) died after ingesting an elixir containing 72% diethylene glycol, 8% sulfanilamide & 20% flavours, saccharin, caramel, plus 10% water for 6-13 days. More recently, half of a group of male prisoners, who had ingested diethylene glycol for 2 years (as a cleaning solution), were found to be suffering some neurological abnormalities. However, ingestion is not an expected route of entry for this industrial substance.*

12. ECOLOGICAL INFORMATION

Bioaccumulation	highly water soluble; cannot bioaccumulate
Biodegradation	biodegrades readily in the presence of oxygen; a wide range of degradation rates are seen: 30% to 70% in 20 – 30 days; also, over 90% after 28 days
Abiotic Degradation	reacts with atmospheric hydroxyl radicals; estimated ½-life in air is 6 to 12 hours
Mobility in soil, water	water soluble; moves readily in soil & water
Aquatic Toxicity	
LC_{50} (Fish, 96hr)	>32,000mg/kg (Gambusia affinis), >10,000mg/kg (Leuciscus idus, 48hr), >5000mg/kg (Carassius auratus, 24hr),
LC_{50} (Crustacea, 24hr)	>10,000mg/kg (Artemia salina), >10,000mg/kg (Daphnia magna)
NOEC (Algae)	800mg/litre (Anacystis aeruginosa)
EC_0 (Algae)	1700mg/litre (Microcystis aeruginosa) – *this is an EC_0, not an EC_{50} – no effect at this dose*
EC_{50} (Bacteria)	29,228mg/litre (Photobacterium phosphoreum, 15min), 40,000mg/litre (mixed bacterial culture)
NOEC (Bacteria)	4000mg/litre (Chilomonas paramaecium), 8000mg/litre (Pseudomonas putida)

13. DISPOSAL

Waste Disposal	**do not flush to sewer**, recycle solvent if possible, local regulations may permit disposal in sanitary landfill, may be incinerated in approved facility after mixing with a flammable waste
Containers	**Drums** should be reused. Recondition and pressure test by a licensed reconditioner prior to re-use. **Pails** must be vented and thoroughly dried prior to crushing and recycling. **IBCs** (intermediate bulk containers): polyethylene bottle must be pressure tested & recertified at 30 months. Replace at 60 months (5yrs). Steel containers must be inspected, pressure tested & recertified every 5 years. ***Never cut, drill, weld or grind on or near this container, even if empty***

Please ensure that this MSDS is given to, and explained to people using this product.

14. TRANSPORT CLASSIFICATION

Canada TDG	**PIN**	**UN - not regulated for transport**
AND	**Shipping Name**	**not regulated for transport**
U.S.A. 49 CFR	**Class & Packing Group**	**not regulated for transport**
Marine Pollutant		not a marine pollutant
ERAP Required		**NO**

EMERGENCY INFORMATION

Canada	**Call CANUTEC (collect)**	**(613) 996-6666**
U.S.A.	**Call CHEMTREC**	**(800) 424-9300**

15. REGULATIONS

Canada DSL	**on inventory**
U.S.A. TSCA	**on inventory**
Europe EINECS	**on inventory**
Europe Classification	**Harmful** 
Europe Risk Phrases	**R: 22 –** *Harmful if swallowed.*
Europe Safety Phrases	**S: 46 –** *If swallowed, seek medical advice immediately.*

Allowable Tolerances: Residues of diethylene glycol are exempted from the requirement of a tolerance when used in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. Use: deactivator, adjuvant for formulations used before crop emerges from soil. Residues of diethylene glycol are exempted from the requirement of a tolerance when used in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. Use: deactivator for formulations used before crop emerges from soil, stabilizer.

FIFRA Requirements: Residues of diethylene glycol are exempted from the requirement of a tolerance when used in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. Use: deactivator, adjuvant for formulations used before crop emerges from soil. Residues of diethylene glycol are exempted from the requirement of a tolerance when used in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. Use: deactivator for formulations used before crop emerges from soil, stabilizer.

FDA Requirements: Diethylene glycol is an indirect food additive for use only as a component of adhesives.

16. OTHER INFORMATION

Prepared for Megaloid Laboratories by Peter Bursztyn, (705) 734-1577
*Data from **RTECS**, **HSDB** (Haz. Substance Data Base), **Cheminfo** (CCOHS), **IUCLID** Datasheets (ESIS – European Chem. Substance Info. System), & others.*
Preparation Date: ***June 2001*** *Revision Date*: ***December 2003, October 2006, October 2009; October 2012***

Please ensure that this MSDS is given to, and explained to people using this product.

MATERIAL SAFETY DATA SHEET

SECTION 1 PRODUCT AND COMPANY IDENTIFICATION

PRODUCT

Product Name: CAT HYDO ADVANCED 10
Product Description: Base Oil and Additives
MSDS Number: 19993
Intended Use: Hydraulic fluid

COMPANY IDENTIFICATION

Supplier: **Imperial Oil Products Division**
240 4th Avenue
Calgary, ALBERTA. T2P 3M9 Canada

24 Hour Environmental / Health Emergency Telephone	519-339-2145
Transportation Emergency Phone Number	519-339-2145
Product Technical Information	1-800-268-3183
Supplier General Contact	1-800-567-3776

SECTION 2 COMPOSITION / INFORMATION ON INGREDIENTS

No Reportable Hazardous Substance(s) or Complex Substance(s).

SECTION 3 HAZARDS IDENTIFICATION

This material is not considered to be hazardous according to regulatory guidelines see Section 15.

HEALTH EFFECTS

Low order of toxicity. Excessive exposure may result in eye, skin, or respiratory irritation. High-pressure injection under skin may cause serious damage.

NFPA Hazard ID:	Health:	0	Flammability:	1	Reactivity: 0
HMIS Hazard ID:	Health:	0	Flammability:	1	Reactivity: 0

NOTE: This material should not be used for any other purpose than the intended use in Section 1 without expert advice. Health studies have shown that chemical exposure may cause potential human health risks which may vary from person to person.

SECTION 4 FIRST AID MEASURES

INHALATION

Remove from further exposure. For those providing assistance, avoid exposure to yourself or others. Use adequate respiratory protection. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek

immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

SKIN CONTACT

Wash contact areas with soap and water. If product is injected into or under the skin, or into any part of the body, regardless of the appearance of the wound or its size, the individual should be evaluated immediately by a physician as a surgical emergency. Even though initial symptoms from high pressure injection may be minimal or absent, early surgical treatment within the first few hours may significantly reduce the ultimate extent of injury.

EYE CONTACT

Flush thoroughly with water. If irritation occurs, get medical assistance.

INGESTION

First aid is normally not required. Seek medical attention if discomfort occurs.

SECTION 5 FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA

Appropriate Extinguishing Media: Use water fog, foam, dry chemical or carbon dioxide (CO2) to extinguish flames.

Inappropriate Extinguishing Media: Straight streams of water

FIRE FIGHTING

Fire Fighting Instructions: Evacuate area. Prevent run-off from fire control or dilution from entering streams, sewers or drinking water supply. Fire-fighters should use standard protective equipment and in enclosed spaces, self-contained breathing apparatus (SCBA). Use water spray to cool fire exposed surfaces and to protect personnel.

Unusual Fire Hazards: Pressurised mists may form a flammable mixture.

Hazardous Combustion Products: Smoke, Fume, Aldehydes, Sulphur oxides, Incomplete combustion products, Oxides of carbon

FLAMMABILITY PROPERTIES

Flash Point [Method]: >200C (392F) [Estimated ASTM D-92]
Flammable Limits (Approximate volume % in air): LEL: 0.9 UEL: 7.0
Autoignition Temperature: N/D

SECTION 6 ACCIDENTAL RELEASE MEASURES

NOTIFICATION PROCEDURES

In the event of a spill or accidental release, notify relevant authorities in accordance with all applicable regulations.

PROTECTIVE MEASURES

Avoid contact with spilled material. See Section 5 for fire fighting information. See the Hazard Identification

Section for Significant Hazards. See Section 4 for First Aid Advice. See Section 8 for advice on the minimum requirements for personal protective equipment. Additional protective measures may be necessary, depending on the specific circumstances and/or the expert judgment of the emergency responders. For emergency responders: Respiratory protection: respiratory protection will be necessary only in special cases, e.g., formation of mists. Half-face or full-face respirator with filter(s) for dust/organic vapor or Self Contained Breathing Apparatus (SCBA) can be used depending on the size of spill and potential level of exposure. If the exposure cannot be completely characterized or an oxygen deficient atmosphere is possible or anticipated, SCBA is recommended. Work gloves that are resistant to hydrocarbons are recommended. Gloves made of polyvinyl acetate (PVA) are not water-resistant and are not suitable for emergency use. Chemical goggles are recommended if splashes or contact with eyes is possible. Small spills: normal antistatic work clothes are usually adequate. Large spills: full body suit of chemical resistant, antistatic material is recommended.

SPILL MANAGEMENT

Land Spill: Stop leak if you can do so without risk. Recover by pumping or with suitable absorbent.

Water Spill: Stop leak if you can do so without risk. Confine the spill immediately with booms. Warn other shipping. Remove from the surface by skimming or with suitable absorbents. Seek the advice of a specialist before using dispersants.

Water spill and land spill recommendations are based on the most likely spill scenario for this material; however, geographic conditions, wind, temperature, (and in the case of a water spill) wave and current direction and speed may greatly influence the appropriate action to be taken. For this reason, local experts should be consulted. Note: Local regulations may prescribe or limit action to be taken.

ENVIRONMENTAL PRECAUTIONS

Large Spills: Dyke far ahead of liquid spill for later recovery and disposal. Prevent entry into waterways, sewers, basements or confined areas.

SECTION 7 HANDLING AND STORAGE

HANDLING

Prevent small spills and leakage to avoid slip hazard. Material can accumulate static charges which may cause an electrical spark (ignition source). When the material is handled in bulk, an electrical spark could ignite any flammable vapors from liquids or residues that may be present (e.g., during switch-loading operations). Use proper bonding and/or earthing procedures. However, bonding and earthing may not eliminate the hazard from static accumulation. Consult local applicable standards for guidance. Additional references include American Petroleum Institute 2003 (Protection Against Ignitions Arising out of Static, Lightning and Stray Currents) or National Fire Protection Agency 77 (Recommended Practice on Static Electricity) or CENELEC CLC/TR 50404 (Electrostatics - Code of practice for the avoidance of hazards due to static electricity).

Static Accumulator: This material is a static accumulator.

STORAGE

The container choice, for example storage vessel, may effect static accumulation and dissipation. Do not store in open or unlabelled containers. Keep away from incompatible materials.

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure limits/standards for materials that can be formed when handling this product: When mists / aerosols can occur, the following are recommended: 5 mg/m³ - ACGIH TLV, 10 mg/m³ - ACGIH STEL.

NOTE: Limits/standards shown for guidance only. Follow applicable regulations.

ENGINEERING CONTROLS

The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Control measures to consider:

No special requirements under ordinary conditions of use and with adequate ventilation.

PERSONAL PROTECTION

Personal protective equipment selections vary based on potential exposure conditions such as applications, handling practices, concentration and ventilation. Information on the selection of protective equipment for use with this material, as provided below, is based upon intended, normal usage.

Respiratory Protection: If engineering controls do not maintain airborne contaminant concentrations at a level which is adequate to protect worker health, an approved respirator may be appropriate. Respirator selection, use, and maintenance must be in accordance with regulatory requirements, if applicable. Types of respirators to be considered for this material include:

No special requirements under ordinary conditions of use and with adequate ventilation.

For high airborne concentrations, use an approved supplied-air respirator, operated in positive pressure mode. Supplied air respirators with an escape bottle may be appropriate when oxygen levels are inadequate, gas/vapour warning properties are poor, or if air purifying filter capacity/rating may be exceeded.

Hand Protection: Any specific glove information provided is based on published literature and glove manufacturer data. Glove suitability and breakthrough time will differ depending on the specific use conditions. Contact the glove manufacturer for specific advice on glove selection and breakthrough times for your use conditions. Inspect and replace worn or damaged gloves. The types of gloves to be considered for this material include:

No protection is ordinarily required under normal conditions of use.

Eye Protection: If contact is likely, safety glasses with side shields are recommended.

Skin and Body Protection: Any specific clothing information provided is based on published literature or manufacturer data. The types of clothing to be considered for this material include:

No skin protection is ordinarily required under normal conditions of use. In accordance with good industrial hygiene practices, precautions should be taken to avoid skin contact.

Specific Hygiene Measures: Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants. Discard contaminated clothing and footwear that cannot be cleaned. Practise good housekeeping.

ENVIRONMENTAL CONTROLS

See Sections 6, 7, 12, 13.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Typical physical and chemical properties are given below. Consult the Supplier in Section 1 for additional data.

GENERAL INFORMATION

Physical State: Liquid
Colour: Amber
Odour: Characteristic
Odour Threshold: N/D

IMPORTANT HEALTH, SAFETY, AND ENVIRONMENTAL INFORMATION

Relative Density (at 15 C): 0.87
Flash Point [Method]: >200C (392F) [Estimated ASTM D-92]
Flammable Limits (Approximate volume % in air): LEL: 0.9 UEL: 7.0
Autoignition Temperature: N/D
Boiling Point / Range: > 316C (600F)
Vapour Density (Air = 1): > 2 at 101 kPa
Vapour Pressure: < 0.013 kPa (0.1 mm Hg) at 20°C
Evaporation Rate (n-butyl acetate = 1): N/D
pH: N/A
Log Pow (n-Octanol/Water Partition Coefficient): > 3.5
Solubility in Water: Negligible
Viscosity: 42 cSt (42 mm2/sec) at 40°C | 6.7 cSt (6.7 mm2/sec) at 100C
Oxidizing Properties: See Hazards Identification Section.

OTHER INFORMATION

Freezing Point: N/D
Melting Point: N/A
Pour Point: -33°C (-27°F)
DMSO Extract (mineral oil only), IP-346: < 3 %wt

SECTION 10 STABILITY AND REACTIVITY

STABILITY: Material is stable under normal conditions.

CONDITIONS TO AVOID: Excessive heat. High energy sources of ignition.

MATERIALS TO AVOID: Strong oxidizers

HAZARDOUS DECOMPOSITION PRODUCTS: Material does not decompose at ambient temperatures.

HAZARDOUS POLYMERIZATION: Will not occur.

SECTION 11 TOXICOLOGICAL INFORMATION

ACUTE TOXICITY

Route of Exposure	Conclusion / Remarks
Inhalation	
Toxicity (Rat): LC50 > 5000 mg/m3	Minimally Toxic. Based on test data for structurally similar materials.
Irritation: No end point data.	Negligible hazard at ambient/normal handling temperatures. Based on assessment of the components.
Ingestion	
Toxicity (Rat): LD50 > 5000 mg/kg	Minimally Toxic. Based on test data for structurally similar materials.

Skin	
Toxicity (Rabbit): LD50 > 5000 mg/kg	Minimally Toxic. Based on test data for structurally similar materials.
Irritation (Rabbit): Data available.	Negligible irritation to skin at ambient temperatures. Based on test data for structurally similar materials.
Eye	
Irritation (Rabbit): Data available.	May cause mild, short-lasting discomfort to eyes. Based on test data for structurally similar materials.

CHRONIC/OTHER EFFECTS

Contains:

Base oil severely refined: Not carcinogenic in animal studies. Representative material passes IP-346, Modified Ames test, and/or other screening tests. Dermal and inhalation studies showed minimal effects; lung non-specific infiltration of immune cells, oil deposition and minimal granuloma formation. Not sensitising in test animals.

Additional information is available by request.

CMR Status: None.

--REGULATORY LISTS SEARCHED--

1 = IARC 1	3 = IARC 2B	5 = ACGIH A1
2 = IARC 2A	4 = ACGIH ALL	6 = ACGIH A2

SECTION 12 ECOLOGICAL INFORMATION

The information given is based on data available for the material, the components of the material, and similar materials.

ECOTOXICITY

Material -- Not expected to be harmful to aquatic organisms.

MOBILITY

Base oil component -- Low solubility and floats and is expected to migrate from water to the land. Expected to partition to sediment and wastewater solids.

PERSISTENCE AND DEGRADABILITY

Biodegradation:

Base oil component -- Expected to be inherently biodegradable

BIOACCUMULATION POTENTIAL

Base oil component -- Has the potential to bioaccumulate, however metabolism or physical properties may reduce the bioconcentration or limit bioavailability.

SECTION 13 DISPOSAL CONSIDERATIONS

Disposal recommendations based on material as supplied. Disposal must be in accordance with current applicable laws and regulations, and material characteristics at time of disposal.

DISPOSAL RECOMMENDATIONS

Product is suitable for burning in an enclosed controlled burner for fuel value or disposal by supervised incineration at very high temperatures to prevent formation of undesirable combustion products.

REGULATORY DISPOSAL INFORMATION

Empty Container Warning Empty Container Warning (where applicable): Empty containers may contain residue and can be dangerous. Do not attempt to refill or clean containers without proper instructions. Empty drums should be completely drained and safely stored until appropriately reconditioned or disposed. Empty containers should be taken for recycling, recovery, or disposal through suitably qualified or licensed contractor and in accordance with governmental regulations. DO NOT PRESSURISE, CUT, WELD, BRAZE, SOLDER, DRILL, GRIND, OR EXPOSE SUCH CONTAINERS TO HEAT, FLAME, SPARKS, STATIC ELECTRICITY, OR OTHER SOURCES OF IGNITION. THEY MAY EXPLODE AND CAUSE INJURY OR DEATH.

SECTION 14 TRANSPORT INFORMATION

LAND (TDG): Not Regulated for Land Transport

LAND (DOT): Not Regulated for Land Transport

SEA (IMDG): Not Regulated for Sea Transport according to IMDG-Code

AIR (IATA): Not Regulated for Air Transport

SECTION 15 REGULATORY INFORMATION

WHMIS Classification: Not controlled

This product has been classified in accordance with hazard criteria of the Controlled Products Regulations and the (M)SDS contains all the information required by the Controlled Products Regulations.

CEPA: All components of this material are either on the Canadian Domestic Substances List (DSL), exempt, or have been notified under CEPA.

Complies with the following national/regional chemical inventory requirements: AICS, IECSC, DSL, EINECS, ENCS, KECI, PICCS, TSCA

The Following Ingredients are Cited on the Lists Below:

Chemical Name	CAS Number	List Citations
ZINC DITHIOPHOSPHATE	68649-42-3	6

--REGULATORY LISTS SEARCHED--

1 = TSCA 4 3 = TSCA 5e 5 = TSCA 12b

2 = TSCA 5a2 4 = TSCA 6 6 = NPRI

SECTION 16 OTHER INFORMATION

N/D = Not determined, N/A = Not applicable

THIS SAFETY DATA SHEET CONTAINS THE FOLLOWING REVISIONS:

Revision Changes:
Section 09: Pour Point C(F) was modified.
Section 09: Relative Density was modified.
Section 16: MSN,MAT ID was modified.
Section 15: Canadian List Citations Table was modified.
Section 01: Product Identification Product Name was modified.
Section 06: Protective Measures was added.
Section 06: Accidental Release - Protective Measures - Header was added.

WHMIS Classification: Not controlled

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DGN: 7081865 (1012734)

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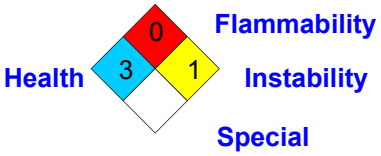
Prepared by: Imperial Oil Limited, IH and Product Safety

enthone

Material Safety Data Sheet

Material Safety Data Sheet

Emergency phone: Enthone Chemtrec #7827
US & Canada: 800 424-9300
Mexico: 01 800 022 1400, (55) 5559 1588
Brasil: 55 11 4353 2700



Health	3
Flammability	0
Physical hazards	1
Personal protection	

1 . Product and company identification

Product name : **SOLDEREX® NF LEAD CONCENTRATE**
Product code : 209710
Material uses Specialty assembly materials for the electronics industries
Manufacturer :

Enthone Inc
350 Frontage Road
West Haven, CT 06516
Phone: (203) 934-8611
Fax: (203) 799-8179
www.cooksonelectronics.com

Enthone OMI deMexico S.A. de C.V.
Norte 59 No. 896
Col. Industrial Vallejo
Mexico, D.F. 02300
Mexico
Phone: 52 55 5078 3904
Fax: 52 555 567 6326
www.cooksonelectronics.com

Cookson Electronics Brasil Ltda
Av.: José Odorizzi, No. 650
São Bernardo do Campo
São Paulo, CEP098100 000
Brasil
Phone: 55 11 4353 2500
Fax: 55 11 4353 2521
www.cooksonelectronics.com

Validation date : **11/20/2011.** **Supersedes Date** : 7/6/2011.
Prepared by : T. Valverde
(203)-799-4940

2. Hazards identification

Physical state : Liquid. [Clear.]
Odor : Sulfur [Slight]
OSHA/HCS status : This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).
Emergency overview : DANGER!
This product contains material(s) that are absorbed through the skin. Toxic by inhalation, in contact with skin and if swallowed. Corrosive to the eyes, skin and respiratory system. Causes burns. Do not breathe vapor or mist. Do not ingest. Do not get in eyes or on skin or clothing. Contains material that can cause target organ damage. Contains material which may cause cancer. Risk of cancer depends on duration and level of exposure. Contains material which may cause heritable genetic effects, based on animal data. Contains material which may cause birth defects, based on animal data. Contains material which can cause developmental abnormalities. Avoid exposure during pregnancy. Contains material which can impair male fertility. Contains material which can impair female fertility. Use only with adequate ventilation. Keep container tightly closed and sealed until ready for use. Wash thoroughly after handling.

Routes of entry : Dermal contact. Eye contact. Inhalation. Ingestion.

Continued on next page

2. Hazards identification

Potential acute health effects

Inhalation : Toxic by inhalation. Can cause target organ damage. Corrosive to the respiratory system. May cause burns to mouth, throat and stomach. Exposure can cause lung irritation, chest pain and edema, which may be fatal.

Ingestion : Toxic if swallowed. Can cause target organ damage. Ingestion may cause gastrointestinal irritation and diarrhea.

Skin : Corrosive to the skin. Causes burns. Prolonged or repeated contact with skin or mucous membrane may result in irritation symptoms, such as redness, blistering, dermatitis etc. Toxic in contact with skin. This product contains material(s) that are absorbed through the skin. Can cause target organ damage. and symptoms similar to those listed under inhalation or ingestion.

Eyes : Corrosive to eyes. Causes burns. Direct contact with the eyes can cause irreversible damage, including blindness.

Potential chronic health effects

Chronic effects : Adverse symptoms may include the following:
lead(II) methanesulphonate: anemia, paralysis, muscle weakness, headache, dizziness/vertigo, constipation, insomnia, metallic taste, death.
methanesulphonic acid:

Target organs : Contains material which may cause damage to the following organs: blood, kidneys, the nervous system, the reproductive system, mucous membranes, bladder, peripheral nervous system, gastrointestinal tract, upper respiratory tract, skin, eyes, central nervous system (CNS).

Carcinogenicity : Contains material which may cause cancer. Risk of cancer depends on duration and level of exposure.

Mutagenicity : Contains material which may cause heritable genetic effects, based on animal data.

Teratogenicity : Contains material which may cause birth defects, based on animal data.

Developmental effects : Contains material which can cause developmental abnormalities.

Fertility effects : Contains material which can impair male fertility. Contains material which can impair female fertility.

California Prop. 65 : **WARNING:** This product contains a chemical known to the State of California to cause cancer and birth defects or other reproductive harm.

Medical conditions aggravated by over-exposure : Pre-existing respiratory, skin and digestive disorders and disorders involving any other target organs mentioned in this MSDS as being at risk may be aggravated by over-exposure to this product.

3. Composition/information on ingredients

Name	CAS number	% by weight
lead(II) methanesulphonate	17570-76-2	50-60
methanesulphonic acid	75-75-2	0.1-1.0

Any ingredient not listed in Section 3 is non-regulated or present in the product in concentrations below legal disclosure limits.

Continued on next page

4 . First aid measures

Eye contact : Get medical attention immediately. Chemical burns must be treated promptly by a physician. Check for and remove any contact lenses. Immediately flush eyes with running water for at least 60 minutes, keeping eyelids open. Provide a readily-accessible eyewash facility and quick-drench safety shower.

Skin contact : Get medical attention immediately. In case of contact, immediately flush skin with plenty of water for at least 60 minutes while removing contaminated clothing and shoes. Provide a readily-accessible eyewash facility and quick-drench safety shower. Chemical burns must be treated promptly by a physician. Remove contaminated clothing and shoes. This product contains material(s) that are absorbed through the skin. See inhalation and ingestion. Wear appropriate personal protective equipment. Avoid direct contact with the human body. Wash contaminated clothing before reuse. Clean shoes thoroughly before reuse.

Inhalation : Get medical attention immediately. Chemical burns must be treated promptly by a physician. Move exposed person to fresh air. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. Keep person warm and at rest. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. If unconscious, place in recovery position and get medical attention immediately. Maintain an open airway. Loosen tight clothing such as a collar, tie, belt or waistband. Move affected person to fresh air. Do not induce vomiting unless directed to do so by medical personnel. If vomiting occurs, the head should be kept low so that vomit does not enter the lungs.

Ingestion : Get medical attention immediately. Wash out mouth with water. Remove dentures if any. Move exposed person to fresh air. Keep person warm and at rest. Do not induce vomiting unless directed to do so by medical personnel. If vomiting occurs, the head should be kept low so that vomit does not enter the lungs. Never give anything by mouth to an unconscious person. If unconscious, place in recovery position and get medical attention immediately. Maintain an open airway. Loosen tight clothing such as a collar, tie, belt or waistband. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel.

Protection of first-aiders : No action shall be taken involving any personal risk or without suitable training. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Wear suitable protective clothing, gloves and eye/face protection. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. Wash contaminated clothing thoroughly with water before removing it, or wear gloves.

5 . Fire-fighting measures

Flammability of the product : In a fire or if heated, a pressure increase will occur and the container may burst. Reacts violently when water is added to this product.

Extinguishing media

Suitable : Use an extinguishing agent suitable for the surrounding fire.

Not suitable : None known.

Special exposure hazards : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. Fire water contaminated with this material must be contained and prevented from being discharged to any waterway, sewer or drain.

Hazardous combustion products : carbon oxides
sulfur oxides
metal oxide/oxides

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Continued on next page

6 . Accidental release measures

Personal precautions : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilled material. Do not breathe vapor or mist. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment (see section 8).

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air). Water polluting material. May be harmful to the environment if released in large quantities.

Large spill : Stop leak if without risk. Move containers from spill area. Approach release from upwind. Prevent entry into sewers, water courses, basements or confined areas. Wash spillages into an effluent treatment plant or proceed as follows. Contain and collect spillage with non-combustible, absorbent material e.g. sand, earth, vermiculite or diatomaceous earth and place in container for disposal according to local regulations (see section 13). The spilled material may be neutralized with sodium carbonate, sodium bicarbonate or sodium hydroxide. Dispose of via a licensed waste disposal contractor. Contaminated absorbent material may pose the same hazard as the spilled product. Note: see section 1 for emergency contact information and section 13 for waste disposal.

Small spill : Stop leak if without risk. Move containers from spill area. Dilute with water and mop up if water-soluble. Alternatively, or if water-insoluble, absorb with an inert dry material and place in an appropriate waste disposal container. Dispose of via a licensed waste disposal contractor.

7 . Handling and storage

Handling : Put on appropriate personal protective equipment (see section 8). Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Avoid exposure during pregnancy. Do not get in eyes or on skin or clothing. Provide a readily-accessible eyewash facility and quick-drench safety shower. Do not breathe vapor or mist. Do not ingest. Avoid release to the environment. Use only with adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Keep in the original container or an approved alternative made from a compatible material, kept tightly closed when not in use. Empty containers retain product residue and can be hazardous. Do not reuse container. Always add acids to water and basic solutions slowly and cautiously. Never add water to acids. The extreme heat generated can cause a violent reaction.

Storage : Store in accordance with local regulations. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Separate from alkalis. Separate from oxidizing materials. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination. Avoid contamination by any source including metals, dust and organic materials. Provide a readily-accessible eyewash facility and quick-drench safety shower.

Keep container tightly closed. Keep container in a cool, well-ventilated area.

Continued on next page

8 . Exposure controls/personal protection

Product name	Exposure limits
lead(II) methanesulphonate	**OSHA Final Rule (United States, 1989).** TWA: 50 µg/m³ 8 hour(s). **NIOSH REL (United States, 2001).** TWA: 0.05 mg/m³ 10 hour(s). **OSHA PEL 1989 (United States, 1989).** TWA: 50 µg/m³ 8 hour(s). **ACGIH TLV (United States, 2/2010).** TWA: 0.05 mg/m³, (as Pb) 8 hour(s). **OSHA PEL 1989 (United States, 3/1989).** TWA: 50 ug/m³, (as Pb) 8 hour(s). **ACGIH TLV (United States, 5/2004). Notes: Substance identified by other sources as a suspected or confirmed human carcinogen. 1995-1996 Adoption. Substances for which the TLV is higher than the OSHA Permissible Exposure Limit (PEL) and/or the NIOSH Recommended Exposure Limit (REL). See CFR 58(124) :36338-33351, June 30, 1993, for revised OSHA PEL. See Notice of Intended changes. Identifies substances identified in the BEI documentation for Methemoglobin inducers (for which methemoglobin is the principle toxicity) and organophosphorous cholinesterase inhibitors are part of this notation.** TWA: 0.05 mg/m³ 8 hour(s). Form: All forms **OSHA PEL 1989 (United States, 3/1989). Notes: Sec. 1910.1025 Lead.** TWA: 50 µg/m³ 8 hour(s). Form: All forms

Consult local authorities for acceptable exposure limits.

Recommended monitoring procedures : If this product contains ingredients with exposure limits, personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment.

Engineering measures : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits. Provide a readily-accessible eyewash facility and quick-drench safety shower. Processes should be designed to minimize airborne and skin exposure to hazardous substances.

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location. Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Take off immediately all contaminated clothing. Contaminated work clothing should not be allowed out of the workplace.

Personal protection

Respiratory : Use a properly fitted, air-purifying or air-fed respirator complying with NIOSH if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator. Risk assessments should be completed by a Certified Industrial Hygienst.

Hands : Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. The user must check that the final choice of type of glove selected for handling this product is the most appropriate and takes into account the particular conditions of use, as included in the user's risk assessment. Risk assessments should be completed by a Certified Industrial Hygienst.

Continued on next page

8 . Exposure controls/personal protection

Eyes : Avoid contact with eyes. Safety eyewear should be used when there is a likelihood of exposure. Direct contact with the eyes can cause irreversible damage, including blindness. Use safety eyewear designed to protect against splash of liquids.

Skin : Avoid contact with skin and clothing. Wear suitable protective clothing. Body garments used should be based upon the task being performed (e.g., lab coat, chemical resistant protective suit, sleevelets, synthetic apron, gauntlets) to avoid exposed skin surfaces. Wash contaminated clothing thoroughly with water before removing it, or wear gloves.

Environmental exposure controls : Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

9 . Physical and chemical properties

Physical state : Liquid. [Clear.]

Flash point : Not available.

Auto-ignition temperature : Not available.

Flammable limits : Not available.

Color : Colorless.

Odor : Sulfur [Slight]

pH : <2

Boiling/condensation point : Not available.

Melting/freezing point : Not available.

Relative density : 1.7

Vapor pressure : Not available.

Vapor density : Not available.

Odor threshold : Not available.

Evaporation rate : Not available.

VOC : 0 g/l

Solubility : Easily soluble in the following materials: cold water and hot water.

10 . Stability and reactivity

Stability : The product may not be stable under certain conditions of storage or use. See "Possibility of Hazardous Reactions" for further information.

Conditions to avoid : No specific data.

Incompatibility with various substances : Reactive with oxidizing agents, alkalis.

Hazardous decomposition products : Under normal conditions of storage and use, hazardous decomposition products should not be produced.

Other Hazardous decomposition products : sulfur oxides (SO_2, SO_3 etc.), lead oxides

Hazardous polymerization : Under normal conditions of storage and use, hazardous polymerization will not occur.

Continued on next page

11 . Toxicological information

Acute toxicity

Product/ingredient name	Result	Species	Dose	Exposure
methanesulphonic acid	LC50 Inhalation Vapor LD50 Dermal LD50 Oral	Rat Guinea pig Rat	>330 ppm >2000 mg/kg 200 mg/kg	6 hours - -

Carcinogenicity Classification

Product/ingredient name	ACGIH	IARC	EPA	NIOSH	NTP	OSHA
lead(II) methanesulphonate	A3	2B	-	-	Possible	-

Enthone has not conducted specific studies on the toxicity of this product.

12 . Ecological information

Aquatic ecotoxicity

Product/ingredient name	Result	Species	Exposure
methanesulphonic acid	Acute EC50 1.7 mg/L Acute LC50 >770 mg/L	Daphnia Fish	24 hours 96 hours

13 . Disposal considerations

Waste disposal : The generation of waste should be avoided or minimized wherever possible. Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe way. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.

Disposal should be in accordance with applicable regional, national and local laws and regulations.

Refer to Section 7: HANDLING AND STORAGE and Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION for additional handling information and protection of employees.

14 . Transport information

Regulatory information	UN number	Proper shipping name	Classes	PG*	Label	Additional information
DOT Classification	UN3265	Corrosive Liquid, Acidic, Organic, N.O.S (Methane Sulfonic Acid). Marine pollutant (lead(II) methanesulphonate)	8	II		ERG# 153
IMDG Class	UN3265	Corrosive Liquid, Acidic, Organic, N.O.S (Methane Sulfonic Acid). Marine pollutant (lead(II) methanesulphonate)	8	II		Marine pollutant

Continued on next page

14 . Transport information

IATA-DGR Class	UN3265	Corrosive Liquid, Acidic, Organic, N.O.S (Methane Sulfonic Acid)	8	II 	-
UN Class	UN3265	Corrosive Liquid, Acidic, Organic, N.O.S (Methane Sulfonic Acid)	8	II 	-

PG* : Packing group

15 . Regulatory information

United States

HCS Classification : Toxic material
Corrosive material
Carcinogen
Target organ effects

U.S. Federal regulations : **TSCA 5(a)2 proposed significant new use rules**: No products were found.
TSCA 5(a)2 final significant new use rules: No products were found.
TSCA 12(b) one-time export: No products were found.
TSCA 12(b) annual export notification: No products were found.

United States inventory (TSCA 8b) : All components are listed or exempted.

SARA 313

	Product name	CAS number	Concentration
Form R - Reporting requirements	lead(II) methanesulphonate	17570-76-2	50-60
Supplier notification	lead(II) methanesulphonate	17570-76-2	50-60

SARA 302/304/311/312 extremely hazardous substances: No products were found.

California Prop. 65

WARNING: This product contains a chemical known to the State of California to cause cancer and birth defects or other reproductive harm.

Canada

WHMIS (Canada) : Class D-1B: Material causing immediate and serious toxic effects (Toxic).
Class D-2A: Material causing other toxic effects (Very toxic).
Class E: Corrosive material

Canada inventory : At least one component is not listed in DSL but all such components are listed in NDSL.

International lists

China inventory (IECSC) : All components are listed or exempted.

Europe inventory : At least one component is not listed in EINECS but all such components are listed in ELINCS.
Please contact your supplier for information on the inventory status of this material.

Australia inventory (AICS) : All components are listed or exempted.

Japan inventory (ENCS) : All components are listed or exempted.

Korea inventory (KECI) : All components are listed or exempted.

Philippines inventory (PICCS) : All components are listed or exempted.

Continued on next page

16 . Other information

Definition of Terms

ACGIH	American Conference of Governmental Industrial Hygienists
Ceiling	Maximum exposure limit defined by OSHA
CAS	Chemical Abstract Service
IARC	International Agency for Research on Cancer
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
REL	Recommended Exposure Limit
RTK	Right to Know
SARA	Superfund Amendments and Reauthorization Act
STEL	Short Term Exposure Limit
TLV	ACGIH Threshold Limit Value
TLV-C	ACGIH Threshold Limit Value, Ceiling
TRADE SECRET	Claimed as allowed under 29CFR§1910.1200
TSCA	Toxic Substances Control Act
PPE	Personal Protection Equipment
CEPA	Canadian Environmental Protection Act
DSL	Domestic Substance List
NDSL	Non-Domestic Substance List
NSN	New Substance Notification Rules

Disclaimer

This Material Safety Data Sheet may be used to comply with OSHA's Hazard Communication Standard, 29CFR§1910.1200. This Material Safety Data Sheet may also be used to comply with the requirements of Workplace Hazardous Materials Information System, of the Controlled Products Regulations, under the Hazardous Products Act. Enthone furnishes the data contained herein in good faith without liability or legal responsibility for same whatsoever, and no warranty or guarantee, express or implied, is made with respect to such data; nor does Enthone grant permission, recommendation, or inducement to infringe any patent whether owned by Enthone or others. The data is offered solely for your information and consideration. Since conditions of use are beyond Enthone's control, user assumes all responsibility and risk.

4.1b1161

Cookson Electronics

Safety data sheet

1. Identification of the substance/mixture and of the company/undertaking

Product identifier

MAGNAFLOC® 351

Relevant identified uses of the substance or mixture and uses advised against

Relevant identified uses: flocculation agent

Details of the supplier of the safety data sheet

Company:
BASF SE
67056 Ludwigshafen
GERMANY
Global Mining Solutions

Telephone: +49 621 60-52555
E-mail address: product-safety-oilfield-applications@basf.com

Emergency telephone number

International emergency number:
Telephone: +49 180 2273-112

2. Hazards Identification

Label elements

According to Regulation (EC) No 1272/2008 [CLP]

The product does not require a hazard warning label in accordance with GHS criteria.

According to Directive 67/548/EEC or 1999/45/EC

Directive 1999/45/EC ('Preparation Directive')

The product does not require a hazard warning label in accordance with EC Directives.

Classification of the substance or mixture

According to Regulation (EC) No 1272/2008 [CLP]

No need for classification according to GHS criteria for this product.

According to Directive 67/548/EEC or 1999/45/EC

Possible Hazards:
May cause some eye irritation which should cease after removal of the product.
May cause some irritation to the respiratory system if dust is inhaled.
Prolonged contact with the product can result in skin irritation.
This type of product has a tendency to create dust if roughly handled. It does not burn readily but as with many organic powders, flammable dust clouds may be formed in air.
Very slippery when wet.

Other hazards

Assessment PBT / vPvB:
According to Annex XIII of Regulation (EC) No.1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH): The product does not contain a substance fullfilling the PBT (persistent/bioaccumulative/toxic) criteria or the vPvB (very persistent/very bioaccumulative) criteria..

3. Composition/Information on Ingredients

Mixtures

Chemical nature

polyacrylamide

4. First-Aid Measures

Description of first aid measures

Remove contaminated clothing.

If inhaled:
If difficulties occur after dust has been inhaled, remove to fresh air and seek medical attention.

On skin contact:
Wash thoroughly with soap and water.

On contact with eyes:
Wash affected eyes for at least 15 minutes under running water with eyelids held open.

On ingestion:

Rinse mouth and then drink plenty of water. Check breathing and pulse. Place victim in the recovery position, cover and keep warm. Loosen tight clothing such as a collar, tie, belt or waistband. Seek medical attention. Never induce vomiting or give anything by mouth if the victim is unconscious or having convulsions.

Most important symptoms and effects, both acute and delayed

Symptoms: No significant symptoms are expected due to the non-classification of the product.

Indication of any immediate medical attention and special treatment needed

Treatment: Treat according to symptoms (decontamination, vital functions), no known specific antidote.

5. Fire-Fighting Measures

Extinguishing media

Suitable extinguishing media:
dry powder, foam

Unsuitable extinguishing media for safety reasons:
water jet

Additional information:
If water is used, restrict pedestrian and vehicular traffic in areas where slip hazard may exist.

Special hazards arising from the substance or mixture

carbon oxides, nitrogen oxides
The substances/groups of substances mentioned can be released in case of fire. Very slippery when wet.

Advice for fire-fighters

Special protective equipment:
Wear a self-contained breathing apparatus.

Further information:
The degree of risk is governed by the burning substance and the fire conditions. Contaminated extinguishing water must be disposed of in accordance with official regulations.

6. Accidental Release Measures

Personal precautions, protective equipment and emergency procedures

Use personal protective clothing.

Environmental precautions

Do not discharge into drains/surface waters/groundwater.

Methods and material for containment and cleaning up

For small amounts: Pick up with suitable appliance and dispose of.
For large amounts: Contain with dust binding material and dispose of.
Spilled product which becomes wet or spilled aqueous solution create a hazard because of their slippery nature. Avoid raising dust.

Reference to other sections

Information regarding exposure controls/personal protection and disposal considerations can be found in section 8 and 13.

7. Handling and Storage

Precautions for safe handling

Breathing must be protected when large quantities are decanted without local exhaust ventilation. Handle in accordance with good industrial hygiene and safety practice. Forms slippery surfaces with water.

Conditions for safe storage, including any incompatibilities

Further information on storage conditions: Store in unopened original containers in a cool and dry place. Avoid wet, damp or humid conditions, temperature extremes and ignition sources.

Storage stability:
Avoid extreme heat.

Specific end use(s)

For the relevant identified use(s) listed in Section 1 the advice mentioned in this section 7 is to be observed.

8. Exposure Controls/Personal Protection

Control parameters

Components with workplace control parameters

Particles, not otherwise specified, respirable

Particles, not otherwise specified, inhalable

Exposure controls

Personal protective equipment

Respiratory protection:
Suitable respiratory protection for lower concentrations or short-term effect: Particle filter with medium efficiency for solid and liquid particles (e.g. EN 143 or 149, Type P2 or FFP2)

Hand protection:
Chemical resistant protective gloves (EN 374)
Suitable materials also with prolonged, direct contact (Recommended: Protective index 6, corresponding > 480 minutes of permeation time according to EN 374):
e.g. nitrile rubber (0.4 mm), chloroprene rubber (0.5 mm), polyvinylchloride (0.7 mm) and other
Supplementary note: The specifications are based on tests, literature data and information of glove manufacturers or are derived from similar substances by analogy. Due to many conditions (e.g. temperature) it must be considered, that the practical usage of a chemical-protective glove in practice may be much shorter than the permeation time determined through testing.
Manufacturer's directions for use should be observed because of great diversity of types.

Eye protection:
Safety glasses with side-shields (frame goggles) (e.g. EN 166)

Body protection:
light protective clothing

General safety and hygiene measures
Handle in accordance with good industrial hygiene and safety practice. Ensure adequate ventilation.
Wearing of closed work clothing is recommended.

9. Physical and Chemical Properties

Information on basic physical and chemical properties

Form:	powder
Colour:	off-white
Odour:	odourless
Melting point:	
	The substance / product decomposes therefore not determined.
Flash point:	
	not applicable
Ignition temperature:	350 °C
Solubility in water:	Forms a viscous solution.
Explosion hazard:	not explosive
Fire promoting properties:	not fire-propagating

Other information

Bulk density: approx. 800 kg/m3

10. Stability and Reactivity

Reactivity
No hazardous reactions if stored and handled as prescribed/indicated.

Corrosion to metals: No corrosive effect on metal.

Chemical stability

The product is stable if stored and handled as prescribed/indicated.

Peroxides: 0 %
The product does not contain peroxides.

Possibility of hazardous reactions
The product is not a dust explosion risk as supplied; however the build-up of fine dust can lead to a risk of dust explosions.

Conditions to avoid
Avoid extreme temperatures. Avoid humidity.

Incompatible materials

Substances to avoid:
strong acids, strong bases, strong oxidizing agents

Hazardous decomposition products

No hazardous decomposition products if stored and handled as prescribed/indicated.

11. Toxicological Information

Information on toxicological effects

Acute toxicity

Experimental/calculated data:
LD50 rat (oral): > 2,000 mg/kg (OECD Guideline 401)

Irritation

Experimental/calculated data:
Skin corrosion/irritation rabbit: non-irritant (OECD Guideline 404)

Serious eye damage/irritation rabbit: non-irritant

Respiratory/Skin sensitization

Experimental/calculated data:
Non-sensitizing.

Other relevant toxicity information

The product has not been tested. The statements on toxicology have been derived from products of a similar structure and composition.

12. Ecological Information

Toxicity

Toxicity to fish:
LC50 (96 h) > 100 mg/l, Oncorhynchus mykiss (static)
(under static conditions in the presence of 10 mg/L humic acid)

Aquatic invertebrates:
LC50 (48 h) > 100 mg/l, Arcatia tonsa

Persistence and degradability

Information on: Polyacrylamide
Elimination information:
Not readily biodegradable (by OECD criteria).

Bioaccumulative potential

Assessment bioaccumulation potential:
Based on its structural properties, the polymer is not biologically available. Accumulation in organisms is not to be expected.

Mobility in soil (and other compartments if available)

Information on: Polyacrylamide
Assessment transport between environmental compartments:
Adsorption to solid soil phase is expected.

Results of PBT and vPvB assessment

According to Annex XIII of Regulation (EC) No.1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH): The product does not contain a substance fullfilling the PBT (persistent/bioaccumulative/toxic) criteria or the vPvB (very persistent/very bioaccumulative) criteria..

Additional information

Other ecotoxicological advice:
The product has not been tested. The statements on ecotoxicology have been derived from products of a similar structure and composition.

13. Disposal Considerations

Waste treatment methods

Dispose of in accordance with national, state and local regulations.

Contaminated packaging:
Packs that cannot be cleaned should be disposed of in the same manner as the contents.
Uncontaminated packaging can be re-used.

14. Transport Information

Land transport

ADR

Not classified as a dangerous good under transport regulations

RID

Not classified as a dangerous good under transport regulations

Inland waterway transport
ADN

Not classified as a dangerous good under transport regulations

Sea transport
IMDG

Not classified as a dangerous good under transport regulations

Air transport
IATA/ICAO

Not classified as a dangerous good under transport regulations

15. Regulatory Information

Safety, health and environmental regulations/legislation specific for the substance or mixture

If other regulatory information applies that is not already provided elsewhere in this safety data sheet, then it is described in this subsection.

Chemical Safety Assessment

Chemical Safety Assessment not yet performed due to registration timelines

16. Other Information

Due to the merger of CIBA and BASF Group all Material Safety Data Sheets have been reassessed on the basis of consolidated information. This may have resulted in changes of the Material Safety Data Sheets. In case you have questions concerning such changes please contact us at the address mentioned in Section I.

Vertical lines in the left hand margin indicate an amendment from the previous version.

The data contained in this safety data sheet are based on our current knowledge and experience and describe the product only with regard to safety requirements. The data do not describe the product's properties (product specification). Neither should any agreed property nor the suitability of the product for any specific purpose be deduced from the data contained in the safety data sheet. It is the responsibility of the recipient of the product to ensure any proprietary rights and existing laws and legislation are observed.

Material Safety Data Sheet

Zinc

1 . Product and company identification

Common name : Zinc

Code : 3025/26

Product type : Pure Metal

Synonym : Zinc Anode ; Zinc (SHG Zinc) ; Zinc Ball round; Zinc ball, Flat Top

Trade name : Zinc

Material uses : Alloying. casting

Validation date : **1/11/2013.**

Contacts : In Canada:
AIM
9100 Henri Bourassa East
Montreal, QC
H1E 2S4
(514) 494-2000

In the United States:
AIM
25 Kenney Drive
Cranston, RI
(800) CALL-AIM

INFOTRAC - Emergency 24h
North America: (800) 535-5053
International: (352) 323-3500

In case of emergency : INFOTRAC
North America: (800) 535-5053
International: (352) 323-3500

2 . Hazards identification

Physical state : Solid.

OSHA/HCS status : This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Emergency overview : WARNING!

CAUSES RESPIRATORY TRACT, EYE AND SKIN IRRITATION. CAN CAUSE TARGET ORGAN DAMAGE.

Avoid contact with skin and clothing. Avoid breathing dust. Keep container closed. Use only with adequate ventilation. Wash thoroughly after handling. Do not ingest.

Routes of entry : Inhalation.

Potential acute health effects

Eyes : Irritating to eyes.

Skin : Irritating to skin.

Inhalation : Irritating to respiratory system.

Ingestion : No known significant effects or critical hazards.

Medical conditions aggravated by over-exposure : Pre-existing disorders involving any target organs mentioned in this MSDS as being at risk may be aggravated by over-exposure to this product.

See toxicological information (section 11)

3 . Composition/information on ingredients

Name	CAS number	%
Zinc	7440-66-6	100

4 . First aid measures

Eye contact : Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention immediately.

Skin contact : In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Clean shoes thoroughly before reuse. Get medical attention immediately.

Inhalation : Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.

Ingestion : Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention immediately.

Protection of first-aiders : No action shall be taken involving any personal risk or without suitable training. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation.

5 . Fire-fighting measures

Flammability of the product : May be combustible at high temperature.

Products of combustion : Decomposition products may include the following materials:
metal oxide/oxides

Extinguishing media

Suitable : Use an extinguishing agent suitable for the surrounding fire.

Not suitable : None known.

Special exposure hazards : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training.

No specific fire or explosion hazard.

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Special remarks on fire hazards : Massive metal is nonflammable. Dust and powders may be flammable.

Special remarks on explosion hazards : Dust and powders may form an explosive mixture with air.

6 . Accidental release measures

Personal precautions : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilled material. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment (see Section 8).

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Methods for cleaning up : Move containers from spill area. Approach release from upwind. Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor. Note: see section 1 for emergency contact information and section 13 for waste disposal.

7 . Handling and storage

Handling : Avoid contact with eyes, skin and clothing. Keep container closed. Use only with adequate ventilation. Avoid breathing dust. Wash thoroughly after handling. Do not ingest.

Storage : Store in accordance with local regulations. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination.

8 . Exposure controls/personal protection

Consult local authorities for acceptable exposure limits.

Engineering measures : Use only with adequate ventilation. If user operations generate dust, fumes, gas, vapor or mist, use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits.

Personal protection

Eyes : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.

Skin : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Respiratory : Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

Hands : Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

9 . Physical and chemical properties

Physical state : Solid.

Molecular formula : Zn

Dispersibility properties : Not dispersible in the following materials: cold water and hot water.

Solubility : Insoluble in the following materials: cold water and hot water.

10 . Stability and reactivity

Stability and reactivity : The product is stable.

Conditions of instability : Stable in normal conditions. Over melting point, will emit toxic metallic oxides.

Incompatibility with various substances : Highly reactive or incompatible with the following materials: acids and alkalis. Incompatibilities : ACIDS, STRONG BASES, CHLORINE, BROMINE. Acids, Ammonium nitrate, Barium dioxide, Barium nitrate, Bromine pentafluoride, Bromine trifluoride, Cadmium, Carbon disulfide, Chlorates, Chlorine, Chlorine trifluoride, Chromic anhydride, Ethyl acetoacetate and Tribromoneopentyl alcohol, Fluorine, Hydrazine mononitrate, Hydroxylamine, Lead azide; Magnesium, Barium nitrate and Barium dioxide; Magnesium chloride, Nitric acid, Performic acid, Potassium chlorate, Potassium nitrate, Potassium peroxide, Selenium, Sodium chlorate, Sodium peroxide, Sulfur, Tellurium, Water, Zinc peroxide--NFPA 491M Reactions with other materials : Reactions with common materials : No data

10 . Stability and reactivity

Hazardous decomposition products : Under normal conditions of storage and use, hazardous decomposition products should not be produced.

Hazardous polymerization : Will not occur.

Conditions of reactivity : Non-flammable in the presence of the following materials or conditions: open flames, sparks and static discharge, heat, shocks and mechanical impacts and oxidizing materials.
Massive metal is nonflammable. Dust and powders may be flammable.

Slightly explosive in the presence of the following materials or conditions: open flames, sparks and static discharge.
Dust and powders may form an explosive mixture with air.

11 . Toxicological information

Chronic effects on humans : **CARCINOGENIC EFFECTS**: Classified A5 (Not suspected for humans.) by ACGIH, 4 (Probably not for humans.) by IARC, None. by NIOSH.
Causes damage to the following organs: skin.

Other toxic effects on humans : This product may cause serious illness in case of inhalation.
Fumes and/or dusts produced by this product may be hazardous in case of ingestion.
This product may be hazardous in case of skin contact (irritant, sensitizer), of eye contact (irritant).

Special remarks on toxicity to animals : No additional remark.

Special remarks on chronic effects on humans : Repeated and prolonged contact may cause skin irritation or dermatitis.
Massive metal is not harmful. Overexposure to fumes may cause irritation to the respiratory tract, digestive system and to the eyes.

Special remarks on other toxic effects on humans : Prolonged and repeated contact may cause skin irritation or dermatitis. MOLTEN METAL can cause severe BURNS! Fumes may irritate eyes, digestive system and respiratory tract.

Specific effects

Carcinogenic effects : No known significant effects or critical hazards.

Mutagenic effects : No known significant effects or critical hazards.

Teratogenicity / Reproductive toxicity : No known significant effects or critical hazards.

Sensitization

Ingestion : No known significant effects or critical hazards.

Inhalation : Irritating to respiratory system.

Eyes : Irritating to eyes.

Skin : Irritating to skin.

12 . Ecological information

Environmental precautions : No known significant effects or critical hazards.

Toxicity of the products of biodegradation : The products of degradation are more toxic than the product itself.

13 . Disposal considerations

Waste disposal : The generation of waste should be avoided or minimized wherever possible. Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe way. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.

13 . Disposal considerations

Disposal should be in accordance with applicable regional, national and local laws and regulations. Local regulations may be more stringent than regional or national requirements.

The information presented below only applies to the material as supplied. The identification based on characteristic(s) or listing may not apply if the material has been used or otherwise contaminated. It is the responsibility of the waste generator to determine the toxicity and physical properties of the material generated to determine the proper waste identification and disposal methods in compliance with applicable regulations.

Refer to Section 7: HANDLING AND STORAGE and Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION for additional handling information and protection of employees.

14 . Transport information

Regulatory information	UN number	Proper shipping name	Class	PG*	Label	Additional information
DOT Classification	Not regulated.	-	-	-		Reportable quantity 1000 lbs. (454 kg)
TDG Classification	Not regulated.	-	-	-		-
ADR/RID Class	Not available.	Not available.	Not available.	-		-
IMDG Class	Not available.	Not available.	Not available.	-		-
IATA-DGR Class	Not regulated.	-	-	-		-

PG* : Packing group

15 . Regulatory information

United States

HCS Classification : Irritating material
Target organ effects

U.S. Federal regulations : **United States inventory (TSCA 8b):** This material is listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: ZINC
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: ZINC : Fire hazard, Immediate (acute) health hazard, Delayed (chronic) health hazard

Clean Water Act (CWA) 307: ZINC

Clean Water Act (CWA) 311: No products were found.

Clean Air Act (CAA) 112 accidental release prevention: No products were found.

Clean Air Act (CAA) 112 regulated flammable substances: No products were found.

Clean Air Act (CAA) 112 regulated toxic substances: No products were found.

State regulations : **Connecticut Carcinogen Reporting:** This material is not listed.
Connecticut Hazardous Material Survey: This material is not listed.
Florida substances: This material is listed.
Illinois Chemical Safety Act: This material is not listed.
Illinois Toxic Substances Disclosure to Employee Act: This material is not listed.
Louisiana Reporting: This material is not listed.
Louisiana Spill: This material is not listed.
Massachusetts Spill: This material is not listed.
Massachusetts Substances: This material is listed.
Michigan Critical Material: This material is listed.
Minnesota Hazardous Substances: This material is not listed.

15 . Regulatory information

New Jersey Hazardous Substances: This material is listed.
New Jersey Spill: This material is not listed.
New Jersey Toxic Catastrophe Prevention Act: This material is not listed.
New York Acutely Hazardous Substances: This material is not listed.
New York Toxic Chemical Release Reporting: This material is not listed.
Pennsylvania RTK Hazardous Substances: This material is listed.
Rhode Island Hazardous Substances: This material is not listed.

Canada

WHMIS (Canada) : Not controlled under WHMIS (Canada).

CEPA Toxic substances: This material is not listed.
Canadian ARET: This material is not listed.
Canadian NPRI: This material is not listed.
Alberta Designated Substances: This material is not listed.
Ontario Designated Substances: This material is not listed.
Quebec Designated Substances: This material is not listed.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.

EU regulations

Risk phrases : This product is not classified according to EU legislation.

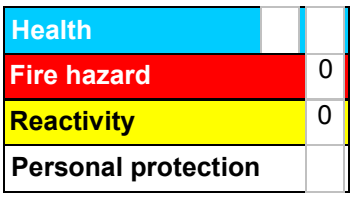
International regulations

International lists : **Australia inventory (AICS):** This material is listed or exempted.
China inventory (IECSC): Not determined.
Japan inventory: Not determined.
Korea inventory: This material is listed or exempted.
New Zealand Inventory of Chemicals (NZIoC): Not determined.
Philippines inventory (PICCS): This material is listed or exempted.

16 . Other information

Label requirements : CAUSES RESPIRATORY TRACT, EYE AND SKIN IRRITATION. CAN CAUSE TARGET ORGAN DAMAGE.

Hazardous Material Information System (U.S.A.) :



National Fire Protection Association (U.S.A.) :



References : -ACGIH, Threshold Limit Values, 1994-1995. -Canada Gazette Part II, Vol. 122, No. 2 Registration SOR/88-64 31 December, 1987 Hazardous Products Act "Ingredient Disclosure List". -CFR29, OSHA's Permissible Exposure Limits, revision July, 1993. -CFR29, part 1910.1200, Hazard Communication. -CHEMTOX database -Components' manufacturer's Material Safety Data Sheet. -CRC Handbook of chemistry and physics, 67 th edition, CRC Press inc., Boca Raton, Florida. -CSST (Comission de Santé et Sé curité au Travail), document #RT-12: Classification of Certain Chemical Substances. -IATA, Dangerous Goods Regulations, 37th edition (January 1, 1996) -NFPA, Fire Protection Guide to Chemical Hazards, 11th edition. -NIOSH, Pocket Guide to Chemical Hazards, revision June 1994. Sigma-Alrich handbook of fine chemicals, 1998 -TSCA (Toxic Substance Contral Act), Chemical Substance Inventory List, 1985.

Other special considerations : -ALL COMPONENTS WITH SUSCEPTIBLE HAZARDS THAT ARE PRESENT IN A CONCENTRATION GREATER THAN 1 % (GREATER THAN 0.1 % FOR CARCINOGENS) HAVE BEEN DISCLOSED IN THIS SAFETY DOCUMENT.

16 . Other information

Date of printing : **1/11/2013.**

Date of issue : **1/11/2013.**

Version : **3**

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

Appendix I – FMC Inventory of Spill Response Materials and Supplies

SPILL RESPONSE MATERIALS AND SUPPLIES

FARO MINE COMPLEX

Ware house Inventory:

1. Spill Kit For Aggressive Fluids
   - 3 disposable hazardous material bags
   - 3 pairs of goggles
   - 2 pairs of silver shield plastic disposable gloves
   - 3 pairs of disposable coveralls
   - 5 yellow absorbent pads
   - Four 4' sock absorbent lengths

2. Chemical Spill Kit
   - 2 disposable bags
   - 1 pair of rubber gloves
   - 4 absorbent socks 12' length
   - 6 absorbent pads
   - 1 pair of goggles
   - 1 spill response hand book

3. Universal Spill Kit
   - 5 disposable bags
   - Ten 4' absorbent
   - 50 absorbent sheets
   - 4 absorbent pads
   - Seven 12' absorbent socks

4. 2 packs of 200 universal/haz-mat absorbent sheets 17"x19"
5. 2 roles of SBS2-9 32x150'x3/8 yellow absorbent material
6. 1 role of 2' absorbent barrier 100'
7. 200 absorbent pads for oil spillage
8. Two 1.8"diameter 12' absorbent socks

Diesel fuel station:

1. Universal Spill Kit
   - 5 disposable bags+ ties
   - Ten 4' absorbent socks
   - 50 absorbent sheets
   - 4 absorbent pads
   - Seven 12' absorbent socks

Gas fuel station:

1. Universal Spill Kit
   - 8 absorbent pads
   - Four 12' socks
   - 50 absorbent sheets
   - 1 emergency response handbook
   - 1 pair of rubber gloves and goggles

Faro Guardhouse Lab:

1. Chemical Spill Kit #1
   - treats up to 1 ltr
   - 4 ltr of chemical (absorbent)
   - 1 pair of chemical gloves
   - 1 pair of chemical apron
   - 1 pair of chemical booties
   - 1 pair of chemical pants
2. Chemical Spill Kit #2
   - treats up to 8 ltr of acid and base (absorbent)
   - 14 ltr of base neutralizer absorbent
   - 14 ltr of acid neutralizer absorbent
   - 2 sets of glasses
   - 1 sponge
   - 2 pairs of gloves
   - 1 scupper
   - 1 spill bag
   - 1 spill response book

Appendix J – FMC Emergency Contact List

Emergency Contact List

For the purposes of emergency response on site, all external notification/requests for assistance will be coordinated through Faro Security.

Emergency Contact	Contact Information
On Site Security (FARO)	**TEES Radio Call**
Faro Office Complex/Security	**994-2600**
Ambulance/Nursing Station	**994-4444**
Fire Department	**994-2222**
RCMP (emergency)	**994-5555**
RCMP (non-emergency)	994-2677
Conservation Officer (TJ Grantham)	994-2862
Yukon Wildfire Management	1-867-393-7415
Dept. of Highways (Drury Creek)	994-3046
Whitehorse General Hospital	1-867-393-8700
Poison Control Centre	1-800-267-1373

Tlicho Engineering and Environmental Services Emergency Contact List

TEES Emergency Contact List	Position	Faro Residence	Mobile	Off Site Residence
Byron O'Connor Eric Domingue	Project Managers	994-2354	867-334-3343	
Barry Wilson	Site Superintendent	994-2058	867-334-4765	
Jodi Boyd	Office Administrator	994-3483	867-335-3240	
Tracy Parkin	Environmental Coordinator	-		1-867-969-2856
Dan Duivenvoorden	WT Supervisor	994-2849		
Chris Wilkinson	Site Services Supervisor	994-3289		
Satellite Phone **011 881 631 655 459**				

Appendix 5F
Emergency Management Plan (TEES)

Emergency Management Plan

FARO MINE COMPLEX

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Original Issue	31-March-2012	J. Buchko
1	Added Appendices	September 2012	B. Barstad
2	Revision	13- May- 2013	G. Allen

Authorized By:			
Area Superintendent:	Rob Wren		**Date:**
Acting Mine Manager:	Barry Wilson		**Date:**
Project Manager	Eric Domingue/ Byron O'Connor		**Date:**

This Emergency Management Plan will be reviewed annually to ensure it remains up to date. The review will be based on an analysis of the types of incidents that are likely to occur, any changes in the risk profile and the appropriate emergency response required.

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EMERGENCY TELEPHONE DIRECTORY

Chain of Command on Site

1. Project Manager – Eric Domingue, Byron O'Connor
2. Acting Site Manager – Barry Wilson
3. Mine Site Superintendent - Rob Wren
4. Site Administrator - Jodi Boyd

Emergency Response Team

Name	Work Phone	Cell Phone
Ray Henderson	867-994-2600 ext 0005	867-994-2103 (house)
Chris Wilkinson	867-994-2600 ext 0007	867-332-1362 867-994-3289 (house)
Paul Kelly	867-994-2600 ext 0000	867-994-3485
Robert Shaw	867-994-2600 ext 0000	867-994-2055
Glenis Allen	867-994-2600 ext 0009	867-994-2007
Shannon Wood	867-994-2600 ext 0000	867-994-2425

Tlicho Engineering and Environmental Services Management

Position	Name	Work Phone	Cell Phone
Project Manager	Eric Domingue/ Byron O Connor	867-994-2600	867-994-2354 (house)
Acting Site Manager	Barry Wilson	867-994-2600	867-334-4765
Site Superintendent	Robert Wren	867-994-2600	867-334-2058 (house) 867-334-3343
Environmental Coordinator	Tracey Parkin	867-994-2600	867-335-6595
Client Services Manager	Donna Palmer	867-669-9481	867-446-0904
Administrator	Jodi Boyd	867-994-2600	867-335-3240

Yukon Government Assessment and Abandoned Mines (NEED TO BE INFORMED OF ANY INCIDENT IMMEDIATELY)

Position	Name	Work Phone	Cell Phone
Project Manager (C&M)	Kaori Torigai	867-456-6768	867-332-4155
Senior Project Manager	Deborah Pitt	867-456-6762	867-332-4154
Director AAM	Stephen Mead	867-393-6904	867-332-4041

Town of Faro Municipal Council/ Local EMO

Town of Faro Box 580 Faro, Yukon Y0B 1K0 Phone: 867-994-2728 Fax: 867-994-3154	Mayor: Heather Campbell Councillors: Debbie Carreau Harold Boehm Mel Smith Heather Grantham	Chief Administration Officer/ Coordinator: Tom Lie Assistant Coordinator: Jim McLachlan Administration Assistant: Erica Ward

Affected First Nation

First Nation	Contact	Phone Number	Fax Number
Liard First Nation	Terry Szabo	867-536-2393	867-536-2392
Ross River Dena Council	Mary Maje	867-969-2097	867-969-2405
Selkirk First Nation	Ellie Marcotte	867-537-3331	867-537-3902

External Resources and Emergency Response Agencies within the Yukon

AIR POLLUTION EMERGENCY
Lead Agency– Faro EMO 994-2728 including EPB (667-5683)

Support Agency(ies):
- Yukon EMO [(667-5220)] including EHS (667-8355) [633-6202]
- MHO (667-5716) [333-3168 or 668-4191]
- EnvHS (667-8391) [668-3204]

Because of the wide-ranging health and safety issues, the local and Yukon EMO would coordinate the response and support Public Health and Environmental Health monitoring programs.

BOMB THREATS
Lead Agency–RCMP [(911)] in Faro 994- 5555

Support Agency(ies):
- Fire Department
- EMS
- Faro EMO 994-2728
- Yukon EMO [(667-5220)

CHEMICAL, BIOLOGICAL, RADIOACTIVE, NUCLEAR EVENT (CBRN)
Lead Agency–RCMP [(911)] in Faro 994-5555

Support Agency(ies):
- Fire Department
- EMS
- Faro EMO 994-2728
- Yukon EMO [(667-5220)]

Various response teams may be deployed to respond support the specifics of the incident, i.e. CBRN identification, HAZMAT, ERAP, etc.

DAM FAILURES
Lead Agency– YEC (393-5300) [393-5355]

Support Agency(ies):
- Faro EMO 994-2728
- Yukon EMO [(667-5220)]
- PSEPC[(250-363-3621)] [(867-445-7737)]

Threatened communities would activate their EMO as well as the Yukon's EMO and attempt to mitigate impacts. Emergency power supply may be one of many short-term requirements.

EARTHQUAKES
Lead Agency– Faro EMO 994-2728

Support Agency(ies):
- Yukon EMO [(667-5220)]
- PSEPC [(250-363-3621)] [(867-445-7737)]

Local and Yukon EMOs would be activated in keeping with the scale of the emergency. Support may be coordinated with other provinces, territories, states and PSEPC.

ENERGY SHORTFALL
Lead Agency– Yukon EMO [(667-5220)] Upon Declaration of Emergency

Support Agency(ies):
- Natural Resources Canada (667-3957) [633-4910]
- Energy, Mines, & Resources (667-3130)
- ESS (667-5688) [668-1040]

Fuel shortages may require fuel rationing and the requirement to establish allocation priorities. ESS would be anticipated to look after potential evacuees.

EVACUATION
Lead Agency–Faro EMO 994- 2728

Support Agency(ies):
- RCMP 994-5555
- ESS (667-5688) [668-1040]
- EHS (667-8355) [633-6202]
- Yukon EMO [(667-5220)]

The Municipalities of the Yukon are responsible for implementing their own emergency plans during an event. Where the emergency is large and overwhelming, the municipalities can request assistance from Yukon EMO.

FLOODS on FEDERAL LANDS
Lead Agency– PSEPC[(250-363-3621)] [(867-445-7737)] or Yukon First Nation (393-9200)

Support Agency(ies):
- Faro EMO 994-2728
- Yukon EMO [(667-5220)]
- Transportation Engineering (Highways & Public Works) (667-8820) [668-7816]

FIRES

URBAN
Lead Agency–Faro Fire Dept. 994- 2222

Support Agency(ies):
- Adjacent Fire Departments
- Faro EMO 994-2728
- Fire Marshal's Office (667-5217) [633-3161 or 333-3941]

WILDLAND
Lead Agency–Wildland Fire Management, Protective Services, YG Fire Reporting Line [(1-888-798-3473)]

Support Agency(ies):
- Faro Fire Dept. 994-2222
- Yukon EMO [(667-5220)]
- RCMP 994-5555

HIGHWAY CLOSURES & INFORMATION
Lead Agency– Highways & Public Works (667-3710) [334-3794]

Support Agency(ies):
- RCMP 994-5555
- Faro EMO 994- 2728
- Yukon EMO [(667-5220)]

If Highways and Public Works are not available, the RCMP is authorized to close Yukon highways when conditions are unsafe and normally do so in off-hour periods. Conditions that may close Yukon highways are (but not limited to) floods, forest fires, weather conditions, landslides, etc.
Highway Information: Yukon 24/7 Recording 456-7623 or toll free 877-456-7723

HUMAN EPIDEMIC
Lead Agency–MHO (667-5716) [333-3168 or 668-4191] YCDC (667-8323)

Support Agency(ies):
- ESS (667-5688) [668-1040]
- EHS (667-8355) [633-6202] Yukon EMO [(667-5220)]

Local and Yukon EMO may be activated to support emergency operations, logistics, asset deployment, communications, emergency personnel recruitment/services.

ICE JAMS
Lead Agency– PSEPC[(250-363-3621)] [(867-445-7737)]

Support Agency(ies):
- Faro EMO 994- 2728
- Yukon EMO [(667-5220)]

LANDSLIDES (including Avalanches)
The location of the landslide may determine whether Highways, Municipal Engineering, Municipalities, First Nations or the private sector takes a lead role. The EMO may assist where the impacts are overwhelming.
Lead Agency–Various

Support Agency(ies):
- RCMP 994-5555
- Faro EMO 994-2728

MASS CASUALTY INCIDENT
Lead Agency–Faro EMS 994-4444

Support Agency(ies):
- RCMP [(911)] in Faro 994-5555
- Faro EMO Faro 994-2728
- Yukon EMO [(667-5220)]

Incidents involving multiple casualties may require the activation of Emergency Health Services emergency plans. National Emergency Stockpile System (NESS) items may be deployed (i.e. the mobile hospital, casualty collection units and emergency feeding unit) with authorization from ESS or EHS Director. Support agencies may be called upon to assist in casualty collection, perimeter security, communications support or transportation services.

MINE DISASTER
Lead Agency–Mine Company/WCH&SB–Mine Rescue [(667-5450)]

Support Agency(ies):
- Faro EMS 994-4444
- Faro EMO 994-2728

Specialty rescue services are required in certain mine disasters. The mining company, in compliance with Mine Rescue experts from WCHSB, develops specialized rescue capabilities. Local response agencies would support rescue efforts. Emergency Medical Services may be fully engaged in the event of mass casualties (see Mass Casualty Incident).

PANDEMIC
Lead Agency–PHAC – will notify provincial or territorial MHO of the presence of disease MHO (667-5716) [333-3168 or 668-4191]

Support Agency(ies):
- EHS (667-8355) [633-6202]
- ESS (667-5688) [668-1040]

Local and Yukon EMO(s) would also be activated to support Emergency Operations, logistics, asset deployment, communications, emergency personnel recruitment/services, etc.

POWER OUTAGE
Lead Agency– For Faro - Yukon Energy Corp. 393-5324 or 393-5355

Support Agency(ies):
- Faro EMO 994- 2728
- Yukon EMO [(667-5220)]

Restoration of power is the responsibility of the Utility. Should a power outage affect a community, the local EMO may be able to cope with local resources. Should additional assistance be required, a request would be made to Yukon EMO.

SEARCH AND RESCUE

GROUND & INLAND WATER

Non Park Land
Lead Agency–RCMP 994-5555

Support Agency(ies)
- Faro SAR Team – Bill Wood Team Leader 994- 2425

Body Recovery
Lead Agency–Coroner [(667-5317)]

Support Agency(ies)
- RCMP 994-994-5555
- Faro SAR Team – Bill Wood Team Leader 994-2425

URBAN (Heavy Rescue) – Collapsed structures
Lead Agency–Faro Fire Dept 994-2222

Support Agency(ies):
- Faro EMS 994-4444
- WCHSB–Mine Rescue [(667-5450)]
- Faro EMO Faro 994-2728
- Yukon EMO [(667-5220)]

SPILLS–DANGEROUS GOODS INCIDENTS

ALL SPILLS IN THE YUKON ARE TO BE REPORTED TO THE 24 Hr. NUMBER 867- 667-7244.
Lead Agency–Spills Line [(667-7244)]

Support Agency(ies):

- Various – Lead Agency to contact support agency(ies) as required.

Lead agencies have been designated pursuant to a "Letter of Understanding for Government Response to Spills in the Yukon Territory".

TERRORIST ATTACK
Lead Agency–RCMP (ERT) or National Joint Forces Team (JFT)

Support Agency(ies):

- Faro EMO Faro 994-2728
- Yukon EMO [(667-5220)]

1 INTRODUCTION

This document, the Faro Mine Complex (FMC) Emergency Management Response Plan is written to clearly define what action is required in the event specific high risks actually happen.

1.1 PURPOSE

The aim of this document is to provide the Faro Mine Management with detailed guidance on how to respond to various emergency situations that could occur during normal operations. That is:

- What type of incident could occur;
- What general type of emergency response is required; and
- Any special response requirements.

The information contained in this document has been prepared to act as a guide only and may require some additional responses, depending on the circumstances of the individual emergency situation.

1.2 SCOPE

The FMC Emergency Management Response Plan applies to all TEES team members, sub-contractor team members and all other site visitors.

1.3 IMPLEMENTATION

1.3.1 Who Has Responsibilities - Training Required

The ***Mine Site Manager*** is responsible for the effectiveness of emergency response within the area of responsibility. This includes responsibility for ensuring Emergency Plans and Procedures are periodically tested and reviews conducted to ensure they remain effective.

The ***Mine Site Manager*** is also likely to act as the ***Incident Commander*** (i.e. leader of the Incident Command Team) should a local emergency occur within their area of responsibility. This person will be required to have an understanding of the various responses that may be used to help manage an emergency situation.

Supervisors are responsible for ensuring the development and implementation of the local Area Emergency Plans as appropriate that will utilize response information contained in this document

The **Mine Manager/** ***Health and Safety Coordinator*** is responsible to ensure the Emergency Management System is maintained, including this Plan and associated Procedures. This includes communicating any changes to relevant Managers as soon as practicable and ensuring the training of any team members in effective emergency response.

Team Members assigned particular roles or tasks under the FMC Management Response Plan (e.g. emergency procedures) are responsible for carrying out those roles or tasks to the best of their ability and training.

1.3.2 Who Else Should Know - Awareness Required

This information is important to the safety of everyone associated with the FMC and is to be used by all team leaders. This information must be communicated to any new team leaders through formal induction or instruction so the various requirements are understood and acknowledged.

2 DEFINITIONS

DM&R – Disaster Management & Recovery; This is a process whereby a disaster is managed at a level appropriate for the disaster. This process generally involves the senior management team of the organisation who manage the organisation throughout the period while the organisation is directly and immediately affected by the disaster and then follows through the recovery process to restore normal operations.

Emergency Response; This is the processes applied by a team of people to treat an emergency on a local scale. This generally involves the ERT, or emergency response team.

2.1 GLOSSARY OF ACRONYMS

[ ] Denotes "after hours" contact number(s)

EHS	Emergency Health Services (Health & Social Services)
EnvHS	Environmental Health Services
EMO	Emergency Measures Organization
EMS	Emergency Medical Services
ERT	Emergency Response Team – RCMP
ESS	Emergency Social Services (Health & Social Services)
MHO	Medical Health Officer (Health & Social Services)
PHAC	Public Health Agency of Canada
PSEPC	Public Safety & Emergency Preparedness Canada
SAR	Search and Rescue
WCHSB	Workers Compensation Health and Safety Board
YG AAM	Yukon Government Assessment and Abandoned Mines

3 DETAILS

3.1 APPLICABLE LEGISLATION & STANDARDS

This document has been developed to help ensure compliance with the Occupational Health and Safety Regulations, November 1, 2006 as shown on the Yukon Workers' Health and Safety Board website (www.wcb.yk.ca). This plan has been developed with consideration of:

- identified hazards that might cause an emergency;
- assessment of the risks of an emergency occurring; and
- the means for dealing with such emergencies.

This plan also considers the means for managing and controlling an emergency situation including the provision of training, equipment, facilities, team members and procedures.

3.2 POTENTIAL EMERGENCY INCIDENTS

3.2.1 Emergency Risk Analysis

A high level analysis to determine the types of probable incidents that could occur at FMC has been undertaken. This included:

- A review of FMC risk assessments to identify potential emergency response requirements; and
- A review of similar operations risk assessments and emergency response plans.

This analysis identified incidents with high risk. Each of these were then reviewed to determine the type of response required. The specific responses to these incidents form the basis of the FMC Management Response Plan.

This Chart shows the following information:

a. Potential incidents identified from the above analysis;
b. Types of impacts that could be detrimental to the FMC and TEES, including:
    - assets (A)
    - profit (P)
    - team member safety and health (SH)
    - environment (En)
    - other people e.g. community, family/ friends of team members (OP)
    - company image, reputation, public perception etc. (CI)

The risk assessment considered the types of impact however the risk rating is based on health and safety risk only at this time.

3.2.1.1 Risk Rating Tables

POTENTIAL CONSEQUENCE OF THE INCIDENT				PROBABILITY OF THIS OCCURRING AGAIN					RISK ASSESSMENT SCORE	
4	3	2	1	A	B	C	D	E		
1 – Could kill, permanently disable or cause very serious damage **2 –** Could cause serious injury (major LTI) or major damage **3 –** Could cause typical MTC / LTI or moderate damage **4 –** Could cause First Aid injury or minor damage **5 –** Couldn't cause injury or damage				**A** = ALMOST CERTAIN TO HAPPEN **B** = LIKELY to happen at some point **C** = MODERATE, possible, it might happen **D** = UNLIKELY, not likely to happen **E** = RARE, practically impossible					**Low** **16-25**	**Work your plan**
									Moderate **11-15**	**Re-evaluate the control measures in order to reduce the overall risk.**
									High **4-10**	**Re-evaluate the control measures with the Supervisor. Determine lower risk options.**
									Critical **1-3**	**Job shut down for re-evaluation with Superintendent and the job team.**

Consequence	Probability A	B	C	D	E	Risk Assessment Category
1	1	2	4	7	11	Critical
2	3	5	8	12	16	High
3	6	9	13	17	20	Moderate
4	10	14	18	21	23	Low
5	15	19	22	24	25	

FMC Probable Emergency Incidents Chart

Figure 1 – Potential Incident, Impacts & Risk (Page 1 of 3)

POTENTIAL INCIDENT	Main Impacts	Likelihood*	Consequence*	Level Of Risk	Risk Rank	COMMENTS
Section 3.5 Natural Disasters						
3.5.1 Major Earthquake/Seismic Event	A, SH, En, OP	E	1	M	11	
3.5.2 Open Pit Wall/ Ramp Failure	SH, En, A	D	2	M	12	
3.5.3 Inrush Into Open Pit	A, En, SH,OP, CL	E	1	M	11	
3.5.4 Animal Attack	SH, OP	D	1	D	7	Bear, Wolverine, Moose
3.5.5 Whiteout	SH, En	C	3	M	13	
3.5.6 Severe Electrical Storm	A, P, SH, En	E	2	L	16	Persons or equipment struck by lightning
3.5.7 Severe Rain Storm	SH, En	E	3	L	20	General flood
3.5.8 Infectious Disease Outbreak	CI, SH, OP, P	D	1	H	7	E.g. legionnaires, salmonella, TB, Hepatitis
3.6 On – site Incidents						
3.6.1 Vehicle Accident	A, P, SH, En	D	1	H	7	Spill (fuel etc.)
3.6.2 Heavy Equipment Break Through Ice	A, SH ,En	D	1	H	7	Spill/ Entrapment/ Drowning
3.6.3 Dangerous Goods Truck Accident/ Incident	A, P, SH, En	D	1	H	7	Spill/ release/explosion
3.6.4 Light Vehicle Accident/ Incident	SH	Unlikely (D)	Catastrophic (5)	Extreme	7	Liquid spill (fuel etc.)
3.6.5 Heavy Vehicle Accident/ Incident	CI, SH, En	Unlikely (D)	Catastrophic (5)	Extreme	7	Liquid spill (fuel, hydraulic oil)

Figure 1 – Potential Incident, Impacts & Risk (Page 2 of 3)

Section 3.7 On-site Surface continued						
3.6.6 Hazardous Substance Release	P, SH, En, Cl	D	1	H	7	E.g. chemical, diesel fuel
3.6.7 Water Treatment Plant Failure	P, CI, SH, OP	D	1	H	7	E.g. pumping systems, clarifier
3.6.8 Fire/ Explosion	A, SH, En, OP, Cl	D	1	M	7	Site Wide Damage
3.6.9 Building Collapse	A, P, SH, En	E	1	M	11	WTP, Shop
3.6.10 Working at Height Accident/ Incident	SH, OP	D	2	M	12	
3.6.11 Confined Space Accident/ Incident	SH	D	2	M	12	
3.6.12 Malicious Damage (Arson etc)	A, P, SH, En	D	2	M	12	
3.6.13 Bomb Threat	SH	D	4	L	21	Threat only (no explosion)
3.6.14 Armed hold up/ Hostage situation	SH, CI	E	1	M	11	

3.3 DISASTER MANAGEMENT RESPONSE PLAN

This Disaster Management Response Plan describes the detailed Emergency Management response to the potential critical incidents identified in Section 3.0. Each of these detailed responses includes the following information:

- The main “threats” associated with the incident
- How the incident may be notified (aside from emergency telephone/ radio call)
- Alarms or methods to alert persons of an emergency
- The management response required (i.e. who should be notified, what action should be taken)
- Any special instructions
- Possible contacts for specialist advice

The detailed response to each potential incident is described in Sections 3.6 and 3.7 below.

These should be used as a guide only and are not “all inclusive”. That is, there may be additional response steps or the steps may be in a different order of execution, depending on the circumstances of the individual emergency situation.

3.5 NATURAL DISASTERS

3.5.1 Major Seismic Event/Earthquake

A major earthquake or seismic event may cause damage to mine infrastructure and result in a significant disruption to operations or injury to team member(s)

Main Threats:	• Collapse of mine infrastructure (e.g. Dike Failure, underground workings, pit walls, mine access ways, surface buildings or structures &, rock dump slide) • Loss of access to open pit (loss of ramps, portal etc) • Release of contaminated water and tailings into the environment • Induces major fire/explosion (e.g. fuel storage) • Disruption to security/communications • Injury to team member(s)
Likely Alarms:	• Earthquake likely to trigger security/ other site alarms
Response:	• Initiate affected area(s) Evacuation Alarms Code 1 • Assess likely impact • Call-out Emergency Response Team • Secure access to all areas using Emergency Response Team and other people as required • Initiate appropriate emergency response (e.g. first-aid, fire, persons trapped, explosion etc) • Notify Faro Community Health Centre of possible need for assistance (if several casualties) • Notify Faro EMO • Notify Mine Site Manager • Mine Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Advise other areas on site as required • Advise adjacent operations, if required • Conduct damage assessment of affected area or entire site using competent team members. • Notify site employees and contractors of proposed actions as required • Maintain security of affected area until Mine Site Manager calls for a stand down
External Help	• WCHSB – Mine Rescue if specialized rescue services are required
Lead Agency:	• Faro EMO
Support Agency(ies):	• Yukon EMO • Faro Community Health Centre

- RCMP if fatality
- Spills Line
- Geotechnical Expert (independent advice/ assist with recovery plan)

3.5.2 Open Pit Wall / Ramp Failure

Open Pit wall or access ramp failures are often preceded by cracking and ground movements, which may be visible. Regular monitoring of pit walls crests and berms may help identify any potential failures.

If a sudden failure occurs, evacuation to a safe place within the pit itself is usually the best course of action. Egress from the pit can then be made once an access way is cleared. The possibility of having to evacuate injured persons quickly over the pit wall (if no vehicle access) may require Emergency Response Team call-out.

Main Threats:

- Injury to team member(s)
- Loss of access to open pit (loss of ramps, pit walls ect)
- Introduction of clean water into contaminated water body
- Loss of assets (power line, pipe line, barge, pumps ect)
- Disruption of operations
- Adverse impact on Company image

Response:

- Initiate affected area(s) Evacuation
- Assess likely impact
- Consider Emergency Response Team call-out, if required
- Initiate appropriate emergency response (first-aid/medical/search/pit evacuation/rope rescue, etc)
- Notify Faro Community Health Centre of possible need for assistance (if several casualties)
- Secure access to all areas using Emergency Response Team & other people as required
- Notify Faro EMO if required
- Notify Mine Site Manager
- Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB
- Mine Site Manager to initiate Chain of Command, if required
- Notify RCMP (if potential fatality)
- Advise other areas on site as required
- Advise adjacent operations if required
- Conduct damage assessment of affected area or entire site using competent team members
- Notify site employees and contractors of proposed action as required
- Maintain security of affected area(s) until Mine Site Manager calls a stand down
- Initiate appropriate investigation (may need to maintain security of area

	until completed)
External Help	• Faro EMO
Lead Agency:	• RCMP if fatality • WCHSB – Mine Rescue if specialized services are required
Support Agency(ies):	• Yukon EMO • Faro Community Health Centre • EMS • Geotechnical Expert (independent advice/ assist with recovery plan)

3.5.3 Inrush into Open Pit

An inrush of water, mud or tailings into an open pit is only likely to occur following a major flood event or dike failure. Establishment of an evacuation process in case of major rainfall may alleviate the need for an emergency response.

If a sudden inrush does occur, evacuation from the pit or moving to a safe place within the pit itself is the best course of action. This will depend on the location of the inrush and volume of material involved. Egress from the pit can then be made once the inrush has stabilized. The possibility of having to evacuate injured persons quickly over the pit wall (if no vehicle access) may require Emergency Response Team call-out.

Main Threats:	• Injury to team members • Adverse impact on Company image • Introduction of clean water into contaminated water body
Alarms:	• Initiate affected area(s) Evacuation alarm
Response:	• Assess likely impact • Consider Emergency Response Team call-out, if required • Initiate appropriate emergency response (first-aid/ medical/ search/ pit evacuation/ rope rescue, etc) • Notify Faro Community Health Centre of possible need for assistance (if several casualties) • Secure access to area(s) using Emergency Response Team & other people as required • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Notify Faro EMO • Notify RCMP if potential fatality • Notify Environmental Coordinator (if any likely environmental impact) • Maintain security of affected area(s) until Mine Site Manager calls a stand down

	• Initiate appropriate investigation (may need to maintain security of area until completed)
External Help	• PSEPC
Lead Agency:	• RCMP if fatality
Support Agenc(ies):	• Faro EMO
	• Yukon EMO
	• Transportation Engineering (Highways & Public Works)
	• Faro Community Health Centre
	• Geotechnical Expert (independent advice/ assist with recovery plan)

3.5.4 Animal Attack

An attack by wildlife (bear, wolverine, moose etc).

Main Threats:	• Team member attacked by Wildlife (bear, moose, wolverine)
Likely Alarms:	• Code 1 call
	• ERT & Medic
Response:	• Assess likely impact of incident
	• Initiate appropriate emergency response (e.g. first-aid, conservation officer etc)
	• Notify RCMP if fatality
	• Notify Faro Community Health Centre if required assistance
	• Notify Faro Conservation Officer
	• Notify Mine Site Manager
	• Mine Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB
External Help **Lead Agency:**	• RCMP/ Conservation Officer
Support Agency(ies)	• Faro Community Health Centre

3.5.5 White Out

A white out may occur which stops all operations, travel and significantly hampers emergency response capability. Persons could be trapped in various areas on the mine site.

Main Threats:	• Severe cold, very low visibility, possible high winds
	• Loss of essential supplies (fuel, food etc)
	• Loss of power, heat, communications
	• Injury to team member(s)
Notification:	• As per extreme weather procedure
Likely	• Watch for warning issued by Environment Canada

Alarms:	
Response:	• Obtain up-to-date information from Environment Canada • Assess likely impact • Check status of site essential supplies (fuel, food etc) with Materials Team members • Notify Mine Site Manager • Mine Manager willimmediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • If appropriate shutdown of all operations • Notify contractors & team members of proposed action • As per extreme weather procedure
External Help	• Faro EMO (if not affected by same condition)
Lead Agency:	
Support Agency(ies):	• Yukon EMO

3.5.6 Severe Electrical Storm

Electrical storms are common events during summer and early autumn. All critical equipment should be properly grounded or protected by lightning arrestors. Activities in the open should be stopped. If struck by lightning, cardiac arrest is likely, so quick response is essential.

Some hazardous activities (e.g. working near open water) should also be checked.

Main Threats:	• Team member(s) struck by lightning • Lightning initiating fire or explosion • Disruption to power/ security systems/ communications
Notification:	• May get some advance warning from weather service • Observations of severe lightning strikes/ almost instantaneous thunder • Could be some major power disturbances
Alarms:	• Code 1 call (if fire/ explosion) • Site wide radio call (to stop work & evacuate area)
Response:	• Notify all team members of approaching storm(s) • Initiate evacuation alarms, if fire or explosion • Call-out Emergency Response Team if support required • Initiate appropriate emergency response (first-aid/ medical/ fire) • Notify Faro Community Health Centre if required assistance • Isolate any energy sources or hazardous substances (e.g. power, gas, diesel, chemicals, etc) • Consider shut-down of operations, if storm/s severe • Notify Mine Site Manager

	• Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate DM&R, if required • Inspect affected areas to assess damage (once safe) • If rubber-tired equipment struck by lightning, park up in secured/ isolated area for 24 hours • Maintain security of affected areas until Mine Site Manager calls a stand down
External Help **Lead Agency:**	• Faro EMO
Support Agency(ies)	• Faro Community Health Centre • Faro Volunteer Fire Department • Yukon EMO

3.5.7 Severe Rain Storm/ Flood/ Freshet

A flood could possibly result from a severe rain storm or an intense thawing season creating a severe freshet

Main Threats:	• Open pit in-rush, damage to dike • Release if contaminated water into environment and infrastructure such as: ditches, diversions, retention ponds, dikes ect • Flood damage to site facilities • Injury to team member(s) • Wet/slippery roads increase potential for heavy equipment & light vehicle accidents
Notification:	• Likely to be notified through Environment Canada.
Likely Alarms:	• Storm/weather alert issued by Environment Canada
Response:	• Obtain up-to-date information from Environment Canada • Notify all team members of approaching rains/flood or high temperature during thaw • Assess likely impact • Monitor drainage/access roads/haul roads and pit/ramp road conditions • Consider closing/ barricading access roads, haul roads or pit/ ramp roads, if affected • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Check status of site essential supplies (fuel, chemicals, etc) • If flooding likely to be severe or road conditions hazardous, consider

	closure of all operations • Keep heavy equipment and operators on call in case of emergency repair work to occur on road, diversions, ditches, ponds, berms, ect • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Notify contractors, team members and suppliers of proposed action • If flooding of inspection areas and pits likely, withdraw workforce and stop operations • If inrush occurs, refer to incidents as required
External Help **Lead Agency:**	• Faro EMO
Support Agency(ies)	• Faro Community Health Centre • Yukon EMO • Transportation Engineering (Highways & Public Works) • RCMP if fatality • Faro Community Health Centre • Pump/ Hire Local Contractors

3.5.8 Communicable Disease Outbreak: Human Epidemic

Infectious diseases can be introduced through poor hygiene, contaminated water or food, or contact with other infected persons. They include Legionnaires disease, Influenza, various types of food poisoning, Hepatitis, etc.

As this could involve diseases of a “sensitive” nature,” it is important to maintain confidentiality and avoid undue panic. The Faro Community Health Center must be notified of any “reportable” diseases.

Main Threats:	• Team member illness • Adverse reaction/ panic by other team members
Notifications:	• members reporting sick/ severely ill
Alarms:	• None
Response:	• Isolate infected person(s) from other team members • Initiate appropriate medical response • If medical emergency occurs, contact Faro Community Health Centre if major outbreak and need to evacuate team members to the Health Centre • Notify Mine Site Manager • Mine Manager will immediately report any injuries/ illness to authorities:

	YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Consider independent advice from external medical source (e.g. Whitehorse General Hospital) • Notify MHO (Medical Health Officer) • Assess situation and consider team member briefing (using accurate medical information)
External Help **Lead Agency:** **Support Agency(ies)**	• MHO (Medical Health Officer- Health and Social Services) • ESS (Emergency Social Services) • EHS (Emergency Health Services) • Faro EMO • Faro Community Health Centre

3.6 ON SITE ACCIDENT/ INCIDENT

3.6.1 Vehicle Accident

An accident involving a light and/or heavy vehicle on the YG maintained access road may require some response from site. This type of incident has potential to result in multiple casualties; e.g. if heavy equipment collides with light vehicle/s. An accident involving TEES operated heavy equipment is also likely to have an impact on Company image, particularly if fatalities occur.

Main Threats:	• Injury to operator/ other team member(s) involved • Environmental impact (if spillage results) • Impact to Company image/ reputation
Response:	• Assess likely impact • Initiate appropriate emergency response (first-aid/ medical/ fire/ triage/vehicle extrication) • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Determine what cargo was being carried (e.g. if any chemicals, Dangerous Goods, waste, etc) • Call-out Emergency Response Team if required • Secure area using Emergency Response Team members or other people as required • Notify RCMP • Notify Mine Site Manager • Mine Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB

	• Notify Environmental Coordinator (if any likely environmental impact) • Mine Site Manager to initiate Chain of Command, if required • Maintain security of affected area until RCMP/ Mine Site Manager calls a stand down
External Help **Lead Agency:**	• Faro EMO
Support Agency(ies):	• Faro Community Health Centre • Spills Line • Yukon EMO • RCMP • Chemical Supplier/ Transport Company

3.6.2 Heavy Equipment Break Through Ice

An accident involving a heavy vehicle in the FMC area (open pits, IMP, CVP) may require some response from site. This type of incident has potential to result in multiple casualties depending on how many may be involved.

Main Threats:	• Injury to truck or equipment driver/ other team member(s) involved • Environmental impact (if spillage results)
Response:	• Call-out Emergency Response Team members • Initiate appropriate emergency response (ice rescue/first-aid/ medical/ fire/ triage/vehicle extrication) • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Secure area using Security Department or Emergency Response Team members or other people as required • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Notify Environmental Coordinator (if any likely environmental impact) • Mine Site Manager to initiate Chain of Command, if required • Maintain security of affected area until Mine Site Manager calls a stand down
External Help **Lead Agency:**	• Faro EMO
Support Agency(ies)	• Faro Community Health Centre • Yukon EMO • Spills Line

3.6.3 Dangerous Goods Truck Accident

An accident involving a truck carrying significant quantities of hazardous substances or Dangerous Goods (e.g. lime, diesel fuel, compressed gases, etc) in the FMC will require response from the site.

The presence of leaking hazardous material and possibility of fire / explosion and having to cut persons out using hydraulic cutting equipment may require an Emergency Response Team. Accurate identification of the type/s and quantities of hazardous materials involved is essential.

Main Threats:	• Injury to truck driver/ and other member(s) involved • Injury to team members responding to accident • Environmental impact • Impact to Company image/ reputation
Response:	• Assess impact • Initiate appropriate emergency response (first aid/medical/fire/triage/Hazmat/vehicle extrication) • Call-out Emergency Response Team members if required • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Notify RCMP if fatality • Notify Faro EMO • Secure area Emergency Response Team members or other people as required • Notify Mine Site Manager • Mine Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Notify Environmental Coordinator if environmental impact • Mine Site Manager to initiate Chain of Command, if required • Maintain security of affected area until Mine Site Manager calls a stand down
External Help **Lead Agency:**	• Spills Line
Support Agency:	• Faro Community Health Centre • Faro EMO • Yukon EMO • RCMP if fatality • Chemical Supplier/ Transportation Company (for information)

3.6.4 Light Vehicle Accident/ Incident

Accidents involving light vehicles on site will require response from site team members and or Emergency Response Team. The presence of leaking fuel and possibility of having to cut persons out using hydraulic cutting equipment may require an Emergency Response Team call-out or Local EMO

Main Threats:	• Injury to team member/s • Adverse impact on company image
Alarms:	• Code 1
Response:	• Call-out Emergency Response Team members • Initiate appropriate emergency response (first-aid/ medical/ fire/ vehicle extrication) • Notify Faro Community Health Center • Notify RCMP if fatality • Notify Faro EMO • Secure area using Emergency Response Team members or other people as required • Notify Mine Site Manager • Mine Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Maintain security of affected area until Mine Site Manager calls a stand down • Initiate appropriate investigation (may need to maintain security of area until completed) • Arrange clean-up using crane, excavator, loader etc.
External Help **Lead Agency:**	• RCMP if fatality
Support Agency(ies)	• Faro Community Health Centre • Faro EMO

3.6.5 Heavy Vehicle Accident/ Incident

Accidents involving heavy vehicles (e.g. trucks, cranes, loaders, dump trucks, graders etc) on site will require response from Emergency Response Team members.

An accident involving a heavy vehicle-light vehicle collision has the potential for multiple injuries. If heavy equipment is carrying hazardous substances, environmental impacts may also occur. The presence of leaking fuel and possibility of having to cut persons out using hydraulic cutting equipment may require Emergency Response Team call-out or Faro EMO.

Main Threats:	• Injury to vehicle driver/ other team member(s) involved • Environmental impact (e.g. if carrying hazardous substances) • Impact to Company image/reputation
Response:	• Assess impact • Consider Emergency Response Team call-out, if required • Initiate appropriate emergency response (first

	aid/medical/fire/triage/Hazchem/vehicle extrication) • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Isolate any energy sources or contain hazardous substances (e.g. power if hit power line, gas, diesel, chemicals, etc.) • Notify RCMP if fatality • Notify Faro EMO • Secure area using Emergency Response Team members or other people as required • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Notify Environmental Coordinator (if any likely environmental impact) • Mine Site Manager to initiate Chain of Command, if required • Notify Spills Line • If rubber-tired equipment strikes power line or tires subject to heating or fire, park up in secured/isolated area for 24 hours (Tire Fire/Explosion) • Maintain security of affected area until Mine Site Manager calls a stand down • Initiate appropriate investigation (may need to maintain security of area until completed) • Arrange clean-up using crane, excavator, loader etc.
External Help **Lead Agency:**	• 24 Hour Spills Line
Support Agency(ies):	• Faro Community Health Centre • RCMP if fatality • Faro EMO

3.6.6 Hazardous Substance Release

A release of a hazardous substance can impact people over a wide area, particularly those working down-wind of the release. Common hazardous substances that could be released are lime, compressed gas, etc. If a major release, an area evacuation should be the initial response.

Main Threats:	• Injury to team members • Injury to team members responding to accident • Environmental impact • Impact to Company image/ reputation
Alarms:	• Code 1
Response:	• Call-out Emergency Services team members with full BA gear (Code 1)

	• Initiate Area Evacuation Alarm • Initiate appropriate emergency response (first aid/medical/fire/Hazmat/assisted evacuation) • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Determine likely location and source of release, if safe • Determine likely quantity of hazardous substance • Check MSDS for treatment & control advice • Isolate any energy sources or hazardous substances release (if safe) • Notify Mine Site Manager • Mine Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Notify RCMP if fatality • Advise Local EMO, if require assistance • Secure area using Emergency Response Team members or other people if required • Notify Environmental Coordinator (if any likely environmental impact) • Maintain security of affected area until Mine Site Manager calls a stand down • Initiate appropriate investigation (may need to maintain security of area until completed) • Arrange clean-up or neutralization based on MSDS or supplier's instructions
External Help **Lead Agency:**	• 24 Hour Spills Line
Support Agency(ies):	• Faro EMO • Faro Community Health Centre • Faro RCMP if fatality • Yukon EMO

3.6.7 Water Treatment Plant Failure

System failure at the Faro Mill WTP or Vangorda/Grum WTP may occur during the water treatment season. Examples of a failure are pumping systems, containment tanks, lime delivery systems, electrical components, etc.

Main Threats:	• Injury to team member(s) • Environmental Impact • Impact to Company image/ reputation

	• Assess impact
Response:	• Consider Emergency Response Team call-out, if required
	• Isolate any energy sources or hazardous substances (e.g. turn off power/ pumping systems, chemical addition, etc)
	• Initiate appropriate emergency response (first-aid/ medical/ fire/ entrapment rescue/ HAZMAT procedure etc)
	• Advise Faro Community Health Centre of possible need for assistance (if several casualties)
	• Notify Mine Site Manager
	• Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB
	• Mine Site Manager to initiate Chain of Command, if required
	• Notify Environmental Coordinator (if any likely environmental impact)
	• Secure area using Emergency Response Team members
	• Maintain security of affected area until Mine Site Manager calls a stand down
	• Initiate appropriate investigation (may need to maintain security of area until completed)
	• Initiate appropriate containment of contaminated water released
External Help **Lead Agency:**	• 24 Hour Spills Line
Support Agency:	• Local EMO
	• Yukon EMO

3.6.8 Fire/Explosion

A fire/ Explosion has the potential to result in loss of a key component for the care & maintenance of the site. The initial response should be to evacuate the area to a safe distance and wait for expert assistance.

Main Threats:	• Injury to team member(s) in all work areas
	• Damage to mine infrastructure (depends on location)
	• Disruption to site care and maintenance
	• Adverse impact on Company image
Alarms:	• Code 1
Response:	• Call out Emergency Response Team with full BA gear, if required
	• Initiate area evacuation to muster station
	• Secure area at safe distance (at least 1 km) Emergency Response Team members
	• Maintain *exclusion zone* of at least 1 km radius (do not attempt to

	extinguish fire) • Initiate appropriate emergency response (first-aid/medical/assisted evacuation) • Notify Faro Community Health Centre of possible need for assistance (if several casualties) • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Notify Faro EMO/ Faro Volunteer Fire Department • Notify EMS if mass casualty incident • Mine Site Manager to initiate Chain of Command, if required • Notify WCHSB – Mine Rescue if specialized rescue services are required • Maintain security of affected area until Mine Site Manager calls a stand down (and fire is extinguished) • Arrange clean up of area(s)
External Help **Lead Agency:**	• EMS if mass casualty incident • WCHSB – Mine Rescue if specialized rescue services required • RCMP if fatality • Faro EMO/ Faro Volunteer Fire Department
Support Agency(ies):	• Yukon EMO • Faro Community Health Centre

3.6.9 Building Collapse

Building collapse can be the result of a seismic event, explosion or major structural failure. The area that poses the most risk is the Faro Mill WTP. The initial response should be to evacuate the area to a safe distance and wait for expert assistance.

Main Threats:	• Injury to occupant(s) and team member(s) • Damage to infrastructure/assets • Adverse impact on Company image
Alarms:	• Code 1
Response:	• Call out Emergency Response Team (Code 1) • Initiate area evacuation alarms & evacuate to safe locations (e.g. designated Muster points may be too close) • Secure area at safe distance using Emergency Response Team members or other people • Initiate appropriate emergency response (first-aid/medical/assisted evacuation/ fire fighting/rescue) • Advise Faro Community Health Centre of possible need for assistance (if several casualties)

	• Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Notify WCHSB – Mine Rescue if specialized rescue services are required • Notify RCMP if fatalities • Notify Faro EMO/ Faro Volunteer Fire Department if require assistance • Arrange for expert assistance (e.g. collapse building search) through RCMP • Maintain security of affected area until Mine Site Manager calls a stand down
External Help	• WCHSB – Mine Rescue if specialized rescue services are required
Lead Agency:	• RCMP if fatality • EMS if mass casualty • Faro EMO/ Faro Volunteer Fire Department
Support Agency(ies):	• Faro Community Health Centre • Yukon EMO • Faro SAR through Faro RCMP

3.6.10 Working At Heights Accident/ Incident

Team members work at heights on a daily basis, particularly around processing plants. Should a person fall, it may be necessary to undertake “height rescue” using site team members.

This type of event could involve a person being suspended from fall arrest equipment and being seriously injured or otherwise incapacitated. The possibility of having to extract injured persons (possibly using rope rescue) will require Emergency Response Team call-out.

Main Threats:	• Injury to team member(s)/ Emergency Response Team member(s) • Adverse impact on Company image (if serious injury)
Response:	• Call-out Emergency Response Team members • Assess situation to identify appropriate rescue method (e.g. rope rescue, use of crane with man-basket/ cherry picker etc) • Isolate any energy sources (e.g. power) or hazardous substances, if required • Initiate appropriate emergency response (first-aid/medical/rope rescue/call for back-up equipment etc) • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required

	• Notify RCMP if fatality • Notify Faro EMO if require assistance • Maintain security of affected area until Mine Site Manager calls a stand down • Initiate appropriate investigation (may need to maintain security of area until completed)
External Help	• WCHSB – Mine Rescue if specialized rescue services are required
Lead Agency:	• RCMP if fatality • EMS if mass casualty • Faro EMO
Support Agency(ies):	• Faro Community Health Centre • Yukon EMO

3.6.11 Confined Space Accident/ Incident

Team members work in confined spaces several times a year on the Faro Mine Site. This tends to be a high risk/ low frequency type of accident/ incident. However, the hazards involved may not be unique to confined spaces but, are always exacerbated by the enclosed nature of the confined space.

Main Threats:	• Injury to team members/emergency response team members • Adverse impact on Company image (if serious injury)
Response:	• Call-out Emergency Response Team members • Assess situation to identify appropriate rescue method and equipment (e.g. rope rescue) • Isolate any energy sources (e.g. power) or hazardous substances, if required • Initiate appropriate emergency response (first-aid/medical/rope rescue/call for back-up equipment etc) • Advise Faro Community Health Centre of possible need for assistance (if several casualties) • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Notify RCMP if fatality • Notify WCHSB – Mine rescue if specialized rescue services are required • Notify Faro EMO if require assistance • Maintain security of affected area until Mine Site Manager calls a stand down • Initiate appropriate investigation (may need to maintain security of area until completed)
External Help	• WCHSB – Mine Rescue if specialized rescue services are required
Lead Agency:	• RCMP if fatality

	• EMS if mass casualty • Faro EMO
Support Agency(ies):	• Faro Community Health Centre • Yukon EMO

3.6.12 Malicious Damage

Malicious damage can involve any intentional act by a team member/ contractor/ visitor that is intended to disrupt operations or damage equipment or property.

Examples are setting fires (arson), sabotaging equipment, opening valves to chemicals or other hazardous materials, etc. Malicious intent is often difficult to identify as the deliberate act may be well concealed. Any suspicion that acts may be deliberate should be notified to the RCMP for formal investigation.

Main Threats:	• Injury to team member(s) • Loss of assets (if fire/ explosion occurs) • Disruption to production
Response:	• Consider Emergency Response Team call-out, if required • If fire or explosion, evacuate affected area/s • Initiate appropriate emergency response (first-aid/medical/ fire Hazchem response/assisted evacuation, etc) • Notify Faro Community Health Centre of possible need for assistance (if several casualties) • Isolate any energy sources or hazardous substances (e.g. power, gas, diesel, chemicals, etc) • Secure area using Emergency Response Team • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Mine Site Manager to initiate Chain of Command, if required • Notify RCMP • Maintain security of affected area/s until Mine Site Manager calls a stand down
External Help **Lead Agency:**	• RCMP
Support Agency(ies):	• Faro Community Health Centre • Faro EMO • Faro Volunteer Fire Department

3.6.13 Bomb Threat

Bomb threats are usually made to administration staff by telephone and must be taken seriously. The key aspect here is to remain calm and try to record as much detail as possible about the threat itself.

Main Threats:	• Potential for injury to team member(s) • Impact on person receiving the call/ threat • Disruption to mine site care & maintenance
Alarms:	• Radio Communication Only
Response:	• Person receiving call to remain calm and record information regarding the threat using the "Bomb Threat Check-list" • Initiate area evacuation, if required (but keep people calm) • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Notify RCMP • Initiate appropriate emergency response (first-aid/medical/search/assisted evacuation, etc) • Await RCMP arrival/ instructions • Notify Faro Community Health Center if injuries occur • Notify Faro EMO • If bomb detonates, treat as "Explosion" • Arrange counselling for affected persons, including person who received Bomb Threat • Maintain security of affected area(s) until Mine Site Manager calls a stand down • Assist RCMP with investigation
External Help **Lead Agency:**	• RCMP
Support Agency(ies):	• Faro EMO • Yukon EMO • Faro Volunteer Fire Department • Faro Community Health Centre • EMS

3.6.14 Armed Hold-Up/ Hostage Situation

An armed hold-up at the mine may result in a hostage situation. In all cases, site team members should cooperate with demands made and not attempt to aggravate or apprehend armed robbers. The key aspect here is to remain calm and try to record as much detail as possible about the offenders.

Main Threats:	• Injury/ harm to team member(s) • Impact on company image/ reputation
Response:	• Instruct team members to remain calm and not resist demands • Notify RCMP • Notify Mine Site Manager • Mine Site Manager will immediately report any injuries/ major damage to authorities: YG - AAM, WCHSB • Initiate appropriate emergency response (e.g. first-aid, evacuate), depending on location of armed offenders • Do not announce an emergency call (may distress armed offenders) • Secure area at safe distance using Emergency Services Team members • Allow armed offenders to depart site (i.e. do not attempt to apprehend or hinder) • Await RCMP arrival/ instructions • Isolate and treat/ comfort those involved (while awaiting RCMP arrival) • Mine Site Manager to initiate Chain of Command, if required • Arrange counselling for affected person(s) • Maintain security of area until a stand down has been called by the Mine Site Manager
External Help **Lead Agency:**	• RCMP • Faro EMO (may be requested to for support) • Faro Community Health Centre

Appendix A

Back Pumping I.P. to Faro Pit with Godwin

Back Pumping I.P. to Faro Pit with Godwin

Risk	Outcome	Trigger
Loss of power. Loss of barge.	Exceeding manageable levels in the IP pond	Within 1 meter of spillway
Unable to transfer water from IP to Faro Mill		Loss of barge
DVTP down		
inundation of water due to heavy freshet		
Steps	**Mitigation**	**Time Frame**
	Back pump from IP to Faro Pit/Faro Mill	
1	Isolate power to C-cans at IP	.5 day
2	install Godwin at IP close to water line	.5 day
3	connect suction line and float to Godwin	.5 day
4	install 6" x 14" reducer to Godwin discharge	.5 day
5	disconnect 14" main line from C-can	.5 day
6	connect Godwin discharge to 14" main line	.5 day
7	Move to Faro Mill	
8	disconnect 14" line where enters into Faro Mill only if bypassing Faro Mill	.5 day
9	add 1000 ft. of 14" DR13.5 tie into 24" line to Faro Pit across from old tailings pump house	No line available. Dependent upon lead time. 4-6 weeks
10	start Godwin	
11	check for discharge at faro pit	

APPENDIX B

Faro Pit Pumping – Bypass Mill to I.P.

Faro Pit Pumping – Bypass Mill to I.P.

Risk	Outcome	Trigger
Loss of capacity to treat water in the Faro Mill	Unable to process water through Faro Mill	loss of clarifier/thickener tanks/power/head box
	lower levels of treatment capacity	
Steps	**Mitigation**	**Time Frame**
1	daily inspections	
2	shut down Faro Barge pump	
3	ensure containment of uncontrolled discharge from Faro Mill	
4	Disconnect 30” line across from crusher transfer tower – install 30” x 24” reducer (this reducer is *required)	*follow up on lead time for reducers
5	Extend line 24” for approximately 900’ to 20” x 20” x 20” directional “Y”.	this material is on site
6	Connect 24” line to 24” x 20” reducer (*required). Set values at 24” x 24” x 24” “T” at I.P. to I.P. Make sure value 24” to C.U.P. is closed!	
7	start Faro Barge pump	
8	balance recharge with discharge from IP to CVP	one week to set up Faro Mill depending on lead time for reducers
9	DVTP would need to be in place in order for this to be completed.	three weeks to set up CVP
10		total ~4 weeks

APPENDIX C

I.P. Pumping – Bypass Mill to Faro Pit

I.P. Pumping – Bypass Mill to Faro Pit

Risk	Outcome	Trigger
this has never been done before with the IP pumping system	Unable to process water through Faro Mill	loss of clarifier/thickener tanks/power/head box
inundation of water due to heavy freshet	beyond capacity of DVTP	Within 1 meter of spillway
		beyond capacity of DVTP
Steps	**Mitigation**	**Time Frame**
1	Disconnect 14" line at old coal stock pile 14" x 14" x 4" air relief "T". Extend 14" line approximately 1000' toward sludge drop box.	
2	Connect 14" line to 24" line from old tailings building to Faro Pit (1000' x 14" x DR 13.5 pipe is required).	
3	Pending pump and line pressures and volume delivered, a booster pump may be required in line (88 HP or Godwin) to transfer required volume to Faro Pit.	
4	This would require additional reducers 14" x 8" and 6" x 14" for Godwin pump and a transfer sump or in line adaptor for 88 HP pump and 10" x 14" reducer (all would be required).	lead time for reducers
5	Time line for all of the above will vary depending on availability of materials required.	No line available. Dependent upon lead time. 4-6 weeks

APPENDIX D

Thickener Tank Failure

Thickener Failure

Risk	Outcome	Trigger
thickener fails to the point where by we have to shut down the thickener tank	reduced treating capacity through the Faro Mill	uncontrolled discharge due to tank failure
Steps	**Mitigation**	**Time Frame**
1	daily inspection	
2	yearly inspections on tank	
3	shut down Faro Pit barge	
4	Remove overflow collection boxes and piping from thickener and modify clarifier to same configuration as thickener to increase output.	
5	Extra manpower would be required to accomplish this modification in a timely manner of 2-3 weeks.	2-3 weeks

APPENDIX E
Clarifier Failure

Reduced Flow to Clarifier

Risk	**Outcome**	**Trigger**
clarifier fails to the point where by we have to shut down the clarifier tank	reduced treating capacity through the Faro Mill	uncontrolled discharge due to tank failure
Steps	**Mitigation**	**Time Frame**
1	daily inspection	
2	yearly inspections on tank	
3	shut down Faro Pit barge	
4	close feed valve to clarifier	1 day

APPENDIX F

Power Loss

Loss of power scenario at the FMC

Risk	Outcome	Mitigation	Time Frame
Loss of power between Faro and Whitehorse	No power to site	Notify Yukon Energy to supply power from diesel plant	Yukon Energy has a procedure for the transfer. This would not be days and would only be done during main dewatering season.
Loss of pit isolation transformer	Loss of power to Faro and Grum	Utilize old freshwater pump house feeder. Build two spans to the existing pit power line.	one week
Damage to T-2 sub	Loss of power to 3E MCC. Loss of power to guardhouse and IP	Run 600v temporary jumpers from 3 MCC to 3 E MCC. Run 600v temporary jumper from /33MCC to / 70 MCCPut guardhouse and IP on Cummins standby gen set and run one 150 hp pump at IP.	IP and guardhouse would be powered immediately. Jumpers could take one week. A decision would need to be made as to how long repairs to T-2 sub would take and act accordingly.
Damage to Faro pit 1000 KVA transformer that feeds Faro barge pumps.	Loss of power to Faro pit pumps	Get the 1000 KVA transformer from little creek dam and relocate it to the Faro pit. Hang small bank at LCD for 30 hp pumps.	One week
69 KV power line falls into Grum pit	Loss of power to Grum WTP and VG pumps	Jumper the 4160é69 KV sub at the Faro end and run 4160v to VG pumps. Also jumper the line feed from 5B1 and 5B2 together to feed Grum WTP. If the pumps won't start a 1 meg diesel generator would be required.	One to two weeks depending on the number of qualified people available.
Grum sub falls into Grum pit	Same as above	Same as above	Same as above
Grum 5B1 or 5B2 breaker fail at sub	Loss of power to VG pumps or loss of power to Grum WTP depending on breaker.	Tie powerlines together inside sub.	One day, cable is already in place.
VG barge or booster switch house fails and is unrepairable.	Unable to pump water fromVG pit to Grum WTP.	Modify 5 KV switch gear currently in pit electrical shop.	Two weeks
69 KV repeater transformer fails.	No power to the repeater. Site loss of phones, internet and repeater.	Power repeater with gas genrator until replacement transformer is installed.	1-day.
Loss of power from Faro	Total loss of power from Yukon Energy.	Put guard house on cummins gen set S-007. If necessary run one pump at IP to mill. Run Cat gen set S-005 and pump from thickener to Faro pit.	
Loss of power to V15 C-can	Unable to manage water from seeps	Move in portable light plant to power pump. Portable heater would be insatalled for heat to C-can	2-days
Loss of power to S-Well	Unable to manage water from seeps	Move in the Deutz generator and instal 208 to 600 transformer	2-days
Zone II C-can	Unable to manage ground water	Move in the Cat generator the old Deutz building for the S-well. Back feed power line to Zone II.	1-day

Appendix 5G
Access Management Plan

Draft

Access Management Plan
Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

February 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon

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AAM Site Access Management Approach

Assessment and Abandoned Mines (AAM) is responsible for the management of the Faro Mine Complex (FMC) and as such, needs to be able to ensure the health and safety of those that use the area, while maintaining environmental protection. In order to facilitate this mandate the FMC area is covered by Order-in-Council 2008/168 (OIC 2008/168) as well as the land reserve 2008-2582. Both of these mechanisms cover a geographical area greater than the disturbed area of the former mine site, allowing for the additional works required to support execution of a long term remedial solution. AAM recognizes that there are many traditional and contemporary activities that take place within the OIC and reserve, or that require that people to pass through them en route to outlying areas.

AAM's goal is to provide access to the FMC to those who need it while having in place a strategy to restrict access for unauthorized users who have no recognized purpose on the site. This document describes the access management strategies that AAM applies to effectively balance these competing needs. For the purposes of describing access management strategies, the "site" or "FMC" refers to the disturbed area of the former mine site, not the area covered by the OIC and land reserve.

Authorized Users versus Non-authorized

Members of the public who wish to access the FMC for existing known uses are considered authorized recreational users providing they are within pre-defined areas (see attached Site Access Crossing Points map), or are crossing the site at designated points to access areas beyond. These users include hunters, hikers, ATV riders and snowmobilers. People holding or using trapping and guiding concessions are also considered authorized users.

Non-authorized users are those that either do not have a specific purpose to be on site (such as a contractor or employee) or are NOT accessing an area pre-defined for recreational, traditional or big-game outfitting purposes within or outside the site.

Controlled Access Points

Some areas of the site and the surrounding area have been traditionally used by First Nations and local area users. AAM does not intend to restrict access to these areas. These locations include the following areas on the attached Site Access Crossing Points map:

- The outfitter camp/cabin;
- 6. Hunting cabin;
- 9. Points for tea water collection;
- 10. Shooting range;
- 16. Registered trapline; and,
- 17. The outfitter base.

In addition to the sites themselves, there are access roads and parking areas associated with these areas that are necessary, and they include:

- 2. Road used by the outfitter and hunters;
- 3. Parking area to access hunting area northeast of the Faro Pit;
- 8. Parking area to cross the Haul Road; and,
- 11. The parking area at the fork of the Access Road.

Access points 7 and 12 are crossings of the Haul Road with signs warning the site operations staff to slow sown. In addition, site operations staff must adhere to speed limits on signage posted on the Haul Road.

For those who wish to access the pre-defined areas for recreational and traditional activities it is AAM's preference that they check-in with the gatehouse so site operations staff are aware of their general locations and can inform staff to take precautions as necessary.

Access Restrictions

In general, AAM intends to restrict access outside of the areas listed above, under the authority of the reserve. Gates will be installed in the following locations (see the attached map):

- 5. The fork in the trail that leads to the Faro diversion and Pit, and,
- 13. The trail where ATVs access the Grum side.

These areas do not provide substantive opportunities to access recreational or known traditional activities, and lead to the Faro and Grum Pits, raising significant health and safety concerns. It should be noted that in both instances alternate access across the site is available.

Site 4, on the attached map, a parking area on the Faro side, will also be closed with those accessing that side of the site directed to park vehicles at site 3. This will create one area for site operations staff to monitor.

Map



Faro Mine Site Access Crossing Points

1. Outfitter hunting camp/cabin and horse corral by gravel pits northwest of the site.
2. Road used by outfitter and hunters to access hunting camp and horse corral northwest of site.
3. Parking area to access hunting area northeast of Faro Pit.
4. Parking area to access hunting area northeast of Faro Pit.
5. Fork in the trail where hunters get confused and follow the Faro Creek Diversion road onto the site.
6. Hunting cabin off Access Road.
7. Crossing point on the Haul Road on the Faro side, leads to trapping concession and hiking trail.
8. Parking area to cross Haul Road.
9. Point for tea water collection.
10. Shooting range off Access Road.
11. Parking area at the fork of Access Road and newly opened access route to Grum Side used by hunters, outfitters and hikers.
12. Crossing point on the Haul Road on Grum side, leads to outfitter base camp. Also Town of Faro marked trail to Mount Mye.
13. All terrain vehicle trails near Grum Waste Rock. (Currently overgrown and not actively used)
14. Gate at AEX Road blocking access to the site.
15. AEX Road.
16. Registered trapline and hunting area northeast of site.
17. Outfitter base northeast of site.

YG Environment Signage

Conservation Officer erected four signs regarding moose harvest management in the area. When the maximum allowable harvest is reached, additional signs are posted by the Conservation Officer asking hunters to voluntarily cease hunting in the zones.

Faro Mine Remediation Project
Projet d'assainissement de la mine Faro

www.faromine.ca | info@faromine.ca

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Appendix 5H
Heritage Resource Management Plan

ECOFOR
natural and cultural resource consultants

Heritage Resources Management Plan for the Faro Mine Complex

Prepared for:

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James Mooney and Kevin Wilson (Owner) would like to thank the staff at Assessment and Abandoned Mines, Government of Yukonfor the opportunity to prepare this plan and for providing us with assistance.

Ecofor is solely responsible for any errors evident in this document.

MANAGEMENT SUMMARY

Ecofor Consulting Ltd., (Ecofor) is pleased to provide Assessment and Abandoned Mines (AAM) with this Heritage Resources Management Plan (HRMP) to ensure the immediate and ongoing protection and management of heritage resources within their existing developments and planned work at the Faro Mine Complex. This plan presents action items and communication protocols to assist AAM staff,their contractorsand subcontractors with the orderly and successful management of heritage resources within the Faro Mine Complex. This document is intended to be reviewed by the Ross River Dena Council (RRDC), Liard First Nation (LFN) and the Heritage Resources Unit of the Department of Tourism and Culture prior to implementation.

The action items begin with ensuring each known heritage site is flagged and signed. This will include making sure each known site is flagged with 1" wide yellow flagging tape marked in black with "**No Work Zone**". Signage will be added to each site with clear wording stating "**No Disturbance Zone**". A poster will be created and put on display at Faro Mine Complex officereminding staff of the protected status of heritage resources; that known sites are marked (showing the type of flagging and signage used); and what to do in case of chance finds. Any proposed ground disturbance activities, in areas that have not been the subject of heritage impact assessment, will be reviewed by heritage assessment staff prior to ground disturbance.

A communications protocol will be used between equipment operators and the site manager to review areas of planned impacts compared to known heritage resources prior to heavy equipment use. The entire staff will be reminded of the protected status of heritage resources and instructed on what to do during each step in the management plan. Sites recorded in the future will be flagged and signed in the same manner noted above.

AAM, their contractors and subcontractors will continue to inform the Heritage Resources Unit and relevant First Nations of heritage resources identified and any planned and accidental impacts to heritage resources. If sites are planned to be impacted then individual site mitigation plans will be developed and implemented. If any sites are the subject of mitigation efforts they will remain flagged and signed as noted above and project impacts will be avoided until directed by the Heritage Resources Unit that the mitigation measures, and reporting measures have been completed.

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1.0 INTRODUCTION

This Heritage Resources Management Plan (HRMP) is designed specifically for the ongoingidentification, protection, and management of heritage resources at theFaro Mine Complex.These action items and communication protocols presented here are intended to be used moving forward for the entire remediation project.

The Faro Mine Complex and surrounding area had not been the subject of heritage resources impact assessments until 2013. Previous to this study there were no previously recorded heritage sites within or near the assessment areas, and no others recorded in the larger vicinity. In 2012, Ecofor Consulting Ltd. (Ecofor) completed a Heritage Resources Overview Assessment for the Proposed Faro Mine Remediation Project (Mooney and Smith 2012) which identified likely resources to be found in the area and areas evaluated to contain potential for heritage resources. The following year Ecofor conducted a Historic Resource Impact Assessment of the Proposed Faro Mine Interim Works Borrow Areas (Mooney 2013). The purpose of study was to assess potential impacts to heritage resources through reconnaissance survey and selected shovel testing across the proposed borrow areas.

During the assessment seven (7) areas were subsurface tested and four (4) were found to contain prehistoric artifacts. In addition a number of modern use areas were identified and recorded across the proposed project area. The results of these efforts have been submitted to the developer, the Heritage Resources Unit, and corresponding First Nations. As sites were found in the field they were assessed for their site significance and the potential impacts by proposed developments and management recommendations were presented on a site by site basis. The locations of these sites were flagged by Ecofor.

1.1 Scope of Plan

The objectives of this plan were to protect and manage heritage resources during ongoing and future reclamation activities on site,as well as any development. The protection and managementsteps include direction to:

- Flag and sign known sites to prevent impacts;
- Create, place and annual review of a heritage resources management poster for the site;
- Provide communication protocols to manage future ground disturbances and chance finds to avoid impacts to heritage resources.

These objectives will be met through a combination of field work and continued communication between AAM, the Heritage Resources Unit, the Ross River Dena Council (RRDC), and Liard First Nation (LFN).

1.2 Plan Format

Section 2 reviews relevant legislation and definitions while Section 3presents the action items and communication protocols. Section 4 lists the references cited.Appendix I presents the known locations of heritage resources in the Faro Mine Complex. Appendix II presents the Yukon Heritage Resources

Policy for Heritage Resource Management on Yukon Lands. Appendix III presents the Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon.

2.0 RELEVANT LEGISLATION

Heritage resources in the Yukon are protected and managed under provisions of the Yukon First Nations Umbrella Final Agreement (UFA), Chapter 13 and the enabling legislation: the Yukon *Historic Resources Act*, and the Inuvialuit Final Agreement. Yukon Heritage Resources prepared an operational policy that communicates the Yukon Government's position on ownership and management of heritage resources. This policy document is attached as a reference in Appendix II.

Besides the *Historic Resources Act,*the HRMP was prepared with the following additional legislation in mind so that heritage resources may be protected and managed including chance finds:

- The Placer Mining Regulation (O.I.C. 2003/59) – under the Placer Mining Act specifically Schedule 1 Operating Conditions, Section E regarding historic objects and burial grounds;
- The Quartz Mining Regulation (YOIC 2003/64) – under the Quartz Mining Act specifically Schedule 1 Operating Conditions, Section E regarding historic objects and burial grounds; and,
- The Land Use Regulation under the Territorial Lands (Yukon) Act – specifically Section 9 (Prohibitions).

2.1 Heritage Resources Protection and Long Term Curation of Materials Collected

Heritage resources (with the exception of heritage sites identified in First Nation Final Agreements, and ethnographic objects) on non-settlement Yukon lands are considered the property of all Yukoners and are held in trust for all Yukoners, and are managed by the Yukon Government.

Heritage resources on First Nation Settlement lands are owned and managed by the First Nation. In this case the Faro Mine Complex area does overlap with some of the First Nation Interim Protected lands, Ross River Dena Council block S-11B falls within the Order-in-Council 2008/168 boundary, and the southeast corner of the Study Area is close to the Ross River Dena Council Interim Protected Land block R-11A

Under the *Historic Resources Act* and the Archaeological Sites Regulations heritage contactors prepare required written reports as well as artifacts and materials collected in the field for long term record keeping and artifact curation. This includes preparing artifact catalogs, labeling artifacts, packaging and preparing artifacts to meet specific long term curation goals as needed. In order to ensure proper completion of permit requirements, heritage contractors submit interim and final reporting as well as collected materials to the Yukon Heritage Resources to review. After the permit reporting and artifact curation preparation requirements are met, then the Heritage Resources Unit would submit materials to appropriate First Nations as requested for further management or continue to hold the materials at the direction of the First Nations.

2.2 Resource Definitions

The UFA does not provide specific definitions of heritage resources but it does distinguish the types of resources. Part 6 of the *Historic Resources Act* provides more detailed definitions.Presented below are general definitions used in the common practice of heritage resource impact assessments.

A *Site* is an area or a place, or; a parcel of land which contains heritage resources or objects.

Ethnographic objects refer to an item of material culture relating to the history and traditional culture of an ethnic group.

Historic Sites contain heritage resources that are greater than 45 years in age and posses significant heritage value. By convention, historic sites date to the period for which written records are available; in this case, the historic period commences with the arrival of the Hudson's Bay Company in the early-mid 19th century. Historic sites may include cabins, caches, camps, brush camps, and any other man-made structures, features or objects that date between about 1960 and 1830.

Archaeological or Prehistoric Sites generally represent use before European contact and are found on or under the ground surface, and may consist of the remains of ancient camps, including hearths, animal bone and stone tools and debris. In this usage, an Archaeological Site equates to a Prehistoric Site (a site that dates to the period before written history). Note, however, that in heritage resource management usage, archaeological resources are viewed as resources that are in subsurface context (buried) and may also include historic period objects and features.

*Proto-historic Sites*can be viewed as prehistoric sites from a time period which includes the effects of foreign historic cultures but lacks the first hand written descriptions of that area. For example, in the Yukon the proto-historic period ends with the appearance of first hand written descriptions in the mid 1800s. However the proto-historic time period extends back thru time when foreign materials such as "drift-iron" from ship wrecks on the west coast, or foreign trade items were carried into the Yukon. Examples of foreign historic materials which predate the mid 1800s found in prehistoric contexts usually represent this proto-historic period.

Palaeonotological Resources include the fossilized, mummified, or skeletal remains of previous life forms. These resources may be found in sedimentary rock formations, or eroding streams and creeks and contain a great deal of information concerning past environments. The most common of these resources include the skeletal remains of ice age mammals which are often associated with dark humic deposits. These remains may date from approximately ten of thousands to many hundreds of thousands of years before present.

Human remains means non-fossilized remains of human bodies that are found outside a recognized cemetery or burial site.

3.0 HERITAGE RESOURCES MANAGEMENT PLAN TASKS

The proposed HRMP action items and communication protocols presented below incorporate communications between AAM, the Heritage Resources Unit, the RRDC and the LFN, and are intended to be reviewed by each party listed above and implemented as soon as possible. The site flagging and communication protocols are intended to be carried forward through any future ground disturbing activities located within the Faro Mine Complex.

3.1 Action Items

Action Item 1: Flagging and Signage of Known Heritage Sites

Ecofor staff and a RRDC participant will return to the Faro Mine Complexin 2014 to reflag and add signage to each known heritage site in the project area including those along and near roadways and within proposed borrow pits. Table 1 presents the known sites to be reflagged.

Table 1. Known Sites to be Flagged and Signed within the Faro Mine Complex

Borden Number or Temp Site #	Class	Site Size	Features
KcTq-1	prehistoric	5 x 15 m	isolated lithic tool
KcTq-2	prehistoric	surface find	small lithic scatter
KcTq-3	prehistoric	5 x 18 m	small lithic scatter
KcTq-4	prehistoric	5 x 10 m	small lithic scatter

A 30 m buffer will be marked around each known site with strips of 1" wide yellow flagging tape with black printing that states "**No Work Zone**". Each site will be marked by durable signage that states "**No Disturbance Zone**".

Action Item 2: Creation and Placement of Heritage Resource Warning& Information Poster

Ecofor and AAMwill prepare and produce a poster and place it in a prominent location at the Faro Mine Complex (for example the board room or entrance area) which will display the following:

- a reminder of the protected status of heritage resources;
- how the sites are marked in the field;
- what to do prior to ground disturbance activities; and
- what to do in case of a chance finds discovery.

Ecofor will review the information on this poster with AAM staff and the site managers. Site managers or contractors will review this poster and the HRMP with all current and future staff atthe Faro Mine Complex. This poster will be reviewed and revised each year to allow for additional information that may need to be updated.

Action Item 3: Heritage Resources Review of any Future Ground Disturbances

A qualified archaeological consultant will review any future or planned ground disturbing efforts. Any potential ground disturbing efforts will be reviewed for any previous heritage assessment efforts and if the target has not been previously reviewed by heritage staff then they will be reviewed in the field prior to ground disturbing activities.

If any of the proposed ground disturbing plans are evaluated in the field to contain heritage resources, the resources will be recorded, flagged, and signage installed as noted in action item 1. If a location is evaluated in the field to possess potential for buried heritage resources sub-surface testing will be conducted and if resources are identified they will be recorded, and the site will be flagged and signed as listed in action item 1.

Action Item 4: Flagging and Signage of Newly Recorded Heritage Sites

All heritage sites recorded in relation to the Faro Mine Complex in the future will be flagged and signed as per action item 1. All heritage sites recorded in relation to the Faro Mine Complex will be subjected to this HRMP or the subsequent plan.

3.2 Communication Protocols

Communication Protocol 1: Ground Disturbing Activities

Prior to any new ground disturbing activities the relevant equipment operators will request approval from the appropriate contract manager. The manager will review the location of the planned disturbance against previously recorded heritage site locations. If any sites have been recorded in or near the planned ground disturbance location the manager will review the location of the heritage sites with the equipment operators in the field, on foot, and provide directions to avoid impacts to the flagged and signed 30 m buffer area.

Communication Protocol 2: Chance Finds Procedures

It is possible that heritage resources as noted above may be accidentally discovered during further remediation efforts. These resources may range in size from small flakes and chips of debitage remaining from stone tool manufacturing, up to large historic structures such as cabins. Other possible heritage resources include culturally modified trees, fire cracked rock, historic adits, cache pits, house pits, paleontological remains, isolated prehistoric tools of wood, bone, antler, and isolated historic items.

If any additional heritage resources are identified, all work in the immediate area will cease. The resources will be left in place, recorded (see below), and the area of the find will be protected from further impacts. The manager will be notified of the type, amount, and location of the find. Information collected and passed on regarding the chance find will include:

- GPS location of the find;
- Date and time when the find was identified;
- Approximate size of find and type of materials present;
- Description of setting and access to the location of the find; and
- Digital photographs of the find(s) and general area of the find.

The manager will then contact the Heritage Resources Unit to discuss further management options and notify the appropriate First Nation contacts. If the area can be protected and immediate salvage operations are not required then a resource specific or site specific mitigation plan may be developed to recover data and information as per direction of the Heritage Resources Unit and the appropriate First Nation. If immediate salvage is required to ensure safety of exposed or isolated materials the remains or artifacts may be recorded as noted above, collected, and temporarily stored on site with manager.

If the remains include paleontological remains then the Yukon Paleontologist will also be contacted.

If human remains are identified during operations, all work in the area will immediately cease and further impacts to the area will be prevented, and the R.C.M.P will be notified. If the R.C.M.P. and Coroner determine that the remains were from a historic burial, the First Nation(s) and Yukon Heritage Resources Unit will be notified, as per the Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon (Appendix III).

As part of the ongoing and continuing efforts to increase awareness of the possible heritage resources that may be found in the area, and those that have been recorded, multiple copies of the booklet entitled *Handbook for the Identification of Heritage Sites and Features* (Gotthardt and Thomas 2005) will be left at the Faro Mine Complex guardhouse to be shared with current and future management and staff.

3.2.1 Heritage Resources Contact Information

Mary Maje, YESAA Coordinator Ross River First Nation General Delivery Ross River, YT Y0B 1S0 Ph. (867) 969-2097 Fax. (867) 573-3902 rrdyesaa@northwestel.net	Chief Brian Ladue Ross River First Nation General Delivery Ross River, YT Y0B 1S0 Ph. (867) 969-2277 or 78 Fax. (867) 573-3902 rrdadm@yknet.ca
Chief Daniel Morris Liard First Nation Box 328 Watson Lake, YT Y0A 1C0 Ph. (867) 536-5200 Fax. (867) 536-2109 lfn_reception@kaska.ca	Kirsten MacDonald, Chief Coroner Government of Yukon Whitehorse, Yukon, Y1A 2C6 Ph. (867) 667-5317 Fax. (867) 456-6826 Toll free in Yukon: (800) 661-0408 kirsten.macdonald@gov.yk.ca
Dr. Ruth Gotthardt, Yukon Archaeologist Government of Yukon Yukon Archaeology Program 133A Industrial Road Whitehorse, YT Y1A 2C6 Ph. (867) 667-5983 Fax. (867) 667-5377 ruth.gotthardt@gov.yk.ca	Dr. Grant Zazula, Yukon Palaeontologist Government of Yukon Yukon Palaeontology Program 133A Industrial Road Whitehorse, YT Y1A 2C6 Ph. (867) 667-8089 Fax. (867) 667-5377 grant.zazula@gov.yk.ca
RCMP Faro Detachment PO Box 310 Faro, YT Y0B 1K0 Phone: 867-994-2677 Fax: 867-994-2452	

Communication Protocol 3: Planned Impact of Known Sites

Some heritage sites may be planned to be impacted prior to construction. If these sites are planned to be impacted then approval for impact must be granted by the Heritage Resources Unit. In most cases sites to be impacted will be subjected to a data recovery mitigation plan and fieldwork efforts. In the case of prehistoric archaeological sites, detailed block excavation of a significant sample of the site is often used to collect and record information from the site prior to site impact. In the case of other resources more detailed photographic, ethnographic, informant, and archival research may also be used to document a resource before it is impacted.

Each heritage resource at the Faro Mine Complex will be flagged for avoidance as noted above. If any sites have received data recovery excavations and/or other mitigation efforts these efforts and results must be reviewed by the Heritage Resources Unit and applicable First Nations prior to final approval for the site to be impacted. Until such approval, each site area will remained flagged and signed to avoid additional impacts. Only after approval for impact has been granted may the site be impacted.

Please Note: Some site management recommendations may include construction monitoring after mitigation efforts have been approved.

Communication Protocol 4:
Continued Communication with First Nations and the Heritage Resources Unit

It is imperative that communications regarding newly recorded heritage sites and resources, or impacts to heritage sites or resources be passed along in a timely manner to the Heritage Resources Unit and applicable First Nations. All results from the heritage assessments and mitigation efforts must also be shared in a timely manner with the Heritage Resources Unit and the applicable First Nations.

4.0 REFERENCES CITED

Gotthardt, Ruth M. and Christian Thomas
2005 *Handbook for the Identification of Heritage Sites and Features*. Heritage Resources Unit Cultural Services Branch Department of Tourism and Culture, Government of Yukon.

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2013 *Heritage Resource Impact Assessment of the Proposed Faro Mine Interim WorksBorrow Areas.* Prepared for Assessment and Abandoned Mines, Energy, Mines and Resources, Government of Yukon. On file with the Yukon Heritage Branch.

Mooney, James and Holly Smith
2012 *Heritage Resource Overview Assessment for the Proposed Faro Mine Remediation Project.* Prepared for Assessment and Abandoned Mines, Energy, Mines and Resources, Government of Yukon. On file with the Yukon Heritage Branch.

Yukon Government
1999 Guidelines Respecting the Discovery of Human Remains and First NationBurial Sites in the Yukon. Available at:http://www.tc.gov.yk.ca/pdf/respecting_guidelines_her_1999_08.pdf

2002 *Historic Resources Act*, RSY 2002, c 109.

2003 *Yukon Environmental and Socio-economic Assessment Act*, S.C. 2003, c. 7

2003 *Placer Mining Act, SY 2003, c 13*

2003 *Quartz Mining Act, SY 2003, c 14*

2003 Placer Mining Land Use Regulation, YOIC 2003/59

2003 *Quartz Mining Land Use Regulation, YOIC 2003/64*

2007 Handbook for the Identification of Heritage Sites and Features. Availableat: http://www.tc.gov.yk.ca/publications/publications_heritagehandbook.pdf

2010 *Territorial Lands (Yukon) Act, YOIC 2010/092*

APPENDIX I - Known Heritage Sites in the Faro Mine Complex

APPENDIX II - YG Policy for Heritage Resource Management on Yukon Lands

Yukon
Tourism and Culture

Operational Policy for Heritage Resources Management on Yukon Lands

This document has been developed to communicate the Yukon Government's position on ownership and management of heritage resources in the context of the development assessment and review process in the Yukon. The Operational Policy for Heritage Resources Management is based in the provisions of the Yukon First Nations Umbrella Final Agreement (UFA), Chapter 13 and the enabling legislation: the Yukon *Historic Resources Act,* and the Inuvialuit Final Agreement. In the implementation of the legislation, Yukon Government is acting to protect and manage heritage resources on behalf of all Yukoners.

Ownership and Management Authority – Moveable Heritage Resources
Yukon Government is identified as the responsible authority for heritage resource management on non-settlement (Yukon) lands based on the specific provisions concerning ownership of moveable heritage resources in the UFA, Chapter 13 (13.3.3):

- Government owns all moveable and documentary heritage resources that are not "ethnographic resources directly related to culture and history of Yukon First Nation people".

Significant management direction is provided by the UFA in the use of the term '**moveable**' in connection with heritage resources. Anticipating the requirement to manage heritage resources in future land developments and activities, the option to move heritage resources with the objective of protection is fundamental in the UFA Chapter 13.

Ownership and Management - Heritage Sites
UFA 13.8.1 Ownership and management of Heritage Sites in a Yukon First Nation's Traditional Territory shall be addressed in that Yukon First Nation Final Agreement. Examples of heritage sites that have been identified in First Nation Final Agreements: Fort Selkirk, Forty Mile, Rampart House, Lansing Post, Tagish Post, Canyon City, Lapierre House, Tr'ochëk.

With the exception of heritage sites set out in FNFA as per 13.8.1, heritage sites and non-moveable heritage resources (structures/built heritage) are governed by Laws of General Application (*Historic Resources Act*). Ownership vests in Yukon Government.

Designation of Heritage Sites under the *Historic Resources Act* ensures sites are protected from activity or development impacts. Sites or areas of historical significance in theYukon, beyond those listed in FNFA, may also be nominated for designation under the HRA. The nominations are reviewed by the Yukon Heritage Resources Board, who then recommends to the Minister that a site be designated as a Yukon Historic Site.

Heritage Resources – Definitions
The UFA Chapter 13 does not provide definitions of heritage resources, but makes the distinction among types of heritage resources as follows (13.3.6.): ethnographic objects directly related to the culture and history of Yukon Indian People, palaeontological objects, and archaeological objects. Definitions for these terms are provided in *Historic Resources Act* (Part 6 Historic Objects and Human Remains – Definitions). Generally, palaeontological objects are the fossil remains of ancient plants and animals; archaeological objects are abandoned objects that are older than 45 years. For operational purposes, "**moveable ethnographic objects directly related to the culture and history of Yukon Indian People**" (UFA 13.3.2) are objects that were

known to have been owned or used by First Nations individuals or families within living memory[1]. 'Direct' indicates the line of ownership for the object is unbroken or can be reconstructed. As per UFA 13.3.5 – if an object cannot readily be determined to be ethnographic, it is held in custody by Yukon Government until its nature has been determined.

Protection of Heritage Resources

Accidental discovery of heritage resources (UFA 13.8.7) – heritage resources discovered during construction or excavation are protected under Laws of General Application (*Historic Resources Act, Mining Land Use Regulations; Land Use Regulations*). The *Historic Resources Act* (64) prohibits destruction or alteration of a heritage resource except in accordance with a historic resources permit.

Report of Findings

> *Historic Resources Act* Part 6 Report of Findings:
> 71(1) Every person who finds an object that is or that likely is a historic object, or remains that are or that likely are human remains, shall immediately report the find to the Minister.
> (2) If the object is found on settlement land the finder shall also report the find to the Yukon first Nation which governs the settlement land.
> Quartz and Placer Mining Land Use Regulations – E Historic objects and burial grounds
>
> > **9 .** Any sites containing archaeological objects, palaeontological objects or human remains or burial sites discovered in the course of carrying out an operation must be immediately marked and protected from further disturbance and, as soon as practicable, the discovery reported to the Chief (of Mining Land Use).

In respect of UFA 13.4.8, 13.7.1, Yukon Government provides to First Nations archaeological, palaeontological and historic site inventories and research reports on heritage resources found in their traditional territories.

First Nation Burial Sites

Procedures to manage and protect First Nation burial sites have been established by the Yukon Government and Yukon First Nations: "Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon". http://www.tc.gov.yk.ca/pdf/respecting_guidelines.pdf . General provisions include:

- Restrict access to preserve dignity of the site
- Newly discovered sites/accidental discovery
  - RCMP/Chief Coroner to be informed
  - If determined to be a First Nation burial, First Nation to be informed
  - general rule no further disturbance

Heritage Resource Assessment and Permits

Standard archaeological impact assessment and mitigation procedures are followed to guide heritage resources assessment in the Yukon. The Government of British Columbia Archaeological Impact Assessment Guidelines are the recommended guideline for Yukon and are comparable to standards used in other Canadian jurisdictions: http://www.tsa.gov.bc.ca/archaeology/docs/impact_assessment_guidelines/in dex.htm

Heritage assessments ideally are undertaken in cooperation with affected First Nations. Archaeological consultants are required to communicate with affected First Nations prior to undertaking field research. A First Nation may choose not to provide oral history or traditional knowledge input to the consultant, however. In such cases, the First Nations may keep confidential information on traditional use areas, subsistence resources and

[1] Ethnographic objects of themselves may not be informative of ownership. Many historic objects (for example, guns, axes, knives) were used equally by all Yukoners and attribution of ownership (for example to Nacho Nyak Dun vs. Selkirk First Nation vs. a non-First Nation trapper) cannot be made without direct knowledge of who made or used the object or in whose former camp the object was found. Therefore knowledge or memory of historic use is critical in determining if the objects are ethnographic.

cultural values and work independently with the Yukon Environmental and Socio-Economic Review board to ensure concerns with these values are addressed for a particular project.

Under the *Yukon Environmental and Socio-Economic Assessment Act*, heritage resource assessment is generally required for all activities that will impact or will potentially impact heritage resources. All heritage resource assessments are required to be carried out under permit:

Historic Resources Act

> **62** No person shall search or excavate for historic objects or human remains except in accordance with a historic resources permit. *S.Y. 1991, c.8, s.61.*

Archaeological Sites Regulation

> **3.** No person shall survey and document the characteristics of an archaeological site without a Class 1 or Class 2 permit.
>
> **4.** No person shall excavate, alter, or otherwise disturb an archaeological site, or remove an archaeological object from an archaeological site, without a Class 2 permit.

APPENDIX III - Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites

Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon

With approvals as of August 1999

This document was prepared pursuant to provisions of
Yukon First Nation Final Agreements
and the Yukon Transboundary Agreement with the Gwich'in Tribal Council

Yukon
Tourism
Heritage Branch

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Introduction and Background

The treatment of every burial site requires respect. Legislation of various types protects burial sites and cemeteries from being disturbed. Government agencies and First Nations keep and consult records of known sites so that land use plans or proposals can avoid such sites.

There are many historic and First Nation graves in the Yukon however which are no longer marked and which may be disturbed accidentally through land use or development. Other sites may be disturbed by natural forces, such as erosion, leading to the exposure of human remains.

As more people travel in backcountry areas, for work or pleasure, it is expected that the number of such discoveries may increase. It is important therefore to have guidelines for reporting, investigating and managing such sites in a coordinated and effective manner, to give them proper respect.

Yukon First Nation (YFN) Final Agreements (Section 13.9.0) and the transboundary agreement with the Gwich'in Tribal Council (Tetlit Gwich'in) (Section 9.5) require the development of procedures to protect and manage YFN or TG burial sites, and specify certain actions when such sites are discovered.

Consistent with these obligations, these guidelines were developed at two workshops held jointly in March and October l998, involving First Nation Elders, heritage and implementation staff, the RCMP, Coroner and other Yukon and federal government officials.

Purpose

To provide direction on the reporting, identification, treatment and disposition of human remains found outside of recognized cemeteries in the Yukon, to ensure these remains are respected and protected consistent with legislation and Yukon land claims agreements.

Scope and Application

These guidelines apply to anyone who discovers human remains or grave goods outside of recognized cemeteries in the Yukon, and to the Yukon, Federal and First Nation government officials involved in protecting and caring for such sites.

The guidelines reflect existing practices in many ways. They do not replace legislation or regulations protecting burial sites, but are intended to integrate obligations contained in Yukon land claim agreements with land use permitting regimes and the Development Assessment Process . These guidelines may apply on Settlement Lands at the discretion of each First Nation. Government approval is required for management plans for sites on non-Settlement Land.

Existing known burial sites that are marked or otherwise recorded are protected by existing legislation. Management plans for these sites may be developed on a case by case basis.

Burial sites discovered within the boundaries of a designated heritage site may be subject to the management plan for that site.

The guidelines do not apply within National Historic Sites or National Parks. Parks Canada has its own guidelines respecting burial sites and human remains.

Evaluation and Revision of Guidelines

The implementation of these guidelines will be evaluated as necessary to ensure that they are fulfilling their purpose.

GUIDING PRINCIPLES

All human remains, and items found at graves (grave offerings, markers etc.) shall be treated with respect and dignity regardless of their cultural affiliation.

Actions taken following the discovery of sites will be consistent with Yukon and transboundary land claim agreement provisions respecting Yukon First Nation and Tetlit Gwich'in Burial Sites.

Each discovery will be handled on a case by case basis in consultation with the affected parties, in a coordinated and timely manner.

Definitions - see Appendix 1
References - see Appendix 2
Land claims provisions - see Appendix 3

Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites

See also Figure 1.

These guidelines cover five steps: discovery and notification; site protection and investigation; investigation and reporting; and site disposition or management agreements. A final step, arbitration, is provided for where no disposition agreement is reached.

1. Discovery and Notification

If human burial remains are accidentally discovered the following guidelines apply:

a) The finder will immediately cease any further activity at the site and report the site to the RCMP.

b) *If the finder is operating under a land use licence or permit*, the site must also be reported immediately to the land manager/permitting authority, as set out on the permit. The land manager/permitting authority shall confirm that the site is reported to the RCMP.

c) Based on the information it receives, the RCMP will notify: 1) the Coroner's office if the site is of a forensic or criminal nature; or 2) both the First Nation(s) in whose Traditional Territory the Site is located and the Heritage Branch, if the site is a suspected historic or First Nation burial site.

2. Site Protection and Identification

a) the land manager/permitting authority shall take reasonable measures to protect the site from environmental factors and any form of unauthorized interference or disturbance.

b) based on the evidence reported at the scene, the RCMP/Coroner will investigate the site and make a preliminary determination as to the nature of the remains.

c) *if the site is of a criminal or forensic nature* (potential crime scene or missing person), then the Coroner's office and police will assume authority over the site/remains.

d) Heritage Branch may recommend that an archaeologist assist police or coroner in the preliminary assessment of the site.

e) *If the site is **not** of police/coroner interest* then the Director, Heritage Branch, the affected First Nation(s) and the land manager will assume interim responsibility for protection and investigation of the site. If it's a suspected First Nation site, the Heritage Branch and First Nation would assume this responsibility.

f) the Director, Heritage Branch, the affected First Nation(s) and land manager shall take reasonable measures to restrict access and ensure that the human remains and any grave offerings are not further disturbed pending the investigation and identification of the remains. The RCMP may be consulted about protecting the site.

Figure 1

Guidelines respecting the Discovery of Human Remains and First Nation* Burial Sites

2. Site Protection and Investigation
-protection/no disturbance or access

If not a criminal matter, Heritage Branch takes lead with affected FN or transboundary group. RCMP may assist if requested.

- *First Nation, Minister*
- *permitting authority - person may continue activity*

with FN consent. If consent is not provided, proceed according to terms and conditions of arbitrator(UFA 26.7.0 TG Ch.18)

or

- *rebury, relocate or remove remains*
- *restrict/specify access if necessary and possible*
- *may designate existing or new site as burial site/cemetery or heritage site*
- *management plan (jointly prepared/approved by FN and Government on Non-Settlement Lands)*

Maps, inventories, reports, plans, agreements.

**the Tetlit Gwich'in will be involved in steps to protect and manage Tetlit Gwich'in burial sites discovered within their Primary Use Area (Fort McPherson Group Trapping area within the Peel River Basin).*

g) Where human remains are at risk of being destroyed or damaged, the Minister of Tourism for Heritage may issue a stop work order prohibiting any further activities and may make an agreement with the First Nation or the Tetlit Gwich'in or land owner or user for any investigation, excavation, examination and preservation and removal of the remains, consistent with land claim provisions. (s.*72, Historic Resources Act- This would address concerns about unknown remains.)*

Existing site inventories, land use records, affected First Nations and community elders, and military authorities, should be consulted as soon as possible about possible identification of the remains.

Some examination of the site/remains may be required to determine its cultural affiliation and age, and whether or not the site is modern or historic.

3. Investigation and Reporting

a) The Heritage Branch/land manager will direct an archaeologist or qualified examiner to carry out an investigation under any required permits, in consultation with the affected First Nation and other affected parties, to make an initial report citing, if possible*, the cultural affiliation of the human remains.

b) Within a reasonable time to be specified by the Minister, and the affected First Nation(s), the archaeologist or qualified examiner shall deliver a written report and any notification not yet made, to:

- the Minister, and the affected First Nation(s) if appropriate;
- the Director of the Heritage Branch;
- the land manager/permitting authority;
- any other representative of the interred, if known.

c) The written report shall attempt *to identify:

- the representative group of the interred;
- the geographic boundaries of the site;
- the grave offerings or other heritage resources that may be associated with the remains or the site.

d) The archaeologist or examiner may, with the agreement of the proper authority and the representative of the interred, if known, remove all or part of the human remains for further analysis or for temporary custody where the remains may otherwise be at risk.

e) Any exhumation, examination and reburial of human remains from a YFN/TG burial site shall be at the discretion of the affected YFN/TG; and if ordered by an arbitrator pursuant to land claim provisions, will be done or supervised by the YFN or Tetlit Gwich'in.

*it is often difficult to determine the cultural ancestry or affiliation of fragmentary human remains

3.1 Reporting

a) If the site is determined to be a Yukon First Nation Burial Site, or Tetlit Gwich'in burial site, the appropriate representative will be contacted in writing to provide further direction on the disposition of the remains. *

b) A person carrying out Government or First Nation authorized activity where a First Nation site is discovered can continue that activity with the consent of the First Nation in whose Traditional Territory the Yukon site is located. The consent of the Tetlit Gwich'in is required if the site is in the Tetlit Gwich'in primary use area. If consent is denied, the person can seek terms and conditions from an arbitrator about continuing the activity (see Section 5).

c) If after the final report, the human remains are found to be those of a different aboriginal people than those mentioned previously, the proper authority of that group shall be notified in order that they may assume the role of the representative.

d) Where a site is **not** found to be a Yukon First Nation or Tetlit Gwich'in burial site, or a military or mariner's burial site, the Director, Heritage Branch may publish notice of the discovery in a newspaper or other public notice seeking information on the remains.

4. Site Disposition Agreement (Management Plan)

4.1 When the site or remains are identified

a) The site shall not be disturbed and the Director, Heritage Branch or First Nation if on Settlement Land, shall initiate discussions towards entering into a site disposition agreement with the representative of the interred.

b) If the site is a Yukon First Nation Burial Site or a Tetlit Gwich'in burial site on non-settlement land, there must be joint approval of the site management plan by the Yukon First Nation in whose Traditional Territory the site is located and the Government. If the site is a Tetlit Gwich'in burial site located off Tetlit Gwich'in land but in the primary use area, the management plan must be jointly approved by the Tetlit Gwich'in and the Government.

c) Decisions regarding reburial, relocation or other disposition should be determined on a case by case basis in consultation with those concerned and in a timely manner.

Site disposition agreements shall determine such things as:
1. the interim care of the human remains*;*

2. the scope and extent of analysis to be performed on the human remains, if any;
3. the exact location of the place where the human remains are to remain or to be interred;
4. the style and manner of disinterment, if applicable;
5. the style and manner of reinterment, if applicable;
6. the time period in which disinterment and reinterment is to take place;
7. the procedures relating to, and the final disposition of any grave offerings discovered with the human remains and any additional analysis of them;
8. the provision for future maintenance of the cemetery or site where the human remains are to be located;
9. access to the site and ways to prevent disturbance;
10. any other issue agreed upon.

*it is often difficult to determine the cultural ancestry or affiliation of fragmentary human remains

4.2 When no representative is identified or no disposition is specified:

If disposition is not specified by a representative, or the remains are not claimed or no affiliation is established within a reasonable time, the Minister, or First Nation if on Settlement Land, shall with the necessary permits and approvals provide for the following disposition:

a) cover and leave the remains where they were found and have the site recorded as a burial site/ heritage site, if on land suitable for a burial site; or
b) have the remains disinterred and reinterred in the nearest appropriate cemetery; or
c) remove the remains from the site for analysis and may have them reinterred in a recognized cemetery or;
d) may act as the temporary repository of the remains.

(Where the remains were found on Settlement Land but are not considered First Nations remains, the Government may remove the remains in consultation with the First Nation.)

5. Arbitration

a) If no disposition agreement or management plan is reached within a reasonable time the matter may be referred to arbitration for settlement. If this matter concerns a Yukon First Nation Burial Site, this shall be done pursuant to 26.7.0 of the UFA; or Chapter 18, if the matter concerns a Tetlit Gwich'in site in the primary use area.

6. Records

a) A record of the site and a report of the discovery and disposition plan shall by kept by the Government and the affected First Nation(s)/representative for future reference to protect the site.

b) Access to information about discovered sites will be addressed in any site management plan developed under these guidelines, and will be protected under the *Access to Information and Protection of Privacy Act*, and the *Historic Resources Act* or *any similar First Nations legislation.*

Appendix 1

Definitions

burial site

the location of any human grave or remains that have been interred, cremated or otherwise placed, and include ossuaries, single burials, multiple burials; rock cairns; cave or cache burials etc. not situated within a cemetery

First Nation Burial Site

This refers to a Yukon First Nation Burial Site or a Tetlit Gwich'in burial site, which is defined as: a place outside a recognized cemetery where the remains of a cultural ancestor of a Yukon Indian Person (or the Tetlit Gwich'in) have been interred, cremated or otherwise placed."

[from the Definitions section of the *Umbrella Final Agreement for the Council for Yukon Indians (now Council of Yukon First Nations) and the Transboundary Agreement between Canada and the Gwich'in Tribal Council*]

human remains

mean the remains of a dead human body and include partial skeletons, bones, cremated remains and complete human bodies that are found outside a recognized cemetery" *(adapted from Historic Resources Act)*

grave offering

any object or objects associated with the human remains which may reflect the religious practices, customs or belief system of the interred.

historic

under the Historic Resources Act this generally means something older than 45 years.

land manager

Agency responsible for the administration of the land on which the site is located. For example, currently territorial parks are managed by Yukon Parks and Outdoor Recreation; gravel pits and rural airports are administered by Community and Transportation Services. Settlement Land is administered by the First Nation. Private land is administered by the land owner. (Burial sites may not be disturbed on any land without proper authorization.)

Recognized cemetery

a defined area of land that is set aside for the burial of human bodies.

representative

means a descendant of the interred or of the person whose remains are found, or where no descendant survives or is identified, an official representative of the appropriate First Nation in whose Traditional Territory the burial site is located or the closest culturally affiliated group, religious denomination, military or marine authority as evidenced by the location or mode of burial.

Where no representative can be determined the Minister shall act as the representative on Non-Settlement Lands and on Settlement Lands at the discretion and with the consent of the First Nation

representative group

means the appropriate Yukon First Nation or the closest culturally affiliated group, religious denomination, military or marine authority as evidenced by mode and style of burial which is willing to act as a representative.

Site disposition agreement

means a written agreement to be reached between the Director of the Heritage Branch and the representative of the interred regarding the disposition of the remains, including any disinterment and reinterment, and management plan

Management plan

means a plan to identify the roles of the representative, Government and land owner or manager respecting the care and protection of the site, including a consideration of site records, site access, and ways to protect a site from disturbance.

Appendix 2

References

The following include requirements to protect burial sites and were considered in the development of these Guidelines.

Umbrella and Yukon First Nation Final Agreements, Sections 13.9.0 and 26.7.0, and Implementation Plans
Yukon Transboundary Agreement (Gwich'in Tribal Council), Sections 9 and 18, and Implementation Plan
Yukon Historic Resources Act, Part 6
Criminal Code
Cemeteries and Burial Sites Act
Coroner's Act
Territorial Land Use Regulations
Yukon Archaeological Sites Regulations
Yukon Quartz Mining Act, and Regulations
Yukon Placer Mining Act, and Regulations
Yukon Surface Rights Act
Vital Statistics Act

Appendix 3

Land Claims Provisions Relating to Burial Sites

13.9.0 Yukon First Nation Burial Sites*

13.9.1 Government and Yukon First Nations shall each establish procedures to manage and protect Yukon First Nation Burial Sites which shall:

13.9.1.1 restrict access to Yukon First Nation Burial Sites to preserve the dignity of the Yukon First Nation Burial Sites;

13.9.1.2 where the Yukon First Nation Burial Site is on Non-Settlement Land, require the joint approval of Government and the Yukon First Nation in whose Traditional Territory the Yukon First Nation Burial Site is located for any management plans for the Yukon First Nation Burial Site; and

13.9.1.3 provide that, subject to 13.9.2, where a Yukon First Nation Burial Site is discovered, the Yukon First Nation in whose Traditional Territory the Yukon First Nation Burial Site is located shall be informed, and the Yukon First Nation Burial Site shall not be further disturbed.

13.9.2 Where a Person discovers a Yukon First Nation Burial Site in the course of carrying on an activity authorized by Government or a Yukon First Nation, as the case may be, that Person may carry on the activity with the agreement of the Yukon First Nation in whose Traditional Territory the Yukon First Nation Burial Site is located.

13.9.3 In the absence of agreement under 13.9.2, the Person may refer the dispute to arbitration under 26.7.0 for a determination of the terms and conditions upon which the Yukon First Nation Burial Site may be further disturbed.

13.9.4 Any exhumation, examination, and reburial of human remains from a Yukon First Nation Burial Site ordered by an arbitrator under 13.9.3 shall be done by, or under the supervision of, that Yukon First Nation.

13.9.5 Except as provided in 13.9.2 to 13.9.4, any exhumation, scientific examination and reburial of remains from Yukon First Nation Burial Sites shall be at the discretion of the affected Yukon First Nation.

13.9.6 The management of burial sites of a transboundary claimant group in the Yukon shall be addressed in that Transboundary Agreement.

*This is an excerpt from the Umbrella Final Agreement between Canada, the Council for Yukon Indians and the Government of the Yukon (l993),Ch. 13, pp. 128-129, and subsequent Yukon First Nation Final Agreements.

9.5. Tetlit Gwich'in Burial Sites*

9.5.1 Government and Tetlit Gwich'in shall each establish procedures to manage and protect Tetlit Gwich'in burial sites which shall:

(a) restrict access to Tetlit Gwich'in burial sites to preserve the dignity of Tetlit Gwich'in burial sites;

(b) where the Tetlit Gwich'in burial site is outside the primary use area *(Fort McPherson Group Trapping Area)*, require the joint approval of government and the Yukon First Nation in whose traditional territory the Tetlit Gwich'in burial site is located for any management plans for the Tetlit Gwich'in burial site;

(c) where the Tetlit Gwich'in burial site is on land in the primary use area which is not Tetlit Gwich'in Yukon land, require the joint approval of government and the Tetlit Gwich'in for any management plans for the Tetlit Gwich'in burial site; and

(d) provide that, subject to 9.5.2, where a Tetlit Gwich'in burial site is discovered, the Yukon First Nation in whose traditional territory the Tetlit Gwich'in burial site is located or the Tetlit Gwich'in, if the Tetlit Gwich'in burial site is in the primary use area, shall be informed and the Tetlit Gwich'in burial site shall not be further disturbed.

9.5.2 Where a person discovers a Tetlit Gwich'in burial site in the course of carrying on an activity authorized by government, a Yukon First Nation or the Tetlit Gwich'in, as the case may be, that person may carry on the activity with the agreement of the Yukon First Nation in whose traditional territory the Tetlit Gwich'in burial site is located or the Tetlit Gwich'in if the Tetlit Gwich'in burial site is in the primary use area.

9.5.3 In the absence of agreement under 9.5.2, the person may refer the dispute to arbitration under chapter 18 of this appendix for a determination of the terms and conditions upon which the Tetlit Gwich'in burial site may be further disturbed.

9.5.4 Any exhumation, examination and reburial of human remains from a Tetlit Gwich'in burial site ordered by an arbitrator under 9.5.3 shall be done by, or under the supervision of, the Tetlit Gwich'in.

9.5.5. Except as provided in 9.5.2 to 9.5.4, any exhumation, scientific examination and reburial of remains from Tetlit Gwich'in burial sites shall be at the discretion of the Tetlit Gwich'in**.**

*This is an excerpt from Appendix C - Yukon Transboundary Agreement between Canada and the Gwich'in Tribal Council, (l992), p. 32.

Appendix 5I
Task Authorization 016
Down Valley Interim Hydraulic Upgrades Phase 2 – Basis of Design Report

Final

Task Authorization 016 Down Valley Interim Hydraulic Upgrades Phase 2 – Basis of Design Report

Faro Mine Remediation Project

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 2014

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Acronyms and Abbreviations

1D	one dimensional
2D	two dimensional
BGC	BGC Engineering
BODR	Task Authorization 016 Down Valley Interim Hydraulic Upgrades Phase 2 Basis of Design Report
CDA	Canadian Dam Association
CVD	Cross Valley Dam
DTM	digital terrain model
EBA	EBA Consulting Engineering
FMC	Faro Mine Complex
Golder	Golder Associates
HEC-HMS	Hydrologic Engineering Center Hydrologic Modelling System
ID	Intermediate Dam
IDF	inflow design flood
ITA	Intermediate Tailings Area
km^2	square kilometres
LiDAR	light detection and ranging
m	metre(s)
m/m	metres per metre
m^2	square metre(s)
m^3	cubic metre(s)
m^3/sec	cubic metre(s) per second
NFRC	North Fork Rose Creek
NFRD	North Fork Rock Drain
NHC	Northwest Hydraulic Consultants Ltd.
PMF	probable maximum flood
Project Proposal	Faro Mine Remediation Project Proposal
RCD	Rose Creek Diversion
SFRC	South Fork Rose Creek
SD	Secondary Dam
SRK	SRK Consulting
TAR	Task Authorization Request
WSEL	water surface elevation
WTP	water treatment plant
YG	Government of Yukon

SECTION 1

Introduction

The existing Intermediate Dam (ID) spillway does not have the capacity to safely pass a moderate or major flood event without potentially overtopping and failing the dam, given a breach of the Rose Creek Diversion (RCD) dike and flooding of the Intermediate Impoundment (IP).) The Down Valley Interim Hydraulic Upgrades work package provides an upgrade to the hydraulic capacity of the ID spillway to safely pass a 1-in-500-year flood event, approximately equal to 115 cubic metres per second (m^3/sec), which is the sum of the peak flow into the RCD plus runoff from the watershed contributing to the IP. The increase in hydraulic capacity of the ID spillway will be accomplished by raising the effective height of the dam and by increasing the cross-sectional area of the spillway. The proposed work also includes improvements of the RCD to pass the 1-in-500-year flood event with freeboard.

These improvements to the ID and the RCD have been designed in accordance with the Faro Mine Remediation Medium Term Work Plan (Government of Yukon [YG], 2012).

On March 27, 2013, CH2MHILL prepared the Task Authorization 016A Down Valley Interim Hydraulic Upgrades Phase 1 Design Definition. This report was updated by the Task Authorization 016 Down Valley Interim Hydraulic Upgrades Phase 2 Basis of Design Report (BODR), published on November 25, 2013, as part of the Conceptual Design Phase (30 percent) submittal. The 30 percent BODR is updated by this 60 percent BODR. The BODR is a living document. It will be updated to a final BODR at the Detailed Design Phase (90 percent).

1.1 Task Authorization Purpose

CH2M HILL Canada Limited (CH2M HILL) is providing engineering, regulatory, and management support to the YG for submittal of the Faro Mine Remediation Project Proposal (Project Proposal) to the Yukon Environmental and Socio-economic Assessment Board. It may take several years (estimated at 2 to 4 years) to prepare the Project Proposal, and several more years (estimated at 4 to 6 years), to perform the final design, prepare contract documents, obtain a water licence, and initiate implementation of the final closure measures. It is therefore necessary that certain interim remediation activities take place to manage potential risks to human health and safety and to the environment at the Faro Mine Complex (FMC) during this interim period.

This Draft BODR was prepared to support the 60 percent design. The purpose of the Down Valley Interim Hydraulic Upgrades is to protect the ID until implementation of the final closure plan. It consists of the following project components:

- Increase the ID spillway capacity by deepening the spillway channel.
- Protect the ID spillway channel by placing gabion mattress on the channel surface and gabion cells on the channel sidewalls.
- Raise the effective ID crest by use of gabions and a geomembrane.
- Raise the crest of the RCD dike while meeting freeboard criteria.
- Remove vegetation and other debris from the RCD dike.
- Repair riprap and slope sloughing at some locations in the RCD.

Improvements to the ID spillway and crest are detailed in Section 5. Proposed modifications to the RCD are presented in Section 6.

1.2 Justification for Action

The existing ID spillway (with a capacity of 32 m^3/sec) cannot safely pass a moderate or major flood event without overtopping and potentially breaching the dam. Such ID failure may cause an environmentally damaging discharge of metals-laden tailings to the Rose Creek Valley, Anvil Creek, and the Pelly River. The discharge could result in a significant or major loss of critical fish and wildlife habitat that would be impractical or impossible to restore.

Failure of the Secondary Dam in 1975 within the Rose Creek Valley resulted in a loss of wildlife habitat, with little recovery evident more than 35 years later. Based on the threat to the environment and cultural values, KCB (2008) estimated that the ID has a "High" risk classification. This classification was made in the absence of a formal dam breach and inundation study. YG will be conducting dam breach and inundation studies for the ID and the Cross Valley Dam (CVD) in the near term. These studies will assess downstream consequences of dam failure and may result in a modification of the hazard classifications for these facilities.

In accordance with Canadian Dam Association (CDA) regulations, the required capacity of the permanent ID spillway depends on the hazard classification of the dam. A hazard classification of "High" requires safe passage of an inflow design flood (IDF) with a magnitude of 1/3rd between a 1-in-1,000-year flood event and the probable maximum flood (PMF); a hazard classification of "Extreme" requires safe passage of an IDF equal to the PMF. The permanent spillway construction, however, is a major undertaking that is impractical to implement during Phase 2B because of (1) limitations in time and funding and (2) the need to first submit the permanent spillway concepts to Yukon Environmental and Socio-economic Assessment Board and regulators for environmental and socio-economic assessment and approval before its final design and implementation. The Down Valley Interim Hydraulic Upgrades are intended to temporarily protect the ID until implementation of the final closure plan.

Results of hydraulic analyses demonstrate that the proposed interim upgrades will increase the ID spillway capacity to 115 m^3/sec, equal to the estimated 1-in-500-year flood event peak flow, assuming attenuation of flood flows through the North Fork Rock Drain (NFRD) on the North Fork of Rose Creek (NFRC). Peak flood flows will also be attenuated as the flood is routed through the ID impoundment. Estimates of flow attenuation through the NFRD are discussed in Section 4.2.

An increase in ID spillway capacity will also provide mitigation for other RCD failure mechanisms. These include: (1) failure of the RCD dike by piping or slope instability during moderate flood events, (2) landslide or debris flow originating on the mountainous slopes to the south of the RCD that would block the RCD and cause overtopping of the RCD dike, and (3) icing buildup in the RCD resulting in overtopping of the RCD dike.

1.3 Scope of Work

The scope of work for the Design Definition Phase includes the work elements discussed in the following sections.

1.3.1 Design Criteria and Basis of Design

The following tasks were performed to establish a basis for the Down Valley Interim Hydraulic Upgrades design:

- Define design criteria for the Down Valley Interim Hydraulic Upgrades, including the NFRD.
- Perform hydrological and hydraulic analyses to estimate the flows for the IDF, which is the 1-in-500-year flood event for the interim upgrades.
- Evaluate the adequacy of the NFRD to remain stable during large flood events. Perform ravelling and slope stability evaluations to gain an understanding of embankment stability. Consider other potential failure modes such as wash-out of finer particles in the schistose fill resulting in piping.
- Prepare the BODR, addressing including the following:
  - Project description, project objectives, and design criteria
  - Hydrologic and hydraulic analyses
  - Stability analyses of the NFRD
  - Pipeline relocations design criteria

1.3.2 Surveying & Mapping

In 2010, Challenger Geomatics Ltd. set nine permanent control monuments at the FMC. Permanent control points have been selected near the project area and identified on the drawings to be used for construction staking. All control monuments and project mapping data is based on the following datum:

- Horizontal Geodetic Datum: North American Datum of 1983 Canadian Spatial Reference System Epoch 2002 (NADD83 CSRS)
- Map Horizontal Projection: Universal Transverse Mercator Zone 8 North
- Vertical Geodetic Datum: Canadian Geodetic Vertical Datum of 1928 Height Transformation version 2.0 (CGVD28 HT version 2.0)
- Units: Metres

Light detection and ranging (LiDAR) data and aerial photos of the FMC were acquired by BGC Engineering (BGC) and Terra Remote Sensing Inc. for YG. The data was acquired in October 2011, with a proprietary camera and LiDAR system mounted in the same aircraft; the photography and LiDAR were taken simultaneously. The data was used to develop the contours of the project area, as shown on the construction staking drawings and InRoads digital terrain models (DTM). The DTMs are used for design as well as determining earthwork quantities.

In August 2012, CH2M HILL acquired aerial photography and aerial triangulation files from Eagle Mapping through its subconsultants, Peregrine Aerial Surveys Inc. and 4DGIS Ltd., respectively. The aerial photography is referred to as follows:

- Project Area: Low-altitude photography
- Extended Area: High-altitude photography

The planimetric mapping shown on the drawings was gathered at approximate true 3D elevations using low-altitude stereo photography. Features gathered included major flow lines, major water edges, road edges, culverts, buildings, aboveground utilities, fences, walls, and major berms. The mapping scale is 1:600. Water lines were provided in Microstation V8i curve string format, and a stroked polyline (line string) format for optimized use in a geographic information system and other software.

A bathymetric survey was conducted by Challenger Geomatics, Ltd. on 4 and 5 July 2013 to define the topography beneath the water surface for the impound area upstream from the NFRD. This data was incorporated into the project mapping files and DTMs.

1.3.3 Drawings

This task entails preparation of conceptual, advanced, and detailed drawings of the planned upgrades. See Appendix A, Advanced Design Drawings (60 percent).

1.3.4 Field Exploration Program

The increase in hydraulic capacity of the ID spillway will be accomplished by raising the effective height of the dam and by increasing the cross-sectional area of the spillway. Raising the dam will be accomplished by embedding a vertical geomembrane in a longitudinal trench and extending the geomembrane up and over a single row of gabions, whereas the spillway capacity increase will be accomplished by excavating the bottom of the existing spillway channel and hardening it with gabion mattresses.

A field exploration program was performed in 2013 to support the design of the Down Valley Interim Hydraulic Upgrades. The Task Authorization Request (TAR) 16 Data and Analysis Report is in progress and will be bound and submitted separately from this report. The scope of the fieldwork included the following:

- Seven test pits were excavated on the crest of the ID to confirm the depth to the top of the ID core material and to obtain information about trench stability for the geomembrane installation.
- Three test pits were excavated within the ID spillway channel to assess difficulty excavating the channel.
- Fieldwork was conducted to evaluate requirements for increasing the hydraulic capacity of the RCD. The length of the RCD was field-mapped to determine the following:
  - Locations and areas along the channel bank requiring vegetation removal

  - Locations and areas where sloughing of the dike slopes has occurred and zones where riprap has ravelled or slid into the channel
  - Areas or zones of depressions in the RCD dike crest, including an estimate of the extent and depth of the depressions
- Periodic flow monitoring was performed during the spring freshet in the NFRC, upstream and downstream from the NFRD. Stage readings were obtained at NF1 and NF2 monitoring locations. Discharge was measured just downstream from the NFRD or at the X2 monitoring location. Flow was previously measured in 2005 and 2006 at five locations (R7 gauge, NRFC 20/21 upstream from the NFRD pond, the NFRD pond, NRFC 22/23 downstream from the NFRD, and X2 gauge) (BGC, 2006). This data was used to evaluate the flood attenuation characteristics of the NFRD, as well as the potential for pounding behind the Haul Road embankment.
- Two geotechnical boreholes were advanced at the downstream toe of the NFRD to obtain samples for laboratory testing, to estimate the shear strength and index properties of the foundation material.

1.3.5 Hydraulic and Hydrologic Analysis and Modelling

Hydrological and hydraulic analyses were performed to estimate the flows (discharge) for the design flood event. These flows were determined separately for the South Fork Rose Creek (SFRC), NFRC, south slope area discharging to the RCD, and tailings area discharging to the ID impoundment. The task includes the following hydrological and hydraulic modelling components:

- Hydrology:
  - Determine the design peak instantaneous discharge for NFRC, SFRC, south slope, and tailings area catchments
  - Determine design flood hydrographs for the 1-in-500-year flood event for NFRC, SFRC, south slope, and tailings area catchments
- Hydraulics:
  - Evaluate attenuation characteristics of the NFRD by estimating the flow-through capacity of the NFRD. Field stage and discharge measurements upstream and downstream from the NFRD were used as an initial starting point for determining flow-through characteristics during normal and low flow conditions. Theoretical relationships were used to estimate flow-through capacity during large floods, since field observations are not available to validate flow-through characteristics during such events.
  - Perform one dimensional (1D) hydraulic modelling to route the 1-in-500-year flood event flows from the NFRC, SFRC, south slope, and tailings area catchments to the RCD and tailings areas. Create design hydrographs at the head of the RCD, RCD downstream of the overflow weir, and the ID impoundment for the design recurrence interval event.
  - Perform two dimensional (2D) hydraulic modelling to route the 1-in-500-year flood event through the tailings, the RCD, the overflow weir, Intermediate Impoundment, and the ID spillway.
  - Model the overflow weir to estimate requirements for bypassing the 1-in-500-year flood event without overtopping.
  - Model the ID spillway with the proposed improvements in place.
  - Complete 2D model simulations to evaluate the effect of vegetation removal in the RCD.
  - Perform breach analysis of the NFRD to evaluate downstream flood inundation levels and incremental damage to the dams in the tailings area. Run the 2D model to simulate propagation of flood waves for embankment breach during the 1-in-500-year flood event for different NFRD flow-through scenarios, i.e. for different impoundment volumes and heights. The purpose of performing breach analyses for various flow-through assumptions is to develop an understanding of how sensitive the consequence of

NFRD failure is to the flow-through capacity and blockage of the NFRD. This information can assist in decision making for the interim period and for final closure.

1.3.6 Evaluation of North Fork Rock Drain

The NFRD provides a porous conduit for conveyance of NFRC flows through the Haul Road. A pool forms on the upstream side of the Haul Road embankment as water enters the rock drain. During the freshet, flood events, and other higher flows, the size of the pool increases as flows exceed the flow-through capacity of the rock drain. The rock drain reduces flow velocity, attenuates flows downstream, and collects sediment and debris.

Because failure of the Haul Road embankment during an extreme high flow event has the potential to adversely impact RCD and the ID, analyses were conducted to evaluate: (1) the flow-through capacity of the rock drain, and (2) the stability of the structure under high flow conditions.

The Golder Associates (Golder) design and some inspection reports of the NFRD were reviewed. The results of this review are provided in Appendix I. The appendix also includes a review of the design, construction, and performance of rock drains in general.

The stability evaluations considered the following: (1) slope stability failure under various water levels, and (2) ravelling failure initiated by high discharge velocities exiting the downstream toe of the rock drain. The results of these analyses are provided in Appendix B. These evaluations were performed because it was practical to do and useful to gain understanding of the embankment stability. It is noted, however, that there are other potential failure modes that could be more critical, but are difficult or impossible to evaluate. One such failure mode is wash-out of finer particles in the schistose rockfill resulting in a preferential seepage path and eventual piping of the embankment.

1.3.7 Future Work

The Medium Term Plan identifies the following additional work to be completed for the Down Valley Interim Hydraulic Upgrades:

- Final design, including preparation of detailed, and final contract documents
- Procurement assistance, including preparation of tender-ready subcontract documents plans and specifications and contract assistance
- Permitting
- Construction management, including services during construction and onsite inspections

The work will be initiated and completed within 3 fiscal years. A field investigation and preparation of the 30 percent design was completed and submitted November 25, 2013. Advanced Design (60 percent) and Detailed Design (90 percent) will be completed in the 2013/2014 fiscal year; Final Design (100 percent) and preparation for procurement will be completed in the 2014/2015 fiscal year; procurement will be conducted in 2015/2016 fiscal year; and construction will be conducted in 2016/2017 fiscal year. The construction will be conducted during the summer of 2016 (see Appendix G, Construction Schedule).

SECTION 2

Background

2.1 Description of Existing Elements

Approximately 28.6 million cubic metres (m^3) of flotation-derived process tailings were deposited in the Rose Creek Tailings Area between 1969 and 1998. The tailings are contained by a series of three dams constructed across the Rose Creek Valley. Faro Mill production records indicate that the tailings have an average concentration of lead, zinc, and copper equal to 0.8 percent, 1.3 percent, and 0.12 percent, respectively. Oxidation of the sulfides results in production of low pH (acidic) water with elevated concentrations of sulfate, zinc, and other metals. These metals are toxic to aquatic and terrestrial life.

The existing ID spillway has a capacity of about 32 m^3/sec when the pool reaches the top of the dam core (Northwest Hydraulic Consultants, Ltd. [NHC], 2006). The 1-in-500-year flood event is estimated to have a flow equal to approximately 115 m^3/sec, which includes attenuation by the North Fork Rock Drain and by the Intermediate Impoundment. NHC [2006] estimated that a 1-in-500-year flood event, without attenuation by the NFRD, would have a flow equal to 132 m^3/sec at the ID spillway.

The RCD channel is approximately 4.7 kilometre-long and conveys Rose Creek around the Rose Creek Tailings Area. The diversion was originally designed to carry a 1-in-50-year flood event (approximately 79 m^3/sec) with 1 m of freeboard. It was later modified to convey approximately 140 m^3/sec, approximately equal to the estimated 1-in-500-year flood event without flood attenuation of the NFRD (BGC, 2006; NHC, 2006).

The RCD dike includes a lowered “overflow weir” section which provides an initiation point for overtopping of the RCD dike during flood events. The overflow weir is armored with riprap and large diameter riprap which, by inspection, appears to reduce its erodibility. The existing condition of the RCD is such that vegetative growth and other channel maintenance related issues have decreased the flow capacity at the overflow weir to less than the 1-in-50-year flood flow before overtopping.

Because the RCD dike was constructed on top of frozen ground, the condition of the dike and its performance during large storm events is uncertain. In a large storm event, the overflow weir or another location along the RCD dike could fail, resulting in flooding of the Intermediate Impoundment and overtopping the ID. Depending on the magnitude of the storm event, overtopping the dam could result in minor erosion failures, or under extreme events, could potentially breach the dam. An ID failure and breach would result in tailings-laden water flowing into the Cross Valley Dam Pond, through the CVD, spillway and beyond into Rose Creek and the downstream environment.

2.2 Proposed Project Components

The proposed Down Valley Interim Hydraulic Upgrades will consist of the following elements:

- Increase the existing ID spillway capacity by: (1) increasing the effective depth of the existing spillway channel and (2) increasing the effective height of the ID embankment crest. The proposed modifications will enable the ID Spillway to pass the 1-in-500-year flood event including attenuation by the NFRD and the Intermediate Impoundment, with a freeboard of 1.0 m. The analysis assumes that the overflow weir has completely eroded, resulting in the entire RCD flow being conveyed into the Intermediate Impoundment.

- Protect the ID spillway channel from erosion by installing gabion mattresses along the bottom and gabion retaining structures along the side walls.
- Relocate the existing effluent piping within the ID spillway.
- Increase the RCD capacity to pass the 1-in-500-year flood event by raising the RCD dike by approximately 0.5 m, removing vegetation within the RCD and along the RCD dike slope and 5 m beyond the toe, and repairing or restoring slopes on the RCD banks.

2.3 Design Criteria

The development of design criteria for the Down Valley Interim Hydraulic Upgrades project is discussed in this section. The proposed improvements are intended to reduce risk for an interim period only; therefore, the design criteria for this project are less stringent than the criteria for final closure. To provide context and background, the final closure design criteria are also provided in this section. These criteria, specifically the level of seismic and flood loading, generally depend on the hazard classification of the dam.

The design criteria presented here apply to the following project elements:

- ID
- CVD
- Overflow weir
- RCD
- NFRD

2.3.1 Hazard Classification

The CDA dam safety guidelines (CDA, 2007) are used to classify the hazard level of a dam based on the impacts on the public and the environment from the effects of a dam failure.

2.3.1.1 Intermediate Dam

The most severe consequences of a dam breach are associated with the ID, which contains more than 11.9 million m^3 of copper, lead, and zinc-laden tailings that are toxic to aquatic and terrestrial life. The total tailings volume of all three impoundments (original, secondary, and intermediate) is 28.6 million m^3 (Robertson GeoConsultants Inc., 1996). KCB (2008) estimated that the ID has a “High” risk classification; however, the estimate was made in the absence of a formal dam breach and inundation study. YG will be conducting dam breach and inundation studies for the ID and the CVD in conjunction with the 2014 dam safety evaluation.

Improvements to increase the capacity of the ID spillway consist of two elements: (1) enlarging and reinforcing of the spillway, and (2) moderately raising the effective dam crest. Analysis results presented in this BODR indicate that the modifications proposed in the Medium Term Plan (YG, 2012) will result in an increase in capacity sufficient to safely pass a 1-in-500 year flood event. The analysis described herein confirms this estimate. The proposed modifications will increase the safety of the ID in the interim period while the field investigation, planning, and design take place to construct a spillway for final closure.

2.3.1.2 Cross Valley Dam

The CVD has the same hazard classification as the ID. The main hazard from a CVD breach is not only the uncontrolled release of water from the Cross Valley Dam Pond, but sudden release of the polishing pond could also cause significant danger to the ID. The ID does not have filter and drainage systems in the lower part of the embankment below the downstream bench, and instead depends on the polishing pond to provide a counterbalancing hydrostatic head to reduce seepage and the need for filtering. A sudden drawdown of the pond is likely to result in significant seepage from the saturated ID downstream slope, which in turn could lead to progressive sloughing, even more seepage, possible backward erosion, and eventually could result in piping or loss of the crest from larger slope stability failures.

No changes are proposed to the CVD spillway. Its spill capacity of about 300 m^3/s significantly exceeds the new updated ID spillway capacity of 115 m^3/s.

TABLE 2-1
Dam Classification – CDA 2007
Faro Mine Remediation Project

Dam Class	Population at Risk [a]	Incremental losses		
		Loss of Life [b]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss No long-term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary only	Unspecified	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 people or fewer	Significant loss or deterioration of *important* fish or wildlife habitat Restoration or compensation in kind highly possible	High economic loses affecting infrastructure, public transportation, and commercial facilities
Very High	Permanent	100 people or fewer	Significant loss or deterioration of *critical* fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)
Extreme	Permanent	More than 100 people	Major loss of *critical* fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

[a] Definitions for population at risk:

None = There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary = People are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent = The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more-detailed estimates of potential loss of life (to assist in decision making if the appropriate analysis is carried out).

[b] Implications for loss of life:

Unspecified = The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirements, for example, might not be higher if the temporary population is not likely to be present during the flood season.

2.3.1.3 Secondary Dam

A breach of the Secondary Dam (SD) could lead to a loss of tailings into the environment, but the magnitude of such a tailings loss would be much smaller and more contained than the tailings loss associated with an ID breach. Whereas the ID and CVD need to accommodate hydraulic (flood) loading, as well as seismic (earthquake) loading, the SD only needs to be designed for seismic loading. Seismic loading could cause liquefaction of the dam foundation, and specifically at the locations where Rose Creek sediments are present in the foundation of the dam. At the West Limb, which is the curved portion of the SD that crosses the valley roughly north to south, tailings are present on the downstream toe of the SD. These tailings would prevent failure of the dam during seismic loading even if the foundation soils liquefy. Even if some tailings loss would occur along this portion, the tailings are likely to be contained within the Intermediate Impoundment.

A breach of the East Limb of the SD, which is the portion of the SD parallel to the RCD and without tailings at the toe, could result in tailings flowing into the RCD. It is noted that the likelihood of tailings loss is low even when losing a portion of the East Limb crest; given that the upper layers of the secondary tailings are not saturated and given the relatively small height of about 4.6 m. KCB (2008) did not estimate the risk classification for this dam.

2.3.1.4 North Fork Rock Drain

Although the Haul Road embankment, including the NFRD, was not designed or intended to impound water, it will likely retain a significant pool of water temporarily during very large flood events. The retained volume depends on the flow-through capacity of the rock drain. A high flow-through capacity would result in a smaller volume of retained water; whereas a low flow-through capacity would result in larger volumes of water retained. Because of the uncertainty in the adequacy (stability) of the NFRD to serve as a water-retaining structure under flood conditions, a breach analysis was conducted to evaluate the potential effects on the RCD and ID if failure of the NFRD occurs during a 1-in-500-year flood event. Because flow-through capacity during large storm events is uncertain and difficult to evaluate or estimate, sensitivity analyses were conducted for different flow-through assumptions, including different assumptions of blockage by debris.

2.3.2 Preliminary Design Criteria for Final Closure

Table 2-2 provides the CDA guidelines (CDA, 2007) for required spillway capacity and stability under earthquake conditions based on the dam risk classification. Design criteria for the tailings and other dams at the FMC facilities are not only dictated by the CDA classification of the dams, but were also a condition of the expired water licence. Clause 58 of the expired water licence (Water Use Licence QZ03-059) states that a final closure and reclamation plan for the FMC facilities shall incorporate the following design standards and requirements:

- All decommissioned tailings-related facilities and structures shall be designed to withstand the maximum credible earthquake and the PMF
- Long term physical stability of all watercourses and tailings deposits shall be ensured, with minimum post-operational maintenance
- The long-term water quality in Rose Creek downstream from the tailings facilities shall comply with the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (Canadian Council of the Ministers of the Environment, 1999)

Based on both the requirements of the expired water licence as well as the CDA guidelines, the recommended design criteria for final closure for each of the dams are interpreted as follows:

- The ID and SD shall be required to withstand an earthquake event with a recurrence interval of 10,000 years, which can be considered the maximum credible earthquake. These dams shall also be required to withstand or pass the PMF.
- The final closure concepts for the CVD have not been determined at this time, but it is unlikely to continue to function as a polishing pond. In the future it is likely to be operated in a dewatered state and will only contain significant amounts of liquid when needed for emergency storage. Since it will generally be empty, it is not considered necessary to design the dam for the maximum credible earthquake, but to design it to withstand

the 1-in-500-year earthquake. Considering hydraulic loading, however, it is recommended that the CVD be required to pass the PMF, since it would contain a significant pool during flood loading conditions. In addition, the CVD is the last dam in a series of dams, where the upstream dams (SD and ID) will be required to pass the PMF.

- Similarly, the final closure concepts for the NFRD have not been established. If the structure is retained in its current configuration, it could act as a temporary impoundment during large to very large floods. The likelihood of having a large flood occurring at the same time as a large earthquake is remote. It is therefore anticipated that the NFRD will only have to be designed for a 1-in-500-year earthquake, since there will be no significant pool and associated consequence of failure for most of the time. Given that the ID needs to be designed for the PMF, and the fact that a breach of the NFRD could result in overtopping and breach of the RCD dike and the ID, it is anticipated that the NFRD will also be required to pass the PMF.

TABLE 2-2
CDA Dam Safety Guidelines – Suggested Design Flood and Earthquake Levels for Use in Deterministic Assessments
Faro Mine Remediation Project

	Annual Exceedance Probability	
Dam Class [a]	**Inflow Design Flood [b]**	**Earthquake Design Ground Motion**
Low	1/100	1/500
Significant	Between 1/100 and 1/1,000 [d]	1/1,000
High	1/3 between 1/1,000 and PMF [e]	1/2,500[f]
Very high	2/3 between 1/1,000 and PMF [e]	1/5,000[f]
Extreme	PMF[e]	1/10,000

[a] As defined in Table E4-1 Dam Classification – CDA 2007.

[b] Extrapolation of flood statistics beyond 1/1,000-year flood (10^{-3} annual exceedance probability) is discouraged.

[c] Annual exceedance probability levels for earthquake design ground motion are to be used for mean rather than median estimates of the hazard.

[d] Selected on the basis of incremental flood analysis, exposure, and consequences of failure.

[e] PMF has no associated annual exceedance probability. The flood defined as "1/3 between 1/1,000 year and PMF" or "2/3 between 1/1,000 year and PMF" has no defined annual exceedance probability.

[f] The earthquake design ground motion value must be justified to demonstrate conformance to societal norms of acceptable risk. Justification can be provided with the help of failure modes analysis focused on the particular modes that can contribute to failure initiated by a seismic event. If the justification cannot be provided, the earthquake design ground motion should be 1/10,000.

2.3.3 Design Criteria for the Interim Period

The final closure plan for the FMC will take several years to prepare and initiate construction, therefore it is necessary to provide adequate levels of security of the dams and to implement early remediation activities necessary to manage potential risks to human health and safety, and to the environment during the interim work. Until the closure conveyance strategy and structures are agreed upon and implemented, it is proposed that the existing conveyance structures are designed to safely convey a 1-in-500-year flood event. The criteria will be consistent with the conditions of the expired water licence (Water Use Licence QZ03-059), which states:

> *40. The Rose Creek Diversion shall have a capacity to carry a 1:500 year design flow.*
>
> *41. The spillways on the Intermediate Dam and the Cross Valley Dam shall have a capacity to carry a 1:500 year design flow of Rose Creek.*
>
> *42. The overflow structure on the Rose Creek Diversion Dam shall be maintained to ensure that peak flows can freely pass through it.*

To justify this criteria, the likelihood of a 1-in-500-year flood event during an interim period of 10 years was compared with the likelihood of exceeding the design flows for typical design diversions for constructing high hazard dams; typically, the diversions are designed for a 10- to 20-year flood event with the diversion in place for 2 to 3 years. The likelihood that a 10-year flood or greater could occur during a 2-year construction period is 18 percent, whereas the likelihood that a 1-in-500-year flood event or greater could occur during a 10-year period is 2 percent. If it is assumed that the PMF would have a recurrence interval of 10,000 years, the likelihood that it could occur during a 100-year period is about 1 percent. It appears appropriate that the tailings dams be designed for a flood event with a much lower annual probability of occurrence than for a temporary diversion, given that the consequence of failure for the tailings dams could be significantly higher than consequence of failure of typical diversion works. On the other hand, it also seems appropriate to design it to a flood event with a higher annual probability of occurrence than that of the permanent dam.

Since the NFRD will be in operation for the interim period, flood flows through the NFRC will be attenuated by the structure. To calculate the 1-in-500-year flood event flows, as required in the design criteria stipulated by the water licence, the effects of attenuation of the NFRD will be taken into account. Flow-through calculations indicate that the NFRD could attenuate peak flows during a 1-in-500-year flood event by 18 to 38 percent. Peak flows could be further attenuated by a reduction in flow-through capacity at the NFRD caused by debris blockage or other processes that may occur during a flood of such magnitude. It is recommended that some modest amount of freeboard (for example, 0.5 m) be included in the capacity estimation for the RCD.

The specific approaches and assumptions for each of the project elements are discussed below.

2.3.3.1 ID Spillway and Crest

The following approach is incorporated for design improvements to the ID spillway:

- Assume that the IDF (1-in-500-year flood event) will be directed onto the Intermediate Impoundment, due to a breach of the RCD dike.
- Proposed improvements to the ID spillway and crest will increase the spill capacity such that the spillway will be able to accommodate the 1-in-500-year flood event flowing into the RCD. The improvements will consist of two elements:
  - Enlarging the spillway channel by excavating the bottom of the channel, and hardening or reinforcing the excavated channel using gabions on the side slopes of the channel and a gabion mattress along the bottom of the channel
  - Raising the effective dam crest elevation by excavating a trench into the top of the dam core and installing a geomembrane vertically in the trench between the dam core and the crest surface, and placing a single row gabion cells along the embankment crest to raise the effective crest of dam.

2.3.3.2 Rose Creek Diversion Overflow Weir

The following applies for designing improvements to the overflow weir:

- Although the overflow weir has been referred to as a “fuse plug” in previous studies, there is uncertainty whether this structure will breach soon after being overtopped. The existing structure is heavily armored with large diameter riprap and conveys overflow or breached flows out onto the tailings area through a dedicated relief channel.
- Since it is not desirable that the overflow weir breach for floods smaller than the 500-year flood event, the structure will be raised to prevent overtopping for floods less than this event. No other structural modifications to this structure are being considered to achieve specific breach performance criteria for the interim period. Both scenarios: full breach or overflow without breaching is considered plausible after the 500-year flood event flows are exceeded. For final closure, it is anticipated that this structure will be replaced with a hardened overflow structure with sufficient spill capacity to pass the PMF.

- The overflow weir provides an outlet for flows higher than the 1-in-500-year flood event to prevent overtopping of the RCD dike over its downstream reaches. The crest of the overflow weir will be raised to contain the 1-in-500 year flood event with zero freeboard.

2.3.3.3 Rose Creek Diversion

The following applies for designing interim improvements to the RCD:

- The RCD dike will accommodate the 1-in-500-year flood event with a 0.5 m freeboard.
- In addition to raising the crest of the RCD dike to meet freeboard criteria, vegetation needs to be removed from the dike and riprap; several slopes which have sloughed or are otherwise unarmoured will be repaired.

  Reasons for vegetation removal include the following: (a) allow proper inspection, surveillance, and monitoring for seepage, cracking, displacement, and any other signs of distress in the dike; (b) allow access for operations and maintenance activities; (c) prevent root-related damage, such as shortened seepage paths through the dike or its foundation, and voids in the dike or its foundation due to decayed roots or fallen trees; and (d) limit those habitat characteristics that encourage the creation of animal burrows.
- Slope repair to augment and replace riprap erosion protection is necessary to maintain uniform protection against erosive water forces up to the crest elevation of the RCD dike. Dike slopes will be graded to 2:1 (horizontal to vertical), and armoured with appropriately sized riprap. The higher gradient stepped sections of the RCD which are armoured with large diameter riprap do not require extensive treatment except to replace large boulders which may have been displaced from the dike side slopes. Note that riprap placement is not required on the RCD dike embankment upstream of the overflow weir due to the wide channel geometry and low predicted channel velocities.

2.3.3.4 North Fork Rock Drain

The following applies for designing interim improvements to the NFRD:

1. The adequacy of the Haul Road embankment, including the NFRD, as a water-retaining structure should be considered in the context of the objective of the Down Valley Interim Hydraulic Upgrades, which is primarily to protect the ID until implementation of the final closure plan. If a 500-year flood could result in failure of the Haul Road embankment, the objective of the Down Valley Interim Hydraulic Upgrades would be compromised. Perform breach analyses of the NFRD to evaluate the consequences of failure of the NFRD under the 1-in-500-year flood event. Perform stability evaluations and review design and as-build information of the NFRD to evaluate its likelihood of failure.
2. Maintenance should be conducted on the upstream face of the NFRD to remove debris.
3. In order to develop a better estimate of the flow through capacity of the NFRD, the pool elevation should be measured during significant storm events. Stream flow should be measured upstream and downstream of the Haul Road.

2.3.3.5 North Fork Rock Drain Flood Attenuation Approach

The haul road embankment contains a 70-m-wide zone constructed of calcium-silicate rock. This zone, which is centered on the pre-existing channel, is the NFRD. On both sides of the NFRD, the Haul Road embankment fill consists of schistose rock. The BGC report titled *Task 22D: North Fork Rock Drain*, dated September 15, 2006, provides a basis for evaluation of flood attenuation through the NFRD. The report provides details of the as-built conditions of the NFRD, as well as summaries of construction observations and the design criteria used for the original design.

The flow of water through the rockfill does not follow Darcy's Law, but follows rules related more to turbulent flow. The first memorandum in the BGC report describes the theoretical basis for flow-through rockfill, and recommends that the Wilkins equation be used to estimate flow through the NFRD.

The historical stage (pond level) -discharge relationships developed by Golder (1986, 1988) and BGC (2006) for smaller flood events (spring freshet flows) are used as the initial bases for flood attenuation. To provide a

conservative estimate of peak flow rates during non-breach events for the RCD, zero plugging by debris and a high flow-through capacity is assumed. For evaluation of breach impacts, a medium flow-through scenario, low flow-through scenario, and a low flow-through scenario with increasing levels of debris blockage was considered to determine what conditions may lead to an overtopping of the ID crest.

SECTION 3

Evaluation of North Fork Rock Drain

3.1 Description and Basis of Design

The basis of design of the NFRD is available as documented in the Golder Design Report (1986). Following construction in 1987, Golder inspected and assessed the performance of the rock drain (Golder, 1991, 1993).

To date, the NFRD has performed satisfactorily. The maximum recorded flow through the structure as of 2009 was 22 cubic metres per second (m^3/sec)(Ferris, 2009). The following list summarizes the key design information specified by Golder (1986), as summarized by BGC Engineering (BGC, 2006):

- The drain was to be constructed from calcium-silicate rock, whereas the remainder of the Haul Road could be constructed of schistose rock.
- The design flood for this structure was the 100-year return period flood event (70 m^3/sec).
- The width of the calcium-silicate rock drain was intended to be 70 m, centered on the pre-existing creek channel
- The construction of the NFRD included rock end-dumped from the final road elevation; the final height was approximately 55 m. This method resulted in a natural sorting of the rock, with the largest rocks at the base of the road and the fine material near the top.
- The assumed slope of the upstream and downstream faces of the drain was 37 degrees, the angle of repose for calcium-silicate rock.
- The design assumed that the drain would consist of the lower 3.6 m of the causeway. The representative grain size was assumed to be 0.3 m, given the likely maximum particle size and an allowance for particle breakage due to the overlying weight of the rockfill.
- To determine the capacity of the drain, it was assumed no flow occurred in the upper portions of the rock drain (above 3.6 m drain). The routing analysis indicated that the 100-year flood would produce a 40-m deep pool on the upstream side of the drain, and that the mean annual flow would result in an 11-m deep pool.
- The downstream face of the drain (if left at the assumed angle of repose, 37 degrees) was considered to be unstable under high flows, because of seepage forces. The design included the construction of a “fillet” of large diameter rock, to be installed at the downstream toe. The fillet, which was intended to stabilize the toe from seepage forces, was to have a minimum slope of 3H:1V, and extend to 15 m or more above the toe of the drain. This fillet was never constructed.
- The original design included the construction of an emergency overflow spillway and the abandonment of the NFRD; the spillway was never built and the NFRD remains.

Photos and descriptions indicate that the Haul Road embankment was constructed across an unprepared foundation surface on the valley bottom. Trees, peat, topsoil, and other native materials were not removed prior to construction of the Haul Road embankment and NFRD. During construction, a bulldozer was used to position large rocks in the channel of the NFRC. Outside the calcium-silicate NFRD prism, the Haul Road embankment was constructed of similarly end-dumped schistose (phyllite) rock. This rock is considerably less durable and more prone to breakdown than the calcium-silicate comprising the rock drain.

3.2 North Fork Rock Drain Failure Consequence

Stability of the Haul Road embankment, including the NFRD, must be considered in the context of the objective of the Down Valley Interim Hydraulic Upgrades, which is primarily to protect the ID until implementation of the final closure plan. If a 500-year flood is likely to result in failure of the Haul Road embankment, the objective of the Down Valley Interim Hydraulic Upgrades could potentially be compromised. To evaluate the consequences of

failure under the 1-in-500-year flood event, breach analyses of the Haul Road embankment were performed. The analyses were performed for the following: (1) a best estimate flow-through scenario, (2) a low flow-through scenario, and (3) a low flow-through with 25-percent blockage scenario.

The breach analyses and downstream inundation results are presented in Section 4.

Results from the breach analyses indicate that for the best-estimate scenario (resulting in a relatively smaller pool retained by the NFRD), a breach of the NFRD would result in flows that should be contained within the RCD. Overtopping of the SD, the RCD dike, or the ID would not occur.

For the low flow-through scenario and low flow-through with 25-percent capacity reduction scenario, the flood wave resulting from the breach would exceed the RCD capacity, resulting in overtopping of the RCD dike, spill onto the Secondary Tailings Area and the Intermediate Impoundment. The flood wave would exceed the capacity of the proposed ID spillway and overtop the ID.

The potential breach mechanism assumed in the breach analysis is piping through the schistose fill material or through the foundation.

3.3 North Fork Rock Drain and Haul Road Embankment Stability

3.3.1 Reference Documentation

Available documentation on the Haul Road embankment and the NFRD was reviewed to evaluate the adequacy of the structure as a water-retaining structure. Summaries of the most pertinent reports are provided below, but its contents are discussed in more detail in Appendix I. This documentation includes:

- Evaluation report by BGC Engineering (BGC, 2006), which included theoretical analyses, reference to experience with through-flow rockfill dams, and practical experience gained at Faro through monitoring of flows through the NFRD under low flow conditions. The studies also included description of visual inspections and a limited geotechnical exploration program consisting of two test pits on the crest of the Haul Road embankment. It is noted in the report that there are significant uncertainties and unknowns associated with the studies. For example, BGC concluded that *"Definition of 'best estimate' flow through relationship for the NFRD is difficult due to the unknown material properties of the drain and the assessment of how much water flow will be possible through the schistose rock."* To account for the uncertainty in flow-through, BGC considered a range of flow-through capacities to predict flow-through discharge and impoundment volumes.
- Design Report by Golder (1986), which provides a discussion of the design of the flow-through rock drain and its adequacy at conveying the design flows. The report includes a discussion of potential failure modes for the rock drain including: (1) deposition of sediment within the calcium-silicate rock, (2) downward migration of fines within the haul road embankment, and deposition of these fines within the rock drain, (3) degradation of the coarse rock fragments over time, and (4) potential glaciation (freezing) within the rock drain. Golder (1986) concluded that these failure modes were not expected to be problematic for the performance of the rock drain. However, the report does not include discussion of the performance of the adjacent schistose rockfill zones with high ponding levels, or potential failure modes associated with the foundation of the NFRD.
- The British Columbia Rock Drain Research Program report, *Mined Rock and Overburden Piles* (Minalta and Piteau, 1999), summarized rock drain case histories (particularly through review of a case history at Line Creek waste rock dump) and made general design recommendations. The NFRD construction was compared to these general design recommendations.

Other reports that were not available but are discussed in BGC (2006) include:

- Report by EBA Consulting Engineering (EBA, 1987, as noted by BGC, 2006) documenting foundation investigations prior to Haul Road construction. According to EBA (1987, as noted by BGC, 2006), the sub-soils consisted mainly of till, but a buried peat layer was encountered in 3 of the 5 test pits, and alluvial silt, sand, and gravel was encountered in another test pit. Numerous boulders were encountered at all locations. The ground encountered in the test pits (April) was frozen. The seasonal frost contained up to 20 percent ice by

volume. The permafrost at Test Pit 3 consisted of a "pliable soil" matrix with stratified and randomly oriented clear ice formations (up to 15 percent by volume).

3.3.2 Precedence

BGC (2006) noted that there is successful precedent in Canada, and elsewhere, to use "flow-through rockfill" in mine rock waste dumps, which has saved the cost of culverts or diversion works around the waste dumps. The precedent, however, does not include reliance of the mine waste dumps as water-retaining dams, but perhaps as temporary non-engineered pervious barriers to flow-through.

Comparing the construction of the NFRD with the general recommendations provided in the British Columbia Rock Drain Research Program report, *Mined Rock and Overburden Piles* (Minalta and Piteau, 1999), it was concluded that the Haul Road embankment does not include elements which should be included in engineered rockfill water retaining dams. These elements include:

- Geotechnical investigations should be performed to determine the conditions in the foundation, particularly whether soft soils (clay or silt) are present. If so, special measures will be needed in dump construction, such as building the dump in limited lifts to preclude foundation failure, which could introduce fine erodible sediment into the rock drain. [*The Golder design was based on drilling performed at a location approximately 400 m downstream from the NFRD, however, a test pit exploration was performed at the NFRD location by EBA (EBA, 1987, as noted by BGC, 2006) just prior to construction; Some peat and organic clay layers in the order of 1 to 2 ft thickness were encountered, but foundation soils consist mainly of "sand till and silt"*.]
- Where fine grained erodible soil is present in the valley floor, a bottom layer of gravel or small size rockfill should be placed to protect against scour and the introduction of fines into the streamflow. [*According to construction-era photographs duplicated by BGC (2006), no such layer was placed beneath the NFRD.*]
- Depending on results of field investigations, materials testing, and stability analyses, specific measures may have to be taken to improve marginal to poor foundations to ensure that in situ conditions meet or exceed analysis and design assumptions. Foundation preparation measures which may be required include clearing, stripping, or removal of poor or weak soils, installation of specific underdrainage measures, and preloading of the site. [*Golder (1986) did not mention foundation conditions or specific measures to improve in situ conditions. Construction era photographs in BGC (2006) indicate that no foundation preparation measures were implemented during NFRD construction, with the exception of bulldozer placement of large boulders within the existing stream channel.*]
- The Rock Drain Research Program report (Minalta and Piteau, 1999) did not discuss the treatment of materials adjacent to rock drains, which the NFRD schistose embankment fill materials would experience during flood flows required for the Down Valley Interim Hydraulic Upgrades evaluations. [*The balance of the Haul Road embankment was built with less competent schistose rock, using full-height end-dumping techniques, and without any significant site preparation such as removal of trees and surface organics such as peat.*]

BGC (2006) identifies evidence of sediment and wood debris accumulation at the entrance to the NFRD. It also mentions precedent of instability of the mine waste dump located immediately west of the NFRD. The scope of BGC's work included an assessment of natural hazards of the terrain in the North Fork Rose Creek Basin and the natural slopes above the Rose Creek Diversion Canal. However, it did not include potential hazards from man-made structures (such as those from the canals, dikes, waste rock dumps, roads, and dams). This issue adds to the uncertainties in assessing the reliability of the Haul Road embankment and NFRD, even in an interim flood flow attenuation role.

Also noted is the fact that potential blockage of debris on the NFRD face and plugging of the interstitial space within the NFRD by soil or other material arising from man-made activities had not been examined by BGC (2006), nor assessed during this study. Effects of sediment produced by erosion of the Faro Waste Dump and the upper (predominantly sand and gravel) part of the embankment, are examples of this type of contamination.

3.3.3 Stability Analyses

Ravelling and slope stability evaluations were performed to gain an understanding of the embankment stability. It is noted, however, that there are other potential failure modes that could be more critical, but do not readily lend themselves to quantitative analyses. One such failure mode is wash-out of finer particles in the schistose rockfill resulting in preferential seepage paths and eventual piping of the embankment. Another such failure mode is piping through the foundation under significant flood pool conditions. Because only two out of numerous potential failure modes were considered in analyses, the results of these analyses should not be considered a complete measure of the stability of the rock drain.

The two potential failure modes considered under estimated flood pool conditions include:

- Ravelling failure initiated by high discharge velocities exiting the downstream toe
- Slope stability failure with high phreatic surfaces in the embankment

The analyses and results are provided in Appendix B.

Results from the ravelling analysis suggest that there should be an adequate margin of safety against slope ravelling under high flow-through conditions. By inspection, the reported as-constructed D_{50} diameter of the NFRD (1 m) is more than 3 times as large as the critical D_{50} diameter for the worst-case 1-in-500-year flood event flow.

The slope stability analysis was performed to develop a general understanding of the influence of the impounded water on stability of the Haul Road embankment. It is noted that there is significant uncertainty in the properties assumed in the analyses as described in Appendix B. As a result, the slope stability analysis results represent an estimate of slope stability based on the information that is known and the parametric manipulations which have been performed.

The factors of safety developed for all slope stability cases analyzed meet the recommended minimum criteria, indicating that global slope stability issues should not be a major issue for the embankment. It should be noted that, during the life of the structure, shallow surface sloughing is a likely occurrence on the upstream or downstream face. While this sloughing is not considered to be critical to overall stability of the embankment, the effects of the sloughing could have other impacts on conditions near the toe of the embankment, particularly if left unchecked. For example, sloughing of finer material onto the NFRD slope surface could impair the flow-through. Signs of sloughing need to be monitored and maintenance performed as needed.

3.3.4 Conclusions

The objective of the interim improvements is to prevent an environmentally damaging discharge of metals-laden tailings to the Rose Creek Valley and downstream creeks and rivers. Based on a review of the design and construction records of the NFRD, this objective cannot be met with a sufficiently high degree of confidence by relying on the haul road embankment to act safely and reliably as a flood retarding structure during a 500-year flood event. To achieve a high confidence level, more positive measures will have to be implemented to pass large flood events safely at the Haul Road embankment and NFRD. One such measure might include installation of culverts or tunnels under the embankment.

In the absence of such measures, a risk analysis might be helpful in determining acceptability of the Haul Road embankment and NFRD in the interim period. Since the probability of a 500-year flood occurring within a 10-year interim period is 2 percent, and the conditional probability of failure of the Haul Road embankment given this flood event is less than 1, the probability of failure of the Haul Road embankment would be less than 2 percent over a 10-year period. A risk analyses would not only consider the 500-year flood, but would combine the probability of failures during the interim period with the consequence of failure for the full range of flood loading up to the 500 year event. It is recommended that such a risk analysis be performed if: (1) it is not possible for YG to take more positive measures to ensure the reliability of the Haul Road embankment, or (2) if YG is not willing to accept a risk (not well understood at this time) that could exceed generally accepted tolerable risk guidelines.

SECTION 4

Hydrotechnical Analysis and Modelling

4.1 Hydrology

4.1.1 Summary

A detailed description of the hydrology analysis is contained in this section and includes a description of previous hydrologic studies and flood hydrograph development. Peak flow rates for the SFRC, NFRC, and catchment areas contributing to the RCD and ID spillway are based on results from previous hydrologic studies. Peak flow rates for the 1-in-500-year flood event are:

- SFRC 1-in-500-year flood event peak flow = **49 m^3/sec**
- NFRC 1-in-500-year flood event peak flow at NFRD = **72 m^3/sec**
- Additional NFRC 1-in-500-year flood event peak flow downstream of NFRD = **1.9 m^3/sec**
- South slope adjacent to RCD, discharging to head of RCD, 1-in-500-year flood event peak flow = **7.5 m^3/sec**
- South slope adjacent to RCD, discharging to RCD downstream of overflow weir, 1-in-500-year flood event peak flow = **5.4 m^3/sec**
- North Slope and tailings area, discharging to ID Impoundment, 1-in-500-year flood event peak flow = **9.4m^3/sec**

Flood hydrographs were developed for the SFRC, NFRC at the NFRD, additional NFRC flows downstream of the NFRD, south slope adjacent to the RCD (discharging to the head of the RCD), south slope adjacent to the RCD (discharging downstream of the overflow weir), and the tailings area (discharging to the ID impoundment). The shape and timing are based on a non-dimensional hydrograph created from an observed flood event on Vangorda Creek, while the peak instantaneous discharge is as listed above.

4.1.2 Previous Hydrologic Studies

Previous hydrologic studies for the FMC have generally focused on determining instantaneous peak flows for a range of recurrence interval events. The studies have relied on regional analyses to determine discharge yield based on catchment area for a range of flood events. Regional analyses involve using runoff records from gauges in a geographic region that are expected to be hydrologically similar to catchments in the FMC. The recurrence interval events for the gauges containing longer periods of record are typically fit with a curve relating drainage area to peak flow rate. These curves are then used to predict recurrence interval flood events for the site of interest (Faro mine catchments) based on known drainage areas for various locations.

NHC (2001) conducted a regional analysis based on data obtained from seven regional gauges. At the time of the study, the period of record represented by the gauges ranged from 14 years to 37 years. The catchment areas for the gauges ranged from 91 square kilometres (km^2) to 7,250 km^2. Instantaneous peak discharges were estimated for the 1-in-2-, 1-in-50-, 1-in-100-, 1-in-200-, and 1-in-500-year return period flood events. NHC and BGC (2004) updated the return period flood estimates from NHC (2001) using additional stream gage observations. As part of the study, they also added an estimate of the mean annual flood and the 1-in-1,000-year return period flood.

Another regional study was conducted by Hydrotechnical Consulting (2006) to determine average daily flows for the 1-in-2-, 1-in-100-, 1-in-200-, 1-in-500-, and 1-in-1,000-year flood events. The recurrence interval floods were determined for flow durations ranging from 1 to 365 days. Using plots of peak discharge vs. catchment area, a relatively constant discharge per square kilometer was observed for flow records representing catchment areas ranging from 13.7 km^2 to 7,250 km^2. This observation led to the conclusion that catchment response to floods could be estimated by using recurrence interval estimates from a single gauge with the most extensive period of record (because catchment unit discharge during recurrence interval events appeared to be independent of total catchment area).

SRK Consulting (SRK) performed a regional analysis to estimate instantaneous peak discharges on Vangorda Creek, as part of a draft design report for the Vangorda Creek Diversion (SRK, 2010). Relationships between catchment area and peak instantaneous flood discharge were developed for the 1-in-2-, 1-in-100-, 1-in-200-, and 1-in-500-year flood events. Upper envelope and best-fit equations were developed for the 1-in-500-year flood event.

A PMF analysis was conducted by Water Management Consultants (2006) for the Rose Creek watershed. The PMF study applied the 24-hour probable maximum precipitation (Taylor and Hale, 2006) to the Rose Creek catchment. The antecedent conditions assumed saturated soil conditions and a shallow snowpack across the entire Rose Creek catchment. The HEC-HMS software was used to simulate the rainfall-runoff processes occurring during the probable maximum precipitation event. Outflow hydrographs at the NFRD, SFRC outlet, and lower end of the diversion channel (assumed to be near gauge X14) indicate that the PMF response to the probable maximum precipitation occurs over a period of approximately 2 to 3 days. Peak flows occur between 16 and 17 hours after the initiation of the probable maximum precipitation event for all catchments. The analysis assumed that the NFRD would not be in place during the PMF, and therefore no attenuation was modelled through the NFRD. Peak flood discharges on the NFRC and SFRC were estimated to be approximately 384 and 300 m^3/sec, respectively. Peak flood discharge at the lower end of the diversion channel was estimated to be approximately 692 m^3/sec.

A HEC-HMS model was recently completed by CH2M HILL (2013a) to perform continuous simulation hydrologic modelling for the entire FMC. The model was calibrated based on 8 years of flow and meteorological data gathered at the site with a focus on spring freshet estimation and rainfall-runoff events during the snow free season. The model was investigated for its potential use in estimating flood discharges for the 1-in-50-, 1-in-100-, 1-in-500-, and 1-in-1,000-year recurrence interval flood events. Because the HEC-HMS model developed by CH2M HILL is intended for continuous hydrologic simulations, modelling recurrence interval events would require determining antecedent conditions for each of the events in the study. Detailed monitoring data for key parameters such as snow water equivalent, soil moisture, rainfall, and temperature do not exist at an appropriate density within the study area or with sufficient periods of record to allow for determination of likely conditions that would produce an estimated recurrence interval event. Based on the insufficiencies in available data to predict basin conditions leading to a recurrence interval event, it was determined that the current HEC-HMS model would not be a suitable tool for estimating flood discharges in this study.

Table 4-1 summarizes the peak discharge estimates from the regional analyses and the PMF analysis at various FMC locations. Locations of these features are included on Figure 4-1.

TABLE 4-1
Summary of Peak Discharge Hydrology (Previous Studies)
Faro Mine Remediation Project

Reference	Location	Drainage Area (km^2)	Instantaneous, Daily, or Hydrograph?	Discharge (m^3/sec)							
				Mean Annual	1-in-2-year	1-in-50-year	1-in-100-year	1-in-200-year	1-in-500-year	1-in-1,000-year	PMF
NHC, 2001	R7 gauge	95	Instantaneous	--	7.6	41	51	62	79	--	--
NHC/BGC, 2004	R7 gauge	95	Instantaneous	9.2	--	37	45	54	67	77	--
SRK, 2010	R7 gauge[a]	99[b]	Instantaneous	--	9.7	--	42	50	63	--	--
Hydrotechnical Consulting, 2006	R7 gauge[c]	99[b]	Daily	--	6.7	--	28	33	40	47	--
NHC, 2001	SFRC[d]	73[b]	Instantaneous	--	6.0	--	42	--	--	--	--
NHC/BGC, 2004	SFRC[e]	73[b]	Instantaneous	7	--	29	35	42	53	61	--
SRK, 2010	SFRC[a]	73[b]	Instantaneous	--	7.4	--	33	39	49	--	--
Hydrotechnical Consulting, 2006	SFRC[c]	73[b]	Daily	--	4.9	--	21	25	30	34	--
WMC, 2006	SFRC	83.5	Hydrograph	--	--	--	--	--	--	--	300
NHC, 2001	NFRD	118	Instantaneous	--	9.3	48	59	72	92	--	--
NHC/BGC, 2004	NFRD	118	Instantaneous	11	--	44	54	65	81	93	--
SRK, 2010	NFRD[a]	118	Instantaneous	--	11	--	49	58	72	--	--

TABLE 4-1
Summary of Peak Discharge Hydrology (Previous Studies)
Faro Mine Remediation Project

Reference	Location	Drainage Area (km^2)	Instantaneous, Daily, or Hydrograph?	Discharge (m^3/sec)							
				Mean Annual	1-in-2-year	1-in-50-year	1-in-100-year	1-in-200-year	1-in-500-year	1-in-1,000-year	PMF
Hydrotechnical Consulting, 2006	NFRD[c]	118	Daily	--	8.0	--	34	40	48	55	--
WMC, 2006	NFRD	122.5	Hydrograph	--	--	--	--	--	--	--	384
NHC, 2001	Head of RCD[d]	199[b,f]	Instantaneous	--	15	--	86	--	--	--	--
NHC/BGC, 2004	Head of RCD[e]	199[b,f]	Instantaneous	17	--	70	84	100	125	143	--
SRK, 2010	Head of RCD[a]	199[b,f]	Instantaneous	--	17	--	72	85	106	--	--
Hydrotechnical Consulting, 2006	Head of RCD[c]	199[b,f]	Daily	--	13	--	57	67	81	93	--
NHC, 2001	RCD Channel	203	Instantaneous	--	15	71	88	105	135	--	--
NHC/BGC, 2004	RCD Channel	203	Instantaneous	18	--	71	86	103	130	150	--
SRK, 2010	RCD Channel[a]	203[b,g]	Instantaneous	--	18	--	75	89	111	--	--
Hydrotechnical Consulting, 2006	RCD Channel[c]	203[b,g]	Daily	--	14	--	58	68	83	95	--
WMC, 2006	RCD Channel	(217.3)[h]	Hydrograph	--	--	--	--	--	--	--	674
NHC, 2001	RCD Channel and Tailings Area[d]	208[b,i]	Instantaneous	--	15	--	89	--	--	--	--
NHC/BGC, 2004	RCD Channel and Tailings Area[e]	208[b,i]	Instantaneous	19	--	72	90	105	133	155	
SRK, 2010	RCD Channel and Tailings Area[a]	208[b,i]	Instantaneous	--	19	--	77	91	113	--	--
Hydrotechnical Consulting, 2006	RCD Channel and Tailings Area[c]	208[b,i]	Daily	--	14	--	59	70	85	98	--
NHC, 2001	X14 gauge	230	Instantaneous	--	17	78	96	115	145	--	--
NHC/BGC, 2004	X14 gauge	230	Instantaneous	20	--	79	96	115	145	167	--
SRK, 2010	X14 gauge[a]	229[b]	Instantaneous	--	20	--	83	98	122	--	--
Hydrotechnical Consulting, 2006	X14 gauge[c]	229[b]	Daily	--	15	--	65	77	93	107	--
WMC, 2006	Lower end RCD	(217.3)[h]	Hydrograph	--	--	--	--	--	--	--	692

[a] Best fit curve used to calculate recurrence interval peak discharge (not envelope equation)

[b] Drainage area from Hydrologic Engineering Center Hydrologic Modelling System (HEC-HMS) model (CH2M HILL, 2013a)

[c] Maximum 1-day yield (L/s/km^2) for recurrence interval events used to calculate recurrence interval discharge

[d] Reported value not in NHC report, used 1-in-2- and 1-in-100-year equations to calculate value

[e] Reported value not in NHC report, used plots to extrapolate value

[f] Drainage area includes SFRC and NFRC catchments plus approximately 7 km^2 draining from the south slope adjacent to the RCD contributing at the head of the RCD

[g] Drainage area includes SFRC and NFRC catchments plus approximately 13 km^2 draining from the south slope adjacent to the RCD contributing to the RCD

[h] Unclear in report where discharge point is for lower sub-basin

[i] Drainage area includes Head of RCD contributing area plus approximately 9 km^2 draining from the north slope and tailings area

Table 4-2 summarizes the 1-in-500-year flood event return period instantaneous peak flows adopted for the Down Valley Interim Hydraulic Upgrades. Estimates of peak instantaneous flows by SRK (2010), using the best-fit equation, were generally used since these discharges represent the most current, updated work and subsequently includes recent gage data with longer periods of record than previous studies.

TABLE 4-2
Down Valley Interim Hydraulic Upgrades 1-in-500-year design peak discharge
Faro Mine Remediation Project

Location	1-in-500-year peak discharge (m^3/sec)
NFRC at NFRD	72
NFRC downstream of NFRD	1.9
SFRC	49
South Slope adjacent to RCD, discharging to head of RCD	7.5
South Slope adjacent to RCD, discharging to RCD downstream of overflow weir	5.4
North Slope and tailings area, discharging to ID Impoundment	9.4

4.1.3 Flood Hydrograph Development

In order to determine flow attenuation in the NFRD, a hydrograph representing inflow conditions upstream of the NFRD is required. To route flows appropriately to the head of the RCD, hydrographs representing the attenuated NFRC flows, additional NFRC flows downstream of the NFRD, SFRC, and the portion of the south slope adjacent to the RCD that discharges to the head of the RCD are required. The inflow, retention, and potential attenuation characteristics of NFRC flows and the subsequent downstream hydrograph after combining SFRC and south slope flows will not be reflected if steady state peak flows were used for the analysis.

Design flood hydrographs were developed for the 1-in-500-year recurrence interval flood event at various FMC locations. A non-dimensional hydrograph shape proposed by NHC (2001) was used to create the design flood hydrographs. Design hydrographs are defined by several parameters including the peak discharge, shape (e.g. slope of rising and falling limbs), timing (e.g. duration of rising and falling limbs), and total volume (which is a function of the peak discharge, shape, and timing parameters). The following sections describe the methods used to develop these portions of the design hydrograph and verify that they are suitable for use in the investigation and design of Down Valley Interim Hydraulic Upgrades elements. Figure 4-2 shows the developed 1-in-500-year design hydrographs.

4.1.3.1 Peak Discharge

As discussed in Section 4.1.1, previous hydrologic studies have focused primarily on peak instantaneous discharges. These relationships are well-defined and have been verified by several studies. The instantaneous peak discharges for the 1-in-500-year flood event design hydrographs were selected in accordance with previous studies. Table 4-2 summarizes the peak instantaneous discharges used in this study.

4.1.3.2 Shape and Timing

The shape and timing of design flood hydrographs depends on the meteorological forcing and runoff response characteristics of the catchment. Extreme, typically short-duration, rainfall events provide the meteorological forcing in rain-dominated hydrological systems. Subsequent catchment runoff response times are usually short (on the order of hours to several days). In snowmelt dominated systems peak runoff is typically in response to warming conditions that cause an accumulated snowpack to melt and contribute to stream flow. Catchment response times are typically longer for snow dominated systems than for rain dominated systems. However, snow dominated systems can still experience periods of heavy rainfall that produce a more rapid runoff response within the catchment. Rain-on-snow events can produce particularly high runoff rates for a catchment, since rain falling on a snowpack can quickly increase the internal temperature of the snowpack to a point where rapid melting of the snowpack occurs.

Hydrographs for gradual snowmelt are generally of long duration (on the order of weeks to months) with mild rising and falling limb slopes. A hydrograph resulting from gradual snowpack melt could exhibit the same peak discharge as a hydrograph resulting from an isolated rainfall event (without snowpack). However, the volume associated with the snowmelt hydrograph would be greater than the volume associated with the rainfall event. Catchment parameters such as soil type, vegetation type and areal cover, average hill slope, watercourse slope, and the presence of features such as wetlands and retention basins all influence how a catchment will respond to

a particular hydrograph shape. For some catchments, short peaked hydrographs with relatively small volumes may cause considerable damage while for others response times and storage components may dampen the impact of such an event. Some catchments may experience problems due to prolonged flooding while others exhibit, for example, stream routing or sufficient soil infiltration capacities to effectively handle high volume floods of a prolonged and gradual nature.

The non-dimensional flood hydrograph proposed by NHC (2001) is based on an observed flood on Vangorda Creek in May 1993. The overall hydrograph shape and distribution appears to be consistent with a late spring rain-on-snow runoff event. However, without detailed meteorological data at the FMC it is difficult to determine with certainty what runoff condition the non-dimensional hydrograph represents. A rainfall driven hydrograph without snowmelt would be expected to exhibit a basin response time on the order of 1 to 2 days. A rain-on-snow driven event would be expected to have a basin response time on the order of several days, which is consistent with the non-dimensional hydrograph timing. Environment Canada climate normals from the Faro Airport meteorological station indicate that snow persisted through approximately April 10, 1993 at an elevation of 716.6 m. Since snowmelt for the FMC catchments lag Faro Airport snowmelt by several weeks (maximum catchment elevation of approximately 1,870 m for the NFRC catchment) it is possible that a lingering, but near-melt-state snowpack in May 1993 was available to contribute to runoff in combination with a rainfall event.

The duration of the hydrograph is 20 days and is defined on a daily time step. Table 4-3 summarizes the ratios of daily discharge to event peak discharge that define the hydrograph shape. The peak of the hydrograph occurs on day 10, which is the midpoint of the design hydrograph.

TABLE 4-3
Non-dimension design hydrograph (from NHC, 2001)
Faro Mine Remediation Project

Time (days)	Q/Q_{peak}[a]
1	0.054
2	0.059
3	0.065
4	0.075
5	0.086
6	0.124
7	0.172
8	0.226
9	0.349
9.5	0.457
9.75	0.538
10	1
10.25	0.699
10.5	0.484
11	0.349
12	0.242
13	0.188
14	0.177
15	0.172
16	0.167
17	0.161
18	0.156
19	0.151
20	0.145

[a] Q_{peak} is defined for each catchment in Table 4-2.
Daily flow, Q, is determined by multiplying Q_{peak} by the non-dimensional ratio.

4.1.3.3 Hydrograph Volume and Runoff Yield

The dam breach analysis described in Section 4.3.4 is highly dependent on the volume of water that could potentially be impounded behind the NFRD. Routing flows through the RCD and tailings area are also dependant

on hydrograph volume, since the volume associated with design events may have to fill storage areas prior to contributing to spillway flows (at the ID, for example) or increased channel flows. Therefore, the total volume associated with each event hydrograph has been evaluated to determine if the duration and shape of the hydrograph are reasonable.

The non-dimensional hydrograph in Table 4-3 represents a runoff event where approximately 14 percent of the total volume is represented by the rising limb. The 3-day period making up the hydrograph peak contains 61 percent of the overall volume, with the falling limb of the hydrograph representing the remaining 25 percent of the runoff volume.

The 1-in-500-year annual precipitation at the Faro Airport has been estimated as 451 mm. Precipitation values at the FMC would be greater than values at the Faro Airport due to differences in elevation and observed patterns of greater precipitation at Anvil and other sites. In previous work performed by CH2M HILL (CH2M HILL, 2013a), the factors used for adjusting Faro Airport precipitation to FMC precipitation were split between rainfall (6.8 percent) and snowfall (25 percent).

According to Environment Canada climate normals for the Faro Airport (1971-2000) average annual precipitation equals 316 mm. Of this, rain accounts for 214.4 mm (67.8 percent) while snow accounts for the remaining 101.6 mm (32.2 percent). If these rain and snow percentages are assumed for a year in which the a 1-in-500-year flood event occurs, and the rain and snow fractions are factored up by the previously used factors of 6.8 percent and 25 percent respectively, the 1-in-500-year annual precipitation at the Faro Dump meteorological station is estimated to be 508.1 mm.

Table 4-4 summarizes the total discharge volume and associated runoff depth for each catchment. Compared to the 1-in-500-year precipitation of 508.1 mm, the runoff volumes represent a significant portion of the available annual precipitation. Runoff depths from the NFRC and SFRC catchments during the 1-in-500-year flood event represent approximately 40 to 45 percent of the available 1-in-500-year annual precipitation. Observed spring freshet volumes at the R7 gage for low magnitude flood events (during water year 2003, 2005, 2007, and 2010) indicate that the freshet has typically represented approximately 20 to 30 percent of the annual runoff volume. The NFRC and SFRC ratios calculated for the 1-in-500-year design hydrographs appear reasonable since the 1-in-500-year flood could conceivably lead to a greater percentage of the annual runoff occurring during the freshet period.

Runoff depths from the smaller catchments range from approximately 70 to 100 percent of the available 1-in-500-year annual precipitation. These ratios are higher than those predicted for the larger NFRC and SFRC catchments and it is likely that the hydrograph volumes presented in Table 4-4 are conservative estimates. However, because the contributions from these smaller catchments are insignificant compared with the contributions of larger basins such as the NFRC and SFRC, this level of conservatism is assumed to be appropriate for the current design.

TABLE 4-4
Discharge Volume and Runoff Depth associated with 1-in-500-year hydrograph
Faro Mine Remediation Project

Catchment Description	Catchment Area (km^2)	Runoff Volume (m^3)	Equivalent Runoff Depth (mm)
NFRC upstream of NFRD	118	24,274,470	206
SFRC	73	16,520,130	226
South Slope discharging to head of RCD	6.8	2,528,590	372
North Slope and tailings area discharging to ID spillway	9.1	3,169,167	348
South Slope discharging to RCD downstream of overflow weir	4.5	1,820,585	405
NFRC downstream of NFRD	1.2	640,580	517

4.2 North Fork Rock Drain Flow Attenuation Characteristics

4.2.1 Summary

A detailed description of the analysis of the NFRD flow attenuation characteristics is contained in this section and includes a description of the theoretical basis of flow through the rockfill, historical measurement of flow through the NFRD, and estimates of flow-through capacity of the NFRD. Flow through the NFRD was estimated using the Wilkins equation and results in attenuation of the 1-in-500-year flood event peak flowrate for the NFRC. High, moderate, and low discharge scenarios for flow through the NFRD are based on using a range of values to estimate flow through the NFRD. Additionally, low flow-through scenarios were modelled assuming a 25-, 50-, and 75-percent reduction in flow-through capacity to estimate the potential flow-through when debris or other conditions may cause a reduction in performance at the NFRD.

4.2.2 Theoretical Basis of Flow through Rockfill

BGC (2006) summarizes the hydraulics of flow through rockfill structures. In general, Darcy's Law does not apply for rockfill structures because of turbulent flows that occur in the larger void spaces of the rockfill. The high Reynolds numbers lead to scenarios where Darcy's Law is invalid. The most commonly used equation for computing flow through rockfill is the Wilkins equation (Leps, 1973 and Hansen et al., 2004, as cited in BGC, 2006):

$$Q = nAWm^{0.5}i^{0.54} \quad (1)$$

where:

Q: flow (m^3 per second)
n: porosity (-)
A: cross-sectional area of flow (m^2)
W: Wilkins' empirical constant, 5.243
m: hydraulic mean radius (m)
i: hydraulic gradient (m per m)

The hydraulic mean radius is calculated using the following equation (Hansen et al., 2004, as cited in BGC, 2006):

$$m = \frac{ed}{6r_e} \quad (2)$$

where:

e: void ratio (-)
d: dominant particle diameter (m)
r_e: particle surface area efficiency, taken to be 1.3 for coarse angular rock

The dominant particle diameter for rockfill is typically assumed to be equal to the D_{50} diameter (where D_{50} is the particle size at which 50 percent of the materials are finer [by weight]) (Leps, 1973, as cited in BGC, 2006). Because the seepage gradient in a flow-through situation varies with position within the structure, an "effective" or representative hydraulic gradient can be used to refine the analysis (Hansen et al., 2004, as cited in BGC, 2006):

$$i_{eff} = 0.8A_R^{-3/2}(h/H)^{1.4} \quad (3)$$

where:

i_{eff}: effective hydraulic gradient (m per m)
A_R: aspect ratio, defined by $A_R = \frac{1}{H} \times \left(B_u + B_c + {}^{B_d}/_2\right)$
h: upstream water level (m)
H: height of rockfill structure (m)
B_u: width of upstream portion (m)
B_c: width of central portion (m)
B_d: width of downstream portion (m)

4.2.3 Historical Measurement of Flow through the North Fork Rock Drain

The width of the NFRD is assumed to be 70 m (perpendicular and centered over to the pre-existing creek channel) as noted by BGC (2006). The total height of the coarsest calcium-silicate rock composing the core of the NFRD is assumed to be 3.6 m (BGC, 2006). Based on construction photographs (BGC, 2006), it is assumed that coarse rock is present above the 70-m-by-3.6-m core to an elevation of approximately 1,121 m, effectively increasing the area of coarse flow-through rock to approximately 70 m by 33 m. Outside of the assumed 70-m-by-33-m coarse rock core, it is assumed that schistose rock was used to construct the remainder of the Haul Road.

During the design of the Haul Road, it was assumed that the representative particle size (D_{50}) of the calcium-silicate and coarse rock core would be 0.3 m. The original Golder design (1986) conservatively assumed that there would be no flow through the schistose rock.

Initial routing analyses during the design of the NFRD assumed that a 40-m-deep pool would be present during the 1-in-100-year flood (70 m^3/sec), while the mean annual flood (7 m^3/sec) would produce an 11-m-deep pool (BGC, 2006).

Monitoring of water surface elevations upstream from the NFRD and flow on the NFRC downstream (to develop a stage-discharge curve) was conducted in 2005 and 2006 and more recently in 2012 and 2013. In 2005 and 2006, flow was measured at five locations (R7 gauge, NRFC 20/21 upstream from the NFRD pond, NFRD pond, NRFC 22/23 downstream from the NFRD, and X2 gauge) (BGC, 2006). Water levels were determined by using electronic sensors, staff gauges, or direct survey methods. The BGC (2006) report shows measured water surface elevations and downstream discharge for the NFRD (Figure 18, Memorandum 2). Peak flow during the 2005 and 2006 monitoring was approximately 22.5 m^3/sec in 2005 at gauge X2. The maximum pond elevation corresponding to the peak discharge was approximately 1,096.5 m, or 8.6 m above the pond sensor elevation of 1,087.9 m. The majority of discharge data collected during the monitoring period ranges from 1 to 6 m^3/sec. Pond elevations for lower discharges range from approximately 1,089 m to 1,093 m, or 1.1 m to 5.1 m above the pond sensor elevation of 1,087.9 m.

BGC plotted upstream and downstream water surface elevations and calculated hydraulic gradients through the NFRD during 2005 and 2006 (BGC, 2006, Figure 19, Memorandum 2). Gradients were observed to be approximately 0.015 metres per metre (m/m) for low pond water surface elevations (near 1089.5 m). The highest reported gradient of approximately 0.03 m/m corresponds to a pond water surface elevation near 1,093 m. The relationship between hydraulic gradient and pond water surface elevation appears to be approximately linear within the measured range (BGC, 2006, Figure 20, Memorandum 2).

In 2012 and 2013, stage monitoring was conducted at NF1 and NF2 (See Figure 4-1). Discharge measurements were conducted at X2 and NF2 primarily during the months of May through September. Figure 4-3 shows measured water surface elevations and downstream discharge data. Peak flow during the 2012 and 2013 monitoring was approximately 8.2 m^3/s in 2012 (as measured at the X2 gauge). A peak flow of 10.7 m^3/s was recorded at the X2 gauge on 11 June, 2012 but no upstream water surface elevation is available at the NF1 gauge on this day. Figure 4-4 shows upstream and downstream water surface elevations for 2012 and 2013. Similar to measurements in 2005 and 2006, upstream water surface elevations are observed to generally fall between the elevation range of 1,089 m to 1,094 m. Figure 4-5 shows hydraulic gradients for 2012 and 2013. Gradients of approximately 0.015 and 0.035 m/m for pond elevations of 1089 m and 1094 m, respectively, demonstrate agreement between BGC reported values in 2005/2006 and new measurements in 2012/2013.

In addition to stage and discharge data, two dye tests were conducted. The first dye test was conducted on 11 September, 2013 and the second test was conducted the following day. Discharge measurements at NF2 on 12 September, 2013 indicate that flow on the NFRC was approximately 2.5 m^3/s. The water surface elevation at NF1 on 11 September, 2013 was measured as 1090.3 m. Rhodamine was injected at two separate locations upstream from the NFRD and the breakthrough curve was measured at two locations downstream from the NFRD. Figures 4-6 and 4-7 show the injection and measured breakthrough curves. Residence time of rhodamine within the NFRD is observed to be approximately 1 hour for both dye tests. The flow-through relationships

observed during the 2005, 2006, 2012, and 2013 monitoring campaign are applicable to low flow (approximately 1 to 22 m^3/sec) conditions.

Flow-through relationships during low probability recurrence interval floods and the PMF cannot be directly extrapolated from observed data, because the conditions within the NFRD are not homogenous with increasing height of the rockfill. The observed flow-through relationships can be used to determine if theoretical methods for calculating flow through the NFRD are valid within the range of approximately 1 to 22 m^3/sec and for pond elevations up to approximately 1094 m. Additionally, the dye test data can be used to support conclusions that flow-through characteristics within the 70-m wide calcium-silicate zone are relatively consistent (i.e. the assumption of coarse rock characteristics across the 70-m width appears valid) and that residence times in the NFRD are rather short (i.e. for hydraulic routing conducted with a minimum of 1 hour time steps, little to no lagging is required since outflows from the NFRD are expected to respond quickly to changes in upstream water surface elevation). The following sections describe the methods for calculating theoretical flow through the NFRD and estimating the flow capacity and attenuation characteristics of the NFRD.

4.2.4 Estimate Flow-Through Capacity of the North Fork Rock Drain

At the time of design and construction of the NFRD structure, the designer proposed a stage-discharge relationship for the ponded area behind the NFRD (see Figure 4-8) (Golder, 1986, as cited in BGC, 2006). The exact methods used to determine the flow-through relationship are not clearly stated. However, the report states that the only area considered for flow-through was the 70-m-by-3.6-m zone of calcium-silicate rock (total discharge area of approximately 250 square metres [m^2]). This assumption produced a stage-discharge curve that was quickly discarded based on observations of flow-through for the NFRD. The work conducted by BGC (2006) and the additional observations from 2012 and 2013 indicate that discharge is likely greater than predicted by the original stage-discharge relationship at higher water surface elevations upstream from the NFRD. Figure 4-8 shows the Golder 1986 stage-discharge relationship along with the observed 2012 and 2013 stage and discharge (stage and discharge as observed by BGC, 2006 are similar to those observed during 2012 and 2013). Similarly, 1988 and 1993 measurements produced stage-discharge curves that predicted larger discharges than those presented in the original design (BGC, 2006, Figure 1).

The Wilkins equation can be used to estimate theoretical flow-through the rockfill. The predicted discharge is related to the following:

- Dimensions of the NFRD structure
- Cross-sectional area available for flow
- Characteristics of the rockfill (permeability, particle size distribution, dominant grain size)
- Hydraulic gradient developed within the NFRD structure

BGC (2006) examined each of the controlling factors in their previous report. For this analysis, the parameters have been revisited and updated where necessary or appropriate. Where no additional information is available to modify the analysis conducted by BGC, similar parameter values and assumptions are used in the current flow-through analysis of the NFRD structure.

4.2.4.1 North Fork Rock Drain Structure Dimensions and Impounded Storage Volume

LiDAR data collected October 3, 2011, were used to determine approximate dimensions of the NFRD and develop stage-storage curves for the area upstream from the NFRD. DTMs created from the LiDAR data represent the ground surface elevation, but do not contain any topographic information below the water surface. A bathymetric survey was conducted by Challenger Geomatics, Ltd. on 4 and 5 July 2013 to define the topography beneath the water surface for the impounded area upstream from the NFRD. The survey data were used to create a DTM representative of the elevations below the water surface. This DTM was merged with the LiDAR-based DTM to create a seamless DTM representative of the ground elevations above and below the water surface. Based on this DTM, the minimum elevation upstream from the NFRD is estimated to be approximately 1,087.82 m. The volume of impounded water during low flow conditions (when the upstream water surface is at approximately elevation 1,090 m) is estimated to be approximately 10,800 m^3.

Figure 4-9 shows an aerial photograph of the NFRD and other features of the FMC. Cross sections were extracted from the DTM upstream from the NFRD, along the Haul Road centerline, and downstream from the NFRD. A profile through the NFRD was also extracted from the DTM. Figure 4-10 presents the cross sections (facing downstream) and Figure 4-11 shows the NFRD profile. Figure 4-10 indicates that the minimum elevation of the Haul Road is approximately 1,131 m. The low point in the Haul Road does not coincide with the channel portion of the cross section upstream or downstream from the NFRD. Along the approximate flow path centerline through the NFRD, the Haul Road elevation is approximately 1,144 m, which is 56 m above the minimum elevation of 1,087.82 m upstream from the NFRD and approximately 59 m above the approximate toe elevation of 1,085 m downstream from the NFRD. The approximate base width of the NFRD is 197 m. Rather than contributing to flows on the NFRC, water surface elevations in excess of 1,131 m would result in overtopping flows that would contribute flow to the SFRC catchment. BGC (2006) reports that personal communications received from FMC personnel indicates at a water surface elevation of 1,128 m flow would enter the buried Zone II pit, which is undesirable. The maximum desired water surface elevation upstream from the NFRD was assumed to be 1,125 m, which would provide 3 m of freeboard.

Figure 4-12 shows the stage-storage curve associated with the impounded area behind the NFRD. At an elevation of 1,131 m the impounded volume is approximately 16,900,000 m^3. At elevations of 1,128 and 1,125 the impounded volume is approximately 13,500,000 m^3 and 10,600,000 m^3, respectively.

4.2.4.2 Cross-sectional area available for flow and characteristics of the rockfill

The minimum area available for flow would be the 70-m-by-3.6-m calcium-silicate zone used by Golder to estimate the stage-discharge relationship for the NFRD following construction (Golder, 1986, as cited in BGC, 2006). The stage-discharge relationships have been shown to underestimate flow-through characteristics of the NFRD, so the actual area available for flow-through is likely greater. If coarse rock above the calcium-silicate zone or the adjacent schistose rock is assumed to convey a portion of the flow through the NFRD then the available flow-through area would increase. It is assumed that coarse rock, similar in characteristics to the calcium-silicate core, was used to construct the 70-m wide portion of the Haul Road embankment above the portion that was specially designated for construction using the calcium-silicate.

Detailed grain-size distributions for material used in the NFRD are not available and are difficult to evaluate in-situ due to the large size of the embankment and the large size of the constituent rockfill. Table 4-5 summarizes notes by the design engineer regarding grain-size at various locations within the NFRD (Golder, 1987, as cited in BGC, 2006).

TABLE 4-5
Grain-size Distributions within NFRD
Faro Mine Remediation Project

Height above Toe (m)	Approximate Elevation[a] (m)	D_{50} (m)	D_{65} (m)	Notes
7	1,095	0.3	0.5	--
10	1,098	--	--	Grain-size estimated to be slightly larger than rock 7 m above the toe (estimate of D_{50} or D_{65} not provided)
17	1,105	0.15	0.5	
55	1,143	--	--	Absence of fine material. Fines stated to be evident within upper 10 m of fill.

[a] Location of measurements is not specified. Measurement location is assumed to be at approximately the centerline of the flow-through zone. Toe elevation at this location is 1,087.82 m.

If the location where grain sizes are reported corresponds to the approximate centerline of flow through the NFRD, then the Haul Road surface elevation at this location is approximately 1,144 m. Fines present to a depth of 10 m would result in fine material extending down from the Haul Road surface to an approximate elevation of 1,134 m. Thus, the height of 55 m (elevation 1,143 m) where no fines were observed would appear to be in

contrast to the statement that the upper 10 m of the Haul Road (elevation 1,134 to 1,144 m at the flow-through centerline) contains fine material. The estimated height by the design engineer could have been made at a location other than the flow-through centerline, or be referenced to a toe elevation other than 1,087.82 m.

To account for differences in estimates of height, it was assumed that the maximum height of the calcium-silicate rock is at approximate elevation 1,121 m, which represents a coarse rockfill zone height that is half of the coarse rockfill zone width. Estimated D_{50} values from Golder, 1987 (as cited in BGC, 2006) and independent estimates by BGC, 2006 indicate that rock sizes within this 70-m wide core range from 1 m at the toe to approximately 0.2 m towards the upper extent of the coarse fill. Estimates of the average D_{50} range from approximately 0.3 to 0.7 m. The assumed total area of coarse calcium-silicate rock available for flow-through is approximately 2,300 m^2.

It was assumed that the adjacent schistose rock likely conveys some flow, although the dominant rock size is probably smaller than the calcium-silicate zone and therefore the schistose rock would convey less flow than the calcium-silicate zone. The extents of the schistose rock available for flow-through were assumed to coincide with the portion of the embankment that would route flows to the NFRC catchment and extend to a maximum elevation of 1,131 m. At high water surface elevations, flow through the haul road embankment that would ultimately route to the SFRC was assumed to be negligible. The assumed total area of schistose rock available for flow-through is approximately 8,600 m^2.

Figure 4-13 shows the assumed flow-through area for the coarse rock (including the calcium-silicate core) and the adjacent schistose rock. Figure 4-14 shows the predicted flow-through available area versus water surface elevation developed from the cross section upstream from the NFRD embankment.

4.2.4.3 Hydraulic gradient developed within the North Fork Rock Drain structure

The hydraulic gradient through the NFRD structure was measured in 2005 and 2006 by BGC and calculated from 2012 and 2013 observations of stage at NF1 and NF2. The available hydraulic gradient information represents the total gradient between the upstream and downstream ends of the NFRD. Detailed gradient data within the NFRD have not been measured. The hydraulic gradient information that is available only represents discharges within the range of approximately 1 to 22 m^3/sec. It would be difficult to measure the hydraulic gradient within the NFRD structure itself, so using the overall hydraulic gradient (from the upstream side of the NFRD structure to the downstream side of the NFRD structure) would likely be the most appropriate method for determining a reasonable hydraulic gradient value. An effective hydraulic gradient can be calculated using Wilkins equation (3) to represent the potential gradient at flows greater than 22 m^3/sec.

4.2.4.4 Stage-Discharge Relationships for the North Fork Rock Drain

Similar to the BGC 2006 methods, stage-discharge relationships for the NFRD were estimated by assuming a range of possible parameters to represent the flow-through area and characteristics of the rockfill within the NFRD. Assumptions were also made about the extent and behaviour of the calcium-silicate and schistose rock zones. Using a range of values results in potentially high, moderate, and low discharge scenarios for flow through the NFRD. Estimating potential upper and lower limits for flow-through provides a range of potential scenarios during recurrence interval events. Each scenario is briefly summarized as follows:

- **High-Flow Scenario**: The high-flow scenario is similar to the scenario presented by BGC (2006). The dominant rock size for the entire embankment is assumed to be 0.25 m. The void ratio for both calcium-silicate and schistose rock is assumed to be approximately 0.4. While it is possible that the void ratio of certain portions or pockets of the schistose rock may change as some particles breakdown, if there is not significant settlement the overall void ratio of the schistose rock may not be changed significantly. A high void ratio of 0.4 was selected for the schistose rock to obtain higher flow-through capacities including a higher upper bound estimate for high flow-through. Since a zero flow was assumed for the schistose rock in the low-flow scenario, this facilitates consideration of a wider range in flow-through capacities.
- **Medium-Flow Scenario**: The medium-flow scenario assumes that the dominant rock size for the calcium-silicate zone is approximately 0. 25 m. The dominant rock size for the schistose is assumed to be 0.05 m. The void ratio for both rock types is again assumed to be approximately 0.4. The entire schistose and calcium-

silicate area shown on Figure 4-13 is available for flow-through, but the smaller dominant diameter for the schistose rock will reduce flows through this zone compared with the calcium-silicate zone.

- **Low-Flow Scenario**: The low-flow scenario assumes that there is no flow through the schistose rock. All flow through the NFRD is conveyed through the calcium-silicate zone, which is assumed to have a dominant rock size of 0.25 m and the available flow-through area as depicted on Figures 4-13 and 4-14. The void ratio for the calcium-silicate rock is assumed to be approximately 0.4.
- **Low-Flow Scenario plus 25-Percent Reduction in Flow-Through Capacity:** The low-flow plus 25-percent reduction in flow-through capacity scenario assumes the same parameters as the low-flow scenario, but imposes a 25-percent reduction in flow-through capacity. This capacity reduction is intended to represent a minor blockage resulting from conditions such as debris racking on the NFRD face or plugging of interstitial spaces within the NFRD by soil or other material.
- **Low-Flow Scenario plus 50-Percent Reduction in Flow-Through Capacity:** The low-flow plus 50-percent reduction in flow-through capacity scenario assumes the same parameters as the low-flow scenario, but imposes a 50-percent reduction in flow-through capacity. This capacity reduction is intended to represent a mid-range blockage resulting from conditions such as debris racking on the NFRD face or plugging of interstitial spaces within the NFRD by soil or other material.
- **Low-Flow Scenario plus 75-Percent Reduction in Flow-Through Capacity:** The low-flow plus 75-percent reduction in flow-through capacity scenario assumes the same parameters as the low-flow scenario, but imposes a 75-percent reduction in flow-through capacity. This capacity reduction is intended to represent a major blockage resulting from conditions such as debris racking on the NFRD face or plugging of interstitial spaces within the NFRD by soil or other material.

Stage-discharge relationships for the six flow scenarios are presented in Figures 4-15 and 4-16. Figure 4-15 shows the stage-discharge curves compared to observed 2012 and 2013 stage-discharge data and with the original Golder, 1986 stage-discharge curve shown for reference. The high and medium flow-through scenarios appear to provide the best match to observed data. At impounded water surface elevations less than approximately 1,105 m, the low flow-through scenarios assuming 25-, 50-, or 75-percent reduction in flow-through capacity generally predict a discharge that is less than the 1986 stage-discharge relationship, providing a conservative estimate of flow-through. At impounded water surface elevations greater than approximately 1,105 m, all scenarios predict discharges that exceed the 1986 stage-discharge relationship.

Figure 4-16 shows the stage-discharge curves extended to a maximum water surface elevation of 1,131 m. The behaviour of the flow through curves is observed to diverge for water surface elevations above approximately 1,100 m. Since observed stage-discharge data is valid only for low flow conditions (water surface elevations less than approximately 1,094 m) the validity of the curves for the 1-in-500-year flood event cannot be verified. The six scenarios provide an envelope within which the true stage-discharge relationship is likely to fall, and they also account for potential flow-through capacity reduction at the NFRD.

4.2.5 Routing 1-in-500-Year Hydrograph through North Fork Rock Drain

Level pool reservoir routing was conducted to evaluate the attenuation of the 1-in-500-year inflow hydrograph under the six flow-through scenarios. The attenuated flows at the downstream end of the NFRD were routed downstream using a hydraulic model to create design flood hydrographs for the RCD (see Section 4.3.3). Figures 4-17 and 4-18 show the results of the level pool routing through the NFRD (only the portion of the hydrograph focusing on the flood peak is shown for clarity). Table 4-6 summarizes the peak flow results at the downstream toe of the NFRD, flow reduction compared to the unattenuated peak flow of 72 m^3/sec, and maximum impounded water surface elevation and volume upstream of the NFRD during the 1-in-500-year design flood. Figure 4-19 also shows the extents of impounded water upstream of the NFRD for each scenario.

TABLE 4-6
NFRD Attenuated Peak Discharge and Impounded Water Surface Elevation, 1-in-500-Year Flood Event
Faro Mine Remediation Project

Scenario	Peak Flow, no Attenuation (m^3/sec)	NFRD Attenuated Peak Flow (m^3/sec)	Percent Reduction in NFRD Peak Flow (m^3/sec)	Maximum Impounded WSEL (m)	Storage Volume (m^3)
High Flow-Through	72	59	18%	1,101.9	838,042
Medium Flow-Through		54	25%	1,104.3	1,241,193
Low Flow-Through		45	38%	1,108.0	2,071,410
Low Flow-Through (25-Percent Reduction in Flow-Through Capacity)		40	44%	1,110.2	2,671,369
Low Flow-Through (50-Percent Reduction in Flow-Through Capacity)		34	53%	1,113.3	3,701,514
Low Flow-Through (75-Percent Reduction in Flow-Through Capacity)		23	68%	1,118.5	6,077,155

The uncertainty in flow-through parameters as well as the potential for plugging and flow-through capacity reduction of the NFRD results in a wide range of estimates for downstream peak discharge, upstream water surface elevation, and impounded volume. The six flow-through scenarios predict peak flow attenuation ranging from 18- to 68-percent and maximum impounded water surface elevations ranging from 1,101.9 m to 1,118.5 m. The storage volumes behind the NFRD for these scenarios range from 838,042 m^3 to 6,077,155 m^3. Measurements of the impounded water surface elevation and subsequent downstream discharge during peak flow periods (such as the spring freshet), especially at flows greater than 10 m^3/s, would provide the additional data necessary to verify which curves (high, medium, or low flow-through) best represent the actual flow-through conditions for the NFRD. Ideally, data collected over several years and spanning a range of stages and discharges could be used to create a stage-discharge curve that is specific to observed flow-through characteristics of the NFRD structure and not based on theoretical relationships. A stage-discharge curve such as this could be periodically updated to account for recent observations and could be used as an indicator of the NFRD performance. That is, if flow-through capacity of the NFRD was decreasing over time due to plugging of the interstitial space by fine material or debris, the continuous monitoring and updating of the site specific stage-discharge curve could provide advance notification and verification of such behaviour.

Together the stage-storage curve and theoretical stage-discharge curves were used to route the 1-in-500-year flood event down NFRC to the RCD, where hydrographs were combined with 1-in-500-year hydrographs from other catchments to determine RCD peak flows and the 1-in-500-year hydrograph shape for the RCD and ID tailings area.

4.3 Hydraulic Modelling

4.3.1 Summary

Using topographic and bathymetric data available for the FMC, RCD, and proposed improvements, CH2M HILL prepared 1D and 2D hydraulic models to evaluate hydraulic conditions for the 1-in-500-year flood event.

The 1D hydraulic model was used to route flood hydrographs from the NFRC, SFRC, south slope catchment, and tailings catchment area to the RCD or ID impoundment (depending on modelling assumptions). The NFRD and upstream impoundment were included in the 1D model to estimate attenuation characteristics of the NFRD during the 1-in-500-year flood event under a non-breach scenario. Results of routing the 1-in-500-year flood event flows and assuming high flow-through conditions for the NFRD are as follows (peak flows without attenuation are shown in brackets for reference):

- Head of RCD 1-in-500-year flood event peak flow = **111 m^3/sec** [*130 m^3/sec*]
- RCD, downstream of overflow weir, 1-in-500-year flood event peak flow = **116 m^3/sec** [*136 m^3/sec*]
- ID impoundment 1-in-500-year flood event peak flow = **121 m^3/sec** [*140 m^3/sec*]

Routing 1-in-500-year flood event flows through the NFRD and the associated shift in timing of hydrograph peaks between the NFRC and other catchments results in a reduction in peak flow of approximately 20 m^3/sec for the RCD and at the ID impoundment.

The 1-in-500-year flood event was modelled assuming a breach of the NFRD to estimate downstream impacts during such an event. Because of the uncertainty in the adequacy (stability) of the NFRD to serve as a water-retaining structure under severe flood conditions, it was important to perform breach analysis to develop an understanding of the consequence of a NFRD breach. The information can be used to make decisions during the interim period, as well as a basis for developing concepts for final closure. Breach analyses were initially performed for an average case, assumed to correspond to medium flow-through conditions at the NFRD, and then for progressively reduced flow-through capacities at the NFRD until significant overtopping of the ID crest occurred due to the breach flood wave.

Two methods for predicting breach parameters were used. The Froehlich (2008) method predicts shorter breach development time with smaller final breach geometry, while the Von Thun and Gillette (1990) method predicts longer breach development time with larger final breach geometry. The two separate, but internally congruent, breach methods were used to evaluate the sensitivity of breach peak flows to the assumed breach progression mode. After verifying that the two breach parameter estimation methods provided consistent results, the Von Thun and Gillette (1990) method was used to analyze breach impacts at the ID under three breach scenarios:

- Breach Scenario 1 (assume breach occurs at maximum impounded WSEL during the medium flow-through scenario)
  - Total volume of water impounded upstream of NFRD at start of breach = **1,241,193 m^3**
  - RCD peak flowrate (including flows from SFRC, south slope, and tailings area catchments) = **640 m^3/sec**
- Breach Scenario 2 (assume breach occurs at maximum impounded WSEL during the low flow-through scenario)
  - Total volume of water impounded upstream of NFRD at start of breach = **2,071,410 m^3**
  - RCD peak flowrate (including flows from SFRC, south slope, and tailings area catchments) = **1,262 m^3/sec**
- Breach Scenario 3 (assume breach occurs at maximum impounded WSEL during the low flow-through and 25-percent reduction in flow-through capacity scenario)
  - Total volume of water impounded upstream of NFRD at start of breach = **2,671,369 m^3**
  - RCD peak flowrate (including flows from SFRC, south slope, and tailings area catchments) = **1,669 m^3/sec**

The 2D hydraulic model was used to route flood hydrographs from the upstream end of the RCD through the RCD and for the adjacent tailings area and ID spillway. Performance of the conveyance facilities and improvements to the RCD and ID spillway were evaluated during the 1-in-500-year flood event using the 2D model. The three NFRD breach scenarios were also evaluated with the 2D model. Following are the significant results from these model simulations:

- ID Spillway Results with 1-in-500-year flood event flow rate
  - Flow rate over the spillway = 115 m^3/sec (no flow simulated in the RCD)
  - Water surface elevation at ID = 1,048.6 m
  - Freeboard at ID = 1.0 m
- RCD Results with 1-in-500-year flood event flow rate
  - Existing dike (right bank) does not meet 0.5 m freeboard requirements downstream from fuse to steepened reach.

  - Removal of vegetation from the right bank of the RCD would reduce WSELs from 0.05 to 0.10 m
  - Removal of vegetation from the right and left banks of the RCD would reduce WSELs from 0.10 to 0.15 m
- Breach Scenario 1 (assumes no blockage and medium flow-through condition)
  - Water surface elevation at ID = approximately 1,049.3 m
  - Freeboard at ID = 0.3 m
  - No overtopping of ID or CVD
- Breach Scenario 2 (assumes no blockage and low flow-through condition)
  - Maximum water surface elevation at ID = approximately 1,049.9 m
  - Overtopping of ID and CVD
- Breach Scenario 3 (assumes 25 percent blockage and low flow-through condition)
  - Maximum water surface elevation at ID = approximately 1,050.1 m
  - Overtopping of ID and CVD

4.3.2 Description of 1D Hydraulic Model

To route flood hydrographs through the NFRD and downstream on the NFRC and also from the SFRC to the upstream end of the RCD, CH2M HILL used HEC-RAS version 4.1.0, a 1D hydraulic model developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center. The HEC-RAS model was created using HEC-GeoRAS version 10, which allows HEC-RAS geometry elements to be defined in a geographic information system environment and results in a georeferenced, spatially consistent hydraulic model. The topography of the NFRC and SFRC catchments results in flow paths that are more easily defined than for the RCD and tailings area. As a result, the 1D hydraulic model was considered to be sufficient for routing flood hydrographs to the upstream end of the RCD.

Computational results from the 1D model include depth, average velocity, and WSEL for each cross section defined in the model domain. Estimating these parameters for the continuous surface requires interpolating the 1D hydraulic model results in between the defined cross sections and is one of the notable differences between 1D and 2D hydraulic models, which provide more continuous data across a surface.

4.3.2.1 Spatial Extent

The upstream extent of the model for the NFRC is the ponded area upstream from the NFRD. The total length of the NFRC from the NFRD ponded area to the confluence of the NFRC and SFRC (which corresponds to the upstream end of the RCD) is approximately 2,600 m. The upstream cross section for the SFRC is approximately 1,700 meters upstream from the confluence of the NFRC and SFRC. The model extends approximately 500 m downstream from the confluence of the NFRC and SFRC. Extending the model such that the 1D and 2D model domains overlap reduces the potential for edge effects in the 1D hydraulic model due to proximity to the downstream boundary that could cause instabilities when 1D model results are transferred to the upstream boundary in the 2D hydraulic model.

4.3.2.2 Units and Datum

The 1D model is based on LiDAR data dated October 3, 2011, bathymetric survey data upstream from the NFRD dated July 4 and 5, 2013, and cross section surveys along the NFRC channel dated August 20 to August 27, 2013. All computational data are reported in metric units, CGVD 28 vertical datum, and NAD83 CSRS horizontal datum.

4.3.2.3 Bathymetry

Cross sections were extracted from a single DTM that includes the bathymetry of the ponded area upstream from the NFRD. Cross sections representing the portion of the NFRC channel that is below the water surface were used to define the average channel dimensions and depth of the NFRC channel. These channel dimensions were manually entered into the model geometry to essentially create a low flow pilot channel for the NFRC.

4.3.2.4 Geometry Elements

HEC-RAS geometry elements were used to describe features such as the NFRD, NFRC, and SFRC. The river centerline was manually digitized in HEC-GeoRAS based on the site aerial photograph. Cross section alignments were also manually defined, using topographic contours developed from the LiDAR data to digitize contours that were approximately orthogonal to the predominant flow direction. The impounded area upstream from the NFRD was modelled as a storage area element, using the stage-storage curve (Figure 4-12) to define the storage capacity. An inline structure element was used to represent the geometry of the Haul Road embankment. The flow-through characteristics of the NFRD were modelled as a gate structure with a user-defined rule curve to match the stage-discharge relationships as defined in Figure 4-16.

A lateral structure was used to define the boundary between the NFRC and SFRC catchments, since flood flows may result in flow leaving the NRFC catchment and entering the SFRC catchment. Ineffective flow areas were used in ponded areas to delineate locations where water is likely to accumulate, but no appreciable downstream velocity is anticipated. Two corrugated metal pipe culverts (diameters of 1.78 and 3.65 m) approximately 900 m downstream from the NFRD were not included in the hydraulic model to improve model stability and because the culverts are not anticipated to affect the timing of the hydrograph routing (if the culvert capacity is exceeded during a flood event then flows would overtop the site access road and continue to flow downstream on the NFRC). Also, removal of structures such as culverts is commonly performed for hydraulic models when low probability flood events (and particularly breach scenarios) are being modelled since these structures are not designed for such events and can reasonably be assumed to fail at some point during the flood.

Figure 4-20 shows a plan view of the HEC-RAS model geometry.

4.3.2.5 Upstream and Downstream Boundary Conditions

The HEC-RAS model was developed assuming a subcritical flow regime. This assumption is commonly applied to 1D hydraulic models and generally has little effect on the timing of routed hydrographs. Under the subcritical flow assumption, calculated WSELs in areas where flows tend toward a supercritical regime may be higher than what would actually occur since supercritical flows are associated with lower WSELs than subcritical flows. The assumption of subcritical flow improves model stability and provides a conservative estimate of inundation extents during a flood event.

Subcritical flow requires a downstream boundary condition. A normal depth calculation based on the slope at the downstream end of the model was used to establish the boundary condition. The approximate channel slope of 0.0013 m/m at the head of the RCD was used as the downstream model boundary condition. Internal boundary conditions consist of the starting WSEL in the ponded area upstream from the NFRD and the initial flow through the NFRD. These boundary conditions were initially set based on the starting hydrograph flow and the assumed flow-through scenario (high, medium, low).

4.3.2.6 Unsteady Flow Data

Hydrographs for the NFRC, SFRC, south slope catchment, and tailings area catchment were developed as part of the hydrology analyses and are shown in Figure 4-2. Previous hydraulic analyses indicate the RCD has capacity to convey flows up to approximately 70 m^3/sec (CH2M HILL, 2013b). To reduce model computational time the hydrographs were truncated to flows that are above 20 m^3/sec for the NFRC hydrographs. Since SFRC flows are less than NFRC flows (typically 70 percent of predicted NFRC flows) this results in truncated RCD flows below approximately 35 m^3/sec. Flows less than 35 m^3/sec are assumed to be fully conveyed in the RCD on both rising and falling hydrograph limbs and are assumed to not contribute to volume accumulation in the tailings area behind the ID and will not contribute to ID spillway flows.

4.3.2.7 Model Calibration

Ideally, model calibration would be accomplished by comparing measured and simulated WSEL values for a known discharge. Because no calibration data are available for the high flows analyzed, the model was calibrated by adjusting the channel and floodplain roughness (Manning's *n*) within a range of reasonable values (0.025 to 0.040 for the main channel and 0.04 to 0.07 for the floodplain) to test the sensitivity to roughness and match the

simulated results to previous modelling. A constant roughness value of 0.040 was selected for the main channel and a constant value of 0.055 was selected for the floodplain.

Applying a constant roughness value of 0.040 for the main channel is a conservative approach, based on professional engineering judgment and referencing *n* value tables as presented by Chow (1959). The roughness value of 0.055 for the floodplain is representative of areas of low to medium density vegetation and is also selected based on professional engineering judgment and referencing *n* value tables as presented by Chow (1959).

4.3.2.8 Model Simulations

The 1D hydraulic model was used to route flows on the NFRC and SFRC during the 1-in-500-year flood event. Only the high flow-through scenario was routed to the RCD using the 1D model under a non-breach scenario since this case minimizes the attenuation of flow through the NFRD and thus provides an estimate of the maximum flow for the RCD and ID impoundment. Breach analyses were performed the medium flow-through scenario, low flow-through scenario, and low flow-through scenario assuming a 25-percent reduction in flow-through capacity. These scenarios best represent the average anticipated flow-through and subsequent worst case reduced capacity conditions.

4.3.3 1D Hydraulic Routing of Design Flood Hydrographs – Non-Breach Scenario

Routing the attenuated NFRC flows to the head of the RCD produces a hydrograph that exhibits a reduced peak flow and that is also delayed in time compared to the original design hydrographs as presented in Figure 4-2. The 1D hydraulic model was used to create hydrographs that represent combined NRFC and SFRC flows, taking into account the attenuation of flows through the NFRD. This attenuated hydrograph was combined with hydrographs for the south slope and tailings areas to produce final design hydrographs for the RCD and ID spillway. Two RCD design hydrographs were created along with one hydrograph to represent the tailings area and ID spillway flows.

The hydrograph at the head of the RCD includes the entire catchment area of the NFRC, SFRC, and the portion of the south slope catchment that contributes flow near the head of the RCD. Total catchment area for the head of the RCD flows is approximately 199 km^2. The hydrograph for the RCD, downstream of the overflow weir, includes the additional south slope catchment area of approximately 4 km^2 that contributes flows to the RCD, but would not contribute flows through the overflow weir area in the event of a overflow weir failure. Total catchment area for the RCD flows downstream of the overflow weir is approximately 203 km^2. The hydrograph for the tailings area and ID spillway includes the entire catchment area contributing to the head of the RCD, plus the tailings and surrounding area that drains to the ID spillway. Total catchment area for the ID spillway is approximately 208 km^2.

Table 4-7 summarizes the contributing catchment area, peak flow rates assuming no attenuation through the NFRD, and attenuated peak flow rates for the high flow-through scenario under a non-breach condition. Figures 4-21 through 4-23 show the inflow hydrographs and final design hydrographs for the three locations.

TABLE 4-7
RCD and ID Spillway 1-in-500-year Peak Discharge
Faro Mine Remediation Project

Location	Catchment Area (km^2)	Peak Flow, no Attenuation (m^3/sec)	Attenuated Peak Flow (m^3/sec)	Percent Reduction in Peak Flow (m^3/sec)
Head of RCD	192	130	111	15%
RCD, downstream of overflow weir	203	136	116	15%
Tailings area and ID Impoundment	208	140	121	14%

4.3.4 1D Hydraulic Routing of Design Flood Hydrographs – Breach Scenarios

4.3.4.1 Breach Analysis Approach

As the hydraulic modelling results suggest, behaviour of the NFRD during a 1-in-500-year flood event is subject to uncertainties related to the flow-through capacity of the NFRD. The range of flow-through conditions depend on factors such as rock size, extent of calcium-silicate versus schistose rock, quality of rock over time (relative to breakdown of schistose rock or vertical migration of fines), and blockage of the upstream face or plugging of interstitial spaces causing a reduction in flow-through capacity. Measured stage-discharge data during high flow events approaching the 1-in-500-year flood event is the only way to definitively assess the expected behaviour of the NFRD during such an event. Since the hydraulic modelling predicts a wide range in maximum impounded water surface elevation and impounded storage volume, it was determined that breach scenarios under average and increasing worst-case conditions would provide an estimate of the potential range of downstream consequences. The breach analysis conducted is subject to key assumptions and limitations described below:

1. The analysis performed assumes that a breach of the NFRD Haul Road embankment is possible. Because the actual flow-through characteristics of the NFRD under higher flow-through rates are not well known, this initial analysis aims to bracket the potential downstream impacts. Standard breach parameter estimation techniques are assumed to apply to the NFRD. These equations are typically based upon data sets of observed failures of earthen or rockfill dams and provide estimates of breach time and breach geometry. While constructed of rockfill material, the NFRD is different in many ways from the earthen or rockfill dams that form the basis for the breach parameter estimation techniques. For instance, the range in rock sizes and rock types used to construct the NFRD and Haul Road embankment differ from many earthen and rockfill dams that are constructed with a specified soil and rock type and typically with tighter restrictions on material gradations and quality. Construction methods for the NFRD (end dumped material with little foundation preparation) also differ from the methods used for typical earthen and rockfill dams (which typically require formal foundation preparation and compaction of materials).
2. The failure mode of the embankment was assumed to be piping. Standard breach parameter estimation techniques typically classify the failure mode as either an overtopping failure or a piping failure. Hydraulic modelling results indicate that failure due to overtopping of the Haul Road embankment is not likely. However, overtopping may be possible in conjunction with a ravelling failure, wherein material is removed from the downstream face of the embankment resulting in an oversteepened slope that could lead to slope failure, lowering of the crest, and overtopping. The potential piping failure modes for the Haul Road embankment include (1) wash-out of finer particles within the schistose fill material leaving concentrated flow paths that could result in piping, and (2) piping through the foundation. For the purpose of the breach analyses it was assumed that a piping failure is more likely than an overtopping failure.

Two standard breach parameter estimation methods were used to model the medium flow-through, low flow-through, and low flow-through with 25-percent reduction in flow-through capacity breach scenarios. The selected methods were Froehlich (2008) and Von Thun and Gillette (1990). These methods were selected because they provide internally congruent breach parameter estimates, but represent different breach progression modes. The Froehlich (2008) breach parameter estimation predicts a faster breach development time and smaller final breach geometry. The Von Thun and Gillette (1990) method predicts a slower breach development time and larger final breach geometry. The methods were checked against other envelope equations and methods for predicting peak breach discharge to verify that the breach hydrographs were reasonable.

The initial breach analysis assumed a medium flow-through condition at the NFRD. The 2D hydraulic model was used to route the breach flows through the ID spillway and evaluate flow conditions at the ID crest. Model results indicated that the ID crest would not be overtopped. Subsequent breach analyses, assuming progressively reduced flow-through capacities at the NFRD, were conducted until significant overtopping of the ID crest was observed. Overall, breach analyses of the NFRD were performed for the medium, low, and low plus 25 percent blockage flow-through cases at the NFRD. The following sections further describe the breach parameter estimates, 2D hydraulic model routing, and results of the breach analyses.

4.3.4.2 Breach Development Time, Geometry, and Initiation

A subset of the 1D hydraulic model was used to model the breach scenarios and produce hydrographs. Model parameters defining the breach include breach development time, final breach bottom width, final breach bottom elevation, side slopes of the failed embankment, weir coefficient (to compute overflow capacity), failure mode (piping or overtopping), piping coefficient (to compute piping flow rate), failure trigger mechanism (timing or water surface elevation), and breach progression.

For the purposes of breach modelling the development time is defined as the time between when the structure exhibits significant erosion and full development of the breach. Breach development time does not include initial sloughing of material, minor erosion, or other processes that occur prior to significant failure. Since most structures are observed to fail relatively quickly after significant erosion is observed, the breach development times that are used for earthen embankments are typically on the order of minutes to hours. Estimates of breach development time using the Froehlich (2008) and Von Thun and Gillette (1990) methods are shown in Table 4-8. Froehlich breach development times are faster (5 to 11 minutes) than Von Thun and Gillette development times (40 to 50 minutes) for the average and worst-case scenarios modelled.

TABLE 4-8
Breach Parameters
Faro Mine Remediation Project

Scenario	Parameter Estimation Method	Breach Development Time (hr)	Final Breach Bottom Width (m)	Breach Side Slopes (H:V)	Impounded Water Surface Elevation at Time of Breach Initiation (m)	Impounded Water Volume at Time of Breach Initiation (m^3)
Medium flow-through (average condition)	Froehlich (2008)	0.08	1.0[a]	0.5[b]	1,104.3	1,241,193
	Von Thun and Gillette (1990)	0.65	4.3	1		
Low flow-through	Froehlich (2008)	0.10	1.0[a]	0.5[b]	1,108.0	2,071,410
	Von Thun and Gillette (1990)	0.68	13.4	1		
Low flow-through with 25-percent capacity reduction	Froehlich (2008)	0.12	1.0[a]	0.5[b]	1,110.2	2,671,369
	Von Thun and Gillette (1990)	0.70	18.9	1		

[a] Final breach bottom width of zero (V-notch) changed to 1.0 to improve model stability.

[b] Default breach side slopes of 0.7 adjusted to account for increasing breach bottom width.

The final geometry of the breach is defined by the bottom elevation, width, and side slopes of the fully developed breach. Default side slopes of 0.7 and 1 for the Froehlich (2008) and Von Thun and Gillette (1990) methods were assumed. If applying side slopes of 0.7 for the Froehlich (2008) scenarios resulted in a negative bottom width or a v-notch bottom configuration, the side slopes were steepened until a bottom width of 1.0 m was attained. This change was primarily made to improve model stability over the v-notch bottom configuration. An elevation of 1,092 m was assumed for the final breach bottom elevation. This elevation corresponds to the top of the NFRD core constructed of calcium-silicate rock and represents the assumption that the large rock at the bottom of the NFRD will be immobile during a breach event. Final breach bottom width controls the overall size of the breach. Breach bottom width estimates using the Froehlich (2008) and Von Thun and Gillette (1990) methods are shown in Table 4-8. Froehlich final breach bottom width is narrower (0 to 1.5 m) than Von Thun and Gillette final width (4.3 to 19 m) for the average and worst-case scenarios. The narrower width predicted by Froehlich is consistent with the shorter overall breach time, since a shorter breach time will result in less material removed from the embankment.

As stated above, the failure method was assumed to be piping. A piping coefficient of 0.5 and a weir coefficient of 1.5 were assumed based on recommended values (U.S. Army Corps of Engineers [USACE], 2010). For all model scenarios, failure was assumed to occur at the maximum impounded water surface elevation. This condition would correspond to the maximum impounded water volume upstream of the NFRD. The maximum impounded water surface elevation does not correspond with the timing of the peak discharge hydrograph, so the analysis assumes that peak discharge rates during a breach scenario are attributable to the maximum release of impounded water and not a combination of release of water during a breach coincident with peak inflows. All scenarios also assume that the breach development is linear (i.e. the breach develops at a constant rate rather than defining a breach development curve).

4.3.4.3 Breach Analysis Results

Both parameter estimation methods produce peak discharge results that are consistent with other envelope equations and peak discharge estimation methods. For the medium flow-through scenario the peak discharge predicted by the Froehlich (2008) method is approximately 383 m^3/sec. The peak discharge predicted by the Von Thun and Gillette (1990) method is approximately 588 m^3/sec. The Froehlich (2008) method predicts a peak discharge of 643 m^3/sec during the low flow-through breach case while the Von Thun and Gillette (1990) method predicts a peak discharge of 1,217 m^3/sec. Peak discharge estimates for the low flow-through plus 25-percent capacity reduction scenario range from 861 m^3/sec to 1,627 m^3/sec for the Froehlich (2008) and Von Thun and Gillette (1990) methods, respectively.

Breach flows were routed to the RCD and adjusted by adding design hydrographs for the downstream NFRC catchment, SFRC, south slope discharging to the head of the RCD, and tailings area. The peak breach discharge for the ID impoundment assuming a medium flow-through scenario ranges from 437 m^3/sec to 640 m^3/sec. Peak breach discharge for the ID spillway assuming a low flow-through scenario ranges from 689 m^3/sec to 1,262 m^3/sec. Peak breach discharge for the ID spillway assuming a low flow-through plus 25-percent capacity reduction scenario ranges from 904 m^3/sec to 1,669 m^3/sec. Breach hydrographs predicting maximum peak flows for both scenarios (average and worst-case) were analyzed using a two-dimensional hydraulic model to evaluate impacts to the ID (see Section 4.3.6). Figure 4-24 shows the breach hydrographs including downstream flows added to represent the conditions at the ID.

4.3.5 Description of 2D Hydraulic Model

For this analysis, to describe inundation continuously over the project reach, CH2M HILL used MIKE 21FM, a 2D hydraulic model developed by Danish Hydraulic Institute Water and Environment. MIKE 21 FM® is a 2D finite element model that uses both quadrangular and triangular grid cells that vary in size and shape throughout the model domain (flexible mesh). Because hydraulics (depth and velocity) can be computed continuously throughout the model network, complex flow paths and overland flow characteristics are simulated more accurately with a 2D model. In contrast, a 1D hydraulic model computes average hydraulics at discrete locations (cross sections) and does not provide continuous data across a surface like the Rose Creek tailings.

Outputs from the 2D model include depth, depth-averaged velocity, and WSEL. Model results are presented as colour-coded contours and velocity vectors overlaid on aerial photographs, facilitating the interpretation of depth and velocity at specific locations of interest. As this project proceeds to future phases, the model can be further refined in order to provide valuable information to designers and other interested parties.

The 2D model was used to simulate hydraulic conditions that result from routing the 1-in-500 year flood event hydrographs. Development of input hydrographs is discussed above in Section 4.2 and includes attenuation of peak flows through the NFRD and routing of flows from the NFRC and SFRC. The 2D model was used to estimate flow rates, depths, velocities, and water surface elevations through the RCD, across the tailings, and over the spillway of the ID.

4.3.5.1 2D Model Development

Model development followed a series of specific steps:

- Generate the digital terrain model

- Discretize (transform the continuous surface into its discrete counterparts) the domain and resolution (computational mesh)
- Define hydraulic structures
- Define the boundary conditions (flow and water levels)
- Map the flow-resistance parameter

Each step of the model development process is described in detail below.

Generate Digital Terrain Model. To represent the channel and pond bathymetry and tailings topography, a single DTM was prepared that covers the extent of the model domain for each modelling scenario. The 2D model is based on LiDAR data dated October 3, 2011. All computational data are reported in metric units, CGVD 28 vertical datum, and NAD83 CSRS horizontal datum.

Discretize Domain and Resolution. The model domain extends from its downstream boundary below the polishing pond upstream to the confluence of the NFRC and SFRC, a distance of approximately 5,000 m. CH2M HILL discretized the model domain using both quadrangular and triangular elements. Quadrangular elements were used to define the channel of the RCDC and the ID spillway (features that require tight boundary fitting). Triangular elements were used to define the tailings areas. Elements in the main channel range from 4 m to 6 m (length scale). The tailings elements are specified with a maximum area of 200 m^2 with the larger elements used in elevated floodplain areas that are not expected to become inundated. The final computational mesh included 46,820 elements. Elevation data were interpolated to the mesh using gridded X-, Y-, and Z-point data extracted from the DTM. Figure 4-25 illustrates the computational mesh in the location of the ID spillway.

Model Hydraulic Structures. Within the model domain, the tailings area includes the spillway of the ID and the RCDC includes the overflow weir. These structures were modelled as open channels.

Upstream and Downstream Boundary Conditions. The MIKE 21 hydraulic model solves the partial differential equations (St. Venant Equations), which require defined boundary conditions at all open boundaries. The model simulations have three open boundaries: two at the upstream extent of the model domain and one at the downstream extent. For analysis of the ID spillway, the two upstream boundaries are defined with the 1-in-500-year flood event hydrographs developed for the RCD and the tailings area. For analysis of the RCD, the upstream boundary associated with the RCD is defined with uniform flow (1-in-500-year flood event peak flow rate equal to 111 m^3/sec upstream of the overflow weir and 116 m^3/sec downstream of the overflow weir). For all model simulations, the downstream boundary is defined with a uniform water level (1,014 m). For the dam breach analysis, the upstream boundaries were defined with the flood wave hydrographs developed with the dam break simulation described in Section 4.3.4.

The downstream boundary condition is defined by the WSEL from previous HEC-RAS model results. For a complete discussion and analysis of the design flows, see Section 4.1

Map Flow Resistance Parameter. Water flow experiences two forms of flow resistance: form drag and skin friction. Both of these affect the hydraulics (i.e., water level, velocity, and shear stress) and the associated forces that contribute to sediment transport (i.e., grain shear stress). Vegetation, plan form geometry, bed forms, and bed and bank particle sizes all contribute to flow resistance. Form drag is only a small component and is accounted for directly in 2D models by modelling the physical features of the system that contribute to form drag. Only skin friction needs to be accounted for separately. MIKE 21 FM® accounts for flow resistance due to skin friction using the Manning coefficient, n; however, the direct model input is its inverse, $M = 1/n$.

CH2M HILL mapped n-values using aerial photographs of the project area based on professional engineering judgement and referencing n value tables as presented by Chow (1959). Within the model domain, there are 7 n-value categories as summarized in Table 4-9. Figure 4-26 illustrates the extent of each category.

TABLE 4-9
Manning Coefficient (*n* values) and M values used in 2D Models
Faro Mine Remediation Project

Land Type	*n* value	M value
Bare Soil (no vegetation)	0.030	33.3
Bare Rock (no vegetation)	0.047	21.3
Small Vegetation	0.080	12.5
Large Vegetation	0.120	8.3
Tailings	0.016	62.5
Invert RCDC (submerged)	0.030	33.3
Submerged Tailings	0.016	62.5
ID Spillway	0.030	33.3

Ideally, model calibration would be accomplished by comparing measured and simulated WSEL values for a known discharge and adjusting the roughness values. Because no calibration data are available for the high flows analyzed, no adjustments were applied to the model roughness. For a given reach, the roughness coefficient in a 2D model is lower than in a 1D model because the roughness coefficient only accounts for resistance associated with skin friction. In contrast, roughness in a 1D model must also include bed and plant form resistance (which is accounted for by the spatial representation of the channel in a 2D model).

Model Calibration. To calibrate the model at the ID spillway, an initial model simulation was run with steady state flow equivalent to the peak flow from the 1-in-500-year flood event hydrograph (121 m^3/sec) to determine if results of the hydraulic modelling are reasonable when compared to results calculated using a broad-crested weir equation. Although flow over the spillway does not behave precisely like flow over a weir, open channel flow passes through critical depth entering the spillway and it is assumed that hydraulic results can be approximated using the weir equation to evaluate the reasonableness of hydraulic model simulations. Results from the hydraulic modelling closely match results calculated with the weir equation for the 30-m-wide spillway with a coefficient of discharge equal to 1.6.

4.3.5.2 Model Simulations

All model simulations use a computational mesh interpolated from topography defined by a DTM that is a composite of proposed improvements and LiDAR data that define existing conditions. For the evaluation of improvements, the following seven models were prepared to simulate discharge through the project reach:

- **Model Scenario 1 – ID spillway and dam modifications modelled with input flow hydrograph with recurrence interval of 500 years.** Model simulations assume that the overflow weir has blown out with subsequent erosion of the right bank levee at that location, resulting in the entire design flow conveyed onto the tailings. Model simulations were run with the 1-in-500-year flood event hydrograph with a 72-hour duration. At the start of the model simulations, the tailings area is assumed to be at full pool elevation of 1,046.5 m. As the simulation runs, water is first conveyed down the RCD, then out the overflow weir opening, across the tailings, and is then impounded by the ID. Inflow causes the headwater behind the dam to increase and exceed the elevation of the hydraulic control point on the spillway at elevation 1,046.5 m. Spillway discharge is a function of the headwater depth that builds behind the ID during the 72-hour simulation period. In this model, the peak inflow from 1-in-500-year flood event hydrograph of 121 m^3/sec is attenuated by storage in the ID to a peak flow rate of 115 m^3/sec conveyed over the ID spillway.
- **Model Scenario 2 – Existing conditions in the RCD and required improvement in the RCD to meet freeboard criteria.** Design criteria specify that the RCD maintain 0.5 m freeboard at the 1-in-500-year flood event flow. This model simulation represents the baseline condition where no improvements have been included. To

determine the water surface elevation that would result from conveyance of the 1-in-500-year flood event flow rate, elevations of the right bank dike including the overflow weir were revised so that the 1-in-500-year flood event flow rate could be conveyed in the RCD without overtopping the right bank. A steady state flow simulation with a continuous flow rate (111 m^3/sec in the upper part of the RCD and 116 m^3/sec downstream of the overflow weir) was run in order to extract water surface elevation data along the continuous length of the channel corresponding to the 1-in-500-year flood event peak flow. At the start of the model simulations, the channel is represented by the LiDAR surface. In this model simulation, 100 percent of the 1-in-500-year flood event flow rate is conveyed through the RCD.

- **Model Scenario 3 – Channel modifications to remove vegetation from the right bank of the RCD.** To evaluate the effectiveness of vegetation removal, Model Scenario 2 (Existing conditions in the RCD) was re-run with a revised roughness map to represent the channel cleared of vegetation on the right bank. Model input requires an evaluation of flow resistance expressed as the Manning roughness coefficient, *n*. Vegetation characteristics are commonly represented with the roughness coefficient. Areas mapped as large and small vegetation on the right bank of the RCD were revised to represent the same channel area without vegetation. For example, areas on the right bank classified as large vegetation (*n*=0.12) were revised to bare rock (*n*=0.047) or bare soil (*n* = 0.03). In this model simulation, 100 percent of the 1-in-500-year flood event flow rate is conveyed through the RCD.
- **Model Scenario 4 – Channel modifications to remove vegetation from both the right and left banks of the RCD.** To evaluate the effectiveness of vegetation removal, Model Scenario 2 (Existing conditions in the RCD) was re-run with a revised roughness map to represent the channel cleared of vegetation on the both the left and right banks. For example, areas on both the left and right banks classified as large vegetation (*n*=0.12) were revised to bare rock (*n*=0.047) or bare soil (*n* = 0.03). In this model simulation, 100 percent of the 1-in-500-year flood event flow rate is conveyed through the RCD.
- **Model Scenarios 5, 6, and 7 – Simulated dam breach at the NFRD.** Three scenarios were considered for the breach analysis. Breach Scenario 1 assumes no blockage and medium flow-through condition for the NFRD. Breach Scenario 2 assumes no blockage and low flow-through condition. Breach Scenario 3 assumes 25 percent blockage and low flow-through condition. The three scenarios are based on breach hydrographs described in Section 4.3.4.3. These hydrographs were input to the MIKE 21 2D model at the upstream end of the RCD. The breach model simulations assume that flow can occur down the RCD, discharge through the overflow weir, and flow over the tailings and down the spillway of the ID. Volumes and peak flows associated with each breach scenario are as follows:

  - Breach Scenario 1 (assume breach of NFRD occurs at maximum impounded WSEL during the medium flow-through scenario)
    - Total volume of water impounded upstream of NFRD at start of breach = **1,241,193 m^3**
    - RCD peak flowrate (including flows from SFRC, south slope, and tailings area catchments) = **640 m^3/sec**
  - Breach Scenario 2 (assume breach of NFRD occurs at maximum impounded WSEL during the low flow-through scenario)
    - Total volume of water impounded upstream of NFRD at start of breach = **2,071,410 m^3**
    - RCD peak flowrate (including flows from SFRC, south slope, and tailings area catchments) = **1,262 m^3/sec**
  - Breach Scenario 3 (assume breach of NFRD occurs at maximum impounded WSEL during the low flow-through and 25-percent reduction in flow-through capacity scenario)
    - Total volume of water impounded upstream of NFRD at start of breach = **2,671,369 m^3**
    - RCD peak flowrate(including flows from SFRC, south slope, and tailings area catchments) = **1,669 m^3/sec**

4.3.6 2D Model Results

4.3.6.1 ID Spillway Capacity (Model Scenario 1)

For the 1-in-500-year flood event hydrograph with 72-hour duration, results are summarized:

- Inflow peak flow = 121 m^3/sec
- Peak flow over the spillway = 115 m^3/sec
- Maximum headwater elevation = 1,048.60 m
- Maximum depth at hydraulic control on spillway = 2.10 m
- Minimum freeboard at ID = 1.0 m

Figure 4-27 illustrates the extent of inundation at the 1-in-500-year flood event flow rate. Figure 4-28 presents the 1-500-year flood event hydrographs from the modelling simulation of the ID spillway.

4.3.6.2 Rose Creek Diversion Existing Condition (Model Scenario 2)

Design criteria specify that the RCD maintain 0.5 m freeboard at the 1-in-500-year flood event flow. Results of this model simulation were used to determine the minimum desired elevation of the right bank to achieve the design criteria of 0.5 m freeboard. Locations and elevations for improvements are specified on the design drawings.

4.3.6.3 Rose Creek Diversion Removal of Vegetation (Model Scenarios 3 and 4)

Modelling was performed to evaluate improvements to the RCD by removal of vegetation. WSEL model results for the base case and the vegetation removal scenarios were compared by subtracting the base case results from the results where the roughness values were decreased to represent removal of vegetation. Positive values indicate a reduction in the WSEL as a result of changing the roughness input. These difference plots are depicted in the following figures, which illustrate the reduction in WSEL:

- Figure 4-29 – Reduction in WSEL due to Vegetation Removal on the Right Bank of the RCD
- Figure 4-30 – Reduction in WSEL due to Vegetation Removal on the Right and Left Banks of the RCD

As shown on the difference plots, vegetation removal from the right bank results in an average reduction in the WSEL from 0.05 to 0.10 m. Removal of vegetation from both banks would reduce the WSEL from about 0.10 to 0.15 m. Removal of vegetation is estimated to reduce the WSEL through the total length of the RCD channel. Based on the results, interim improvements specify that vegetation be cleared from the right bank of the RCD.

4.3.6.4 Dam Breach Analysis (Model Scenarios 5, 6, and 7)

As described in Section 4.3.4, NFRD breach scenarios were developed to investigate potential flooding as a result of breach of the NFRD during the 1-in-500-year flood event flow. The breach model simulations assume flow down the RCD, discharge through the overflow weir, and flow over the tailings and down the spillway of the ID. Modelling assumptions are consistent with analysis of the 1-in-500-year flood event cases for the ID spillway, which assume that 100 percent of the 1-in-500-year flood event flow is conveyed into the tailings impoundment and over the spillway. Initial conditions at the start of model simulations assume that the ID impoundment is at the full pool elevation of 1,046.5 m. Following are key results from the breach simulations:

- Breach Scenario 1 (assumes no blockage and medium flow-through condition)
  - Maximum water surface elevation at ID = approximately 1,049.3 m
  - Freeboard at ID = 0.3 m
  - No overtopping of ID or CVD
- Breach Scenario 2 (assumes no blockage and low flow-through condition)
  - Maximum water surface elevation at ID = approximately 1,049.9 m
  - Overtopping of ID and CVD
- Breach Scenario 3 (assumes 25 percent blockage and low flow-through condition)
  - Maximum water surface elevation at ID = approximately 1050.1
  - Overtopping of ID and CVD

Figures 4-31, 4-32, and 4-33 display breach hydrographs for the medium flow-through condition, low flow-through condition, and low flow-through condition with 25-percent blockage. Table 4-10 summarizes the key information associated with each model simulation. As shown in Figure 4-33 and presented in Table 4-10, the low-flow condition with 25-percent blockage results in overtopping of the ID.

TABLE 4-10
Summary of Breach Simulations
Faro Mine Remediation Project

NFRD Flow-through Condition	Blockage	Peak Flow (m^3/sec)	Maximum WSEL (m)	Overtopping at ID
Medium	Zero	640	1,049.3	No
Low	Zero	1,262	1,049.9	Yes[a]
Low	25%	1,669	1,050.1	Yes

[a] Minimal overtopping of ID crest occurs for breach scenario assuming low flow-through condition and no blockage. This is considered the threshold case.

Breach Scenario 2 is considered to be the threshold case, since minimal overtopping of the ID crest occurs and the duration of overtopping is less than one hour. Based on this analysis, overtopping is expected for any breach scenario with a peak flow discharge greater than approximately 1,200 m^3/sec. This estimate of the overtopping flow is dependent on the following conditions occurring concomitantly.

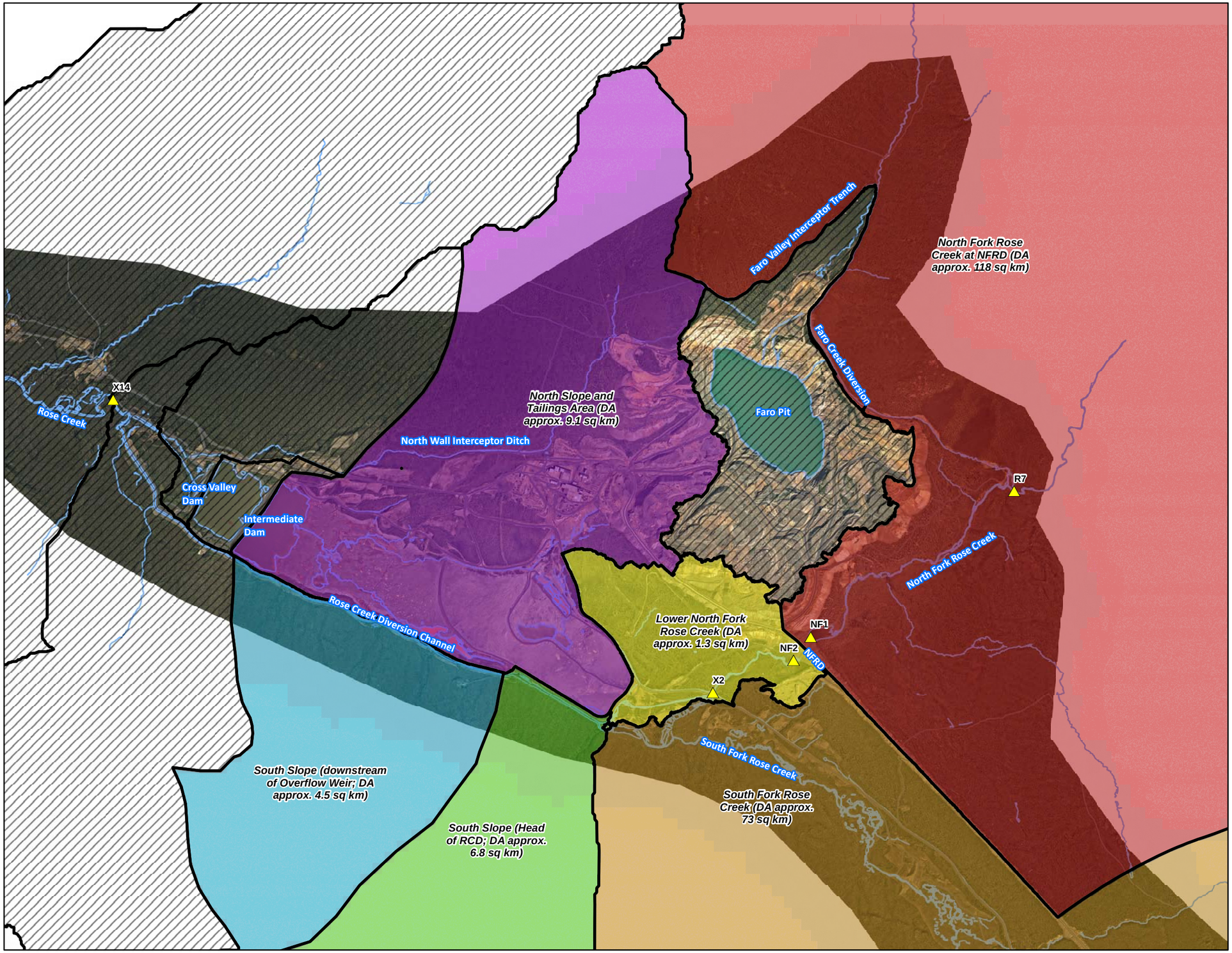
Initial conditions assume that the ID impoundment is at full pool elevation of 1,046.5 m. This assumption limits storage in the ID impoundment and subsequently reduces potential attenuation of the peak discharge.

- In the model simulation, the RCD is blocked off at the overflow weir so that flow is not conveyed down the RCD once the flood is directed onto the ITA. Model simulations that provide for conveyance down the RDC result in an approximate decrease of 0.3 m in water surface elevations at the ID.
- A low flow-through condition was assumed at the NFRD, the most conservative estimate of flow-through capacity.
- Blockage (25 percent) of flow was assumed at the NFRD which reduces capacity further and results in greater impounded volume at the NFRD.

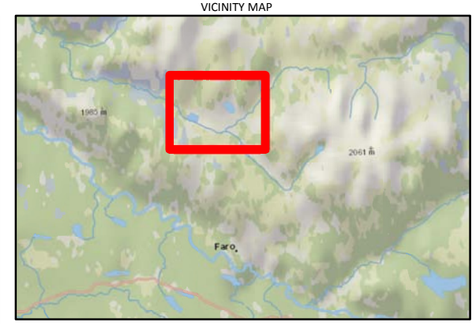
For the medium flow-through condition, a video animation (extracted from model simulation results) was developed to illustrate how the breach flow wave would propagate through the RCD, across the tailings, over the ID spillway, and over the CVD spillway. Four frames were extracted and compiled for display on Figure 4-34. The extent of inundation showing the depth of water is depicted at the top of each frame and progress on the corresponding flood wave hydrograph is included at the bottom. Following are brief descriptions of the images shown:

- Figure 4-34 illustrates Breach Scenario 1, which assumes a medium flow-through condition at the NFRD with zero blockage. The four frames show the following:
  - **Frame 1 (1 hour 15 minutes simulation time)** – This image captures the simulation before the peak of the flood wave arrives at the head of the RCD. The front edge of the flood wave is flowing over the tailings and has not reached the ID.
  - **Frame 2 (5 hours simulation time)** – This image captures the simulation immediately after the peak of the flood wave arrives at the head of the RCD. The ID impoundment has been filled and flow over the spillway has nearly filled the CVD.

- **Frame 3 (7 hours 30-minutes simulation time) –** This image captures the simulation about three hours after the peak of the flood wave has arrived at the head of the RCD. As the flood wave propagates downstream, both the ID impoundment and the CVD are full.
- **Frame 4 (11 hours 30 minutes simulation time) –** This image captures the simulation 6 hours after the peak of the flood wave has arrived at the head of the RCD. As shown, water levels in the CVD are still at full capacity but water levels behind the ID have decreased as compared to Frame 3.



VICINITY MAP



LEGEND

△ Flow Monitoring Location

Catchment

- Catchment does not contribute to RCD/ID
- Lower North Fork Rose Creek (DA approx. 1.3 sq km)
- North Fork Rose Creek at NFRD (DA approx. 118 sq km)
- North Slope and Tailings Area (DA approx. 9.1 sq km)
- South Fork Rose Creek (DA approx. 73 sq km)
- South Slope (Head of RCD; DA approx. 6.8 sq km)
- South Slope (downstream of Overflow Weir; DA approx. 4.5 sq km)

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

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Created by:
CH2MHILL

FIGURE 4-1
Rose Creek Diversion and Intermediate Dam Contributing Catchments
Faro Mine Remediation Project

CH2MHILL

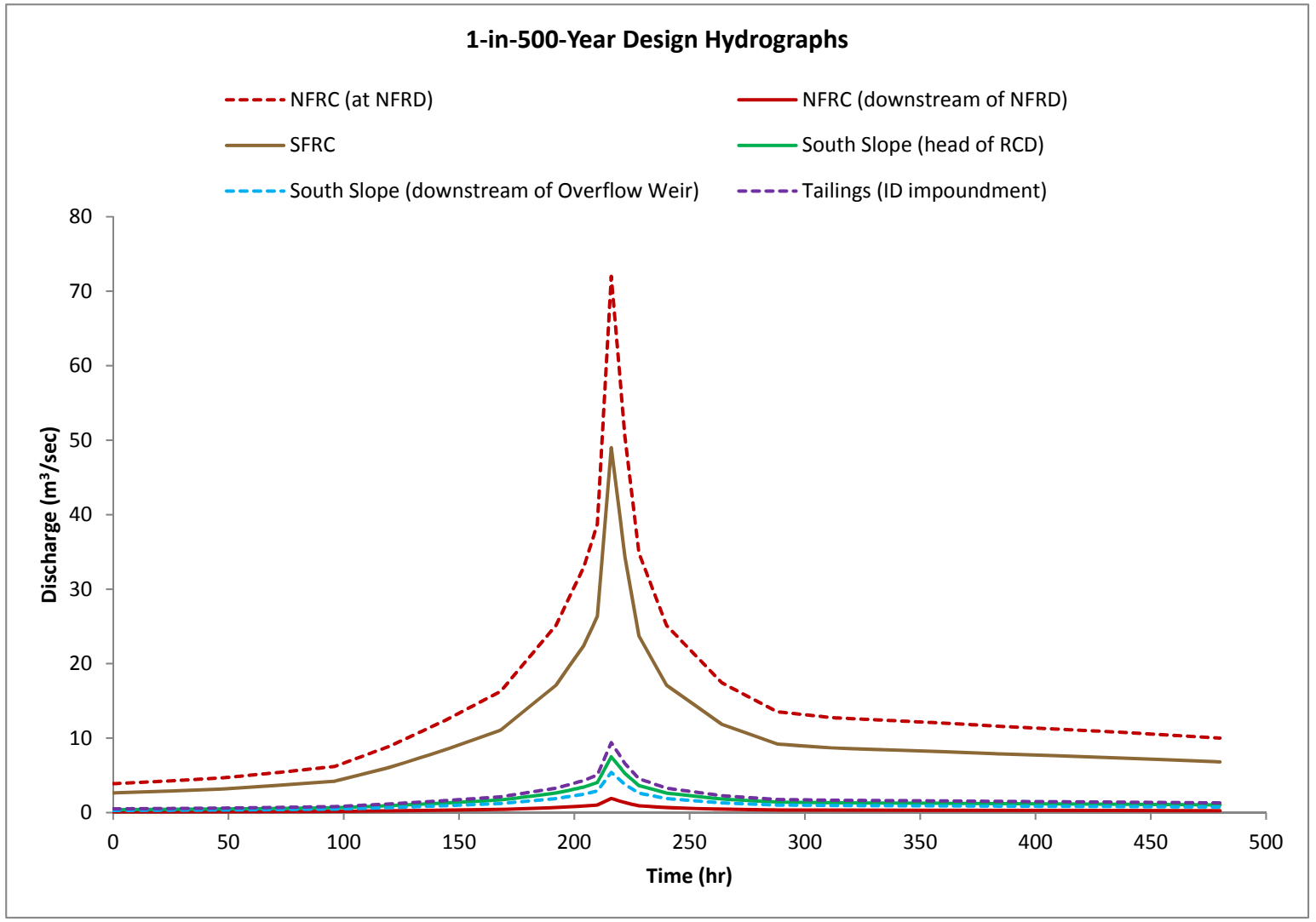

Figure 4-2

1-in-500-year Design Hydrographs

Faro Mine Remediation Project

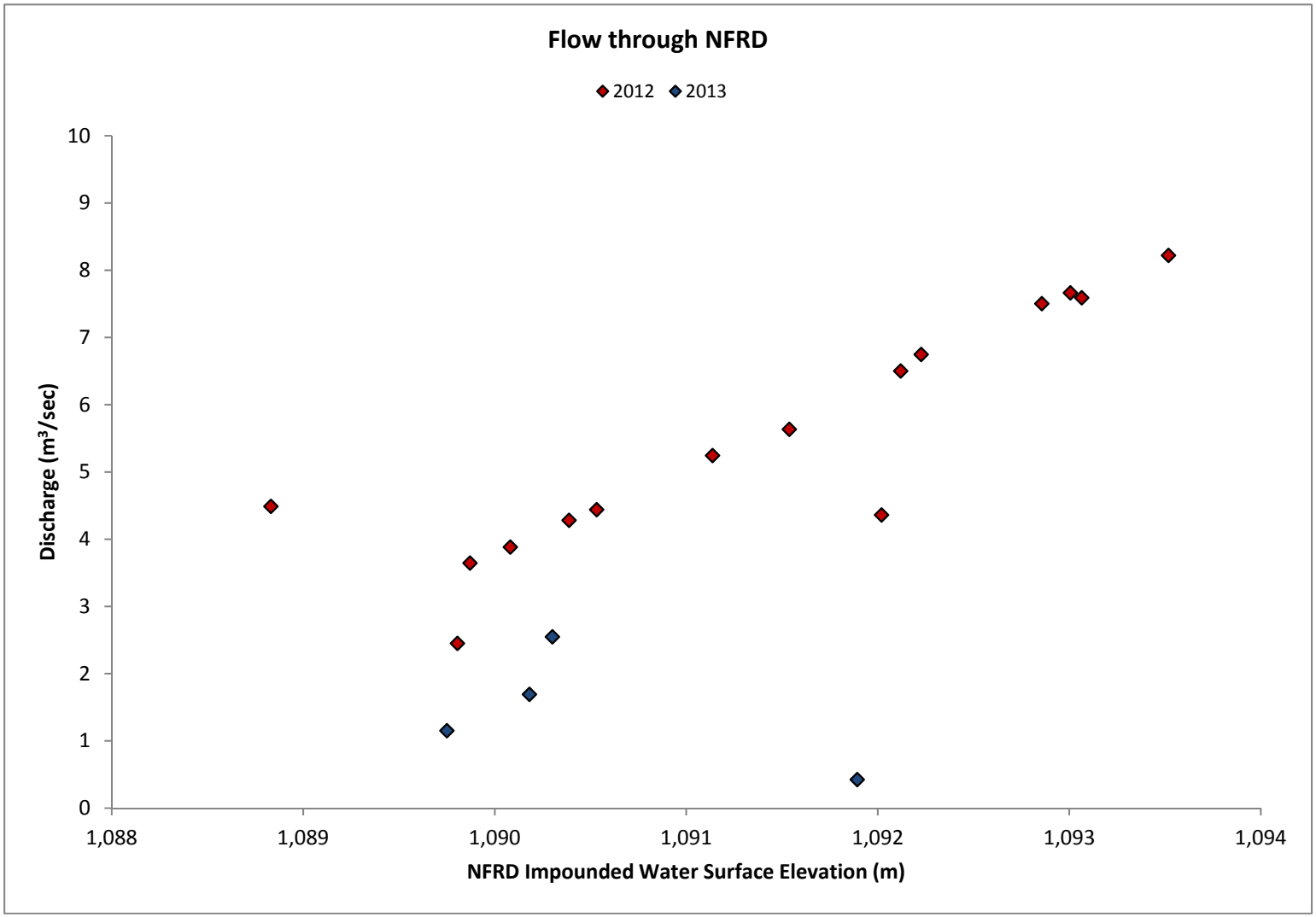

Figure 4-3

Observed Flow through the NFRD

Faro Mine Remediation Project

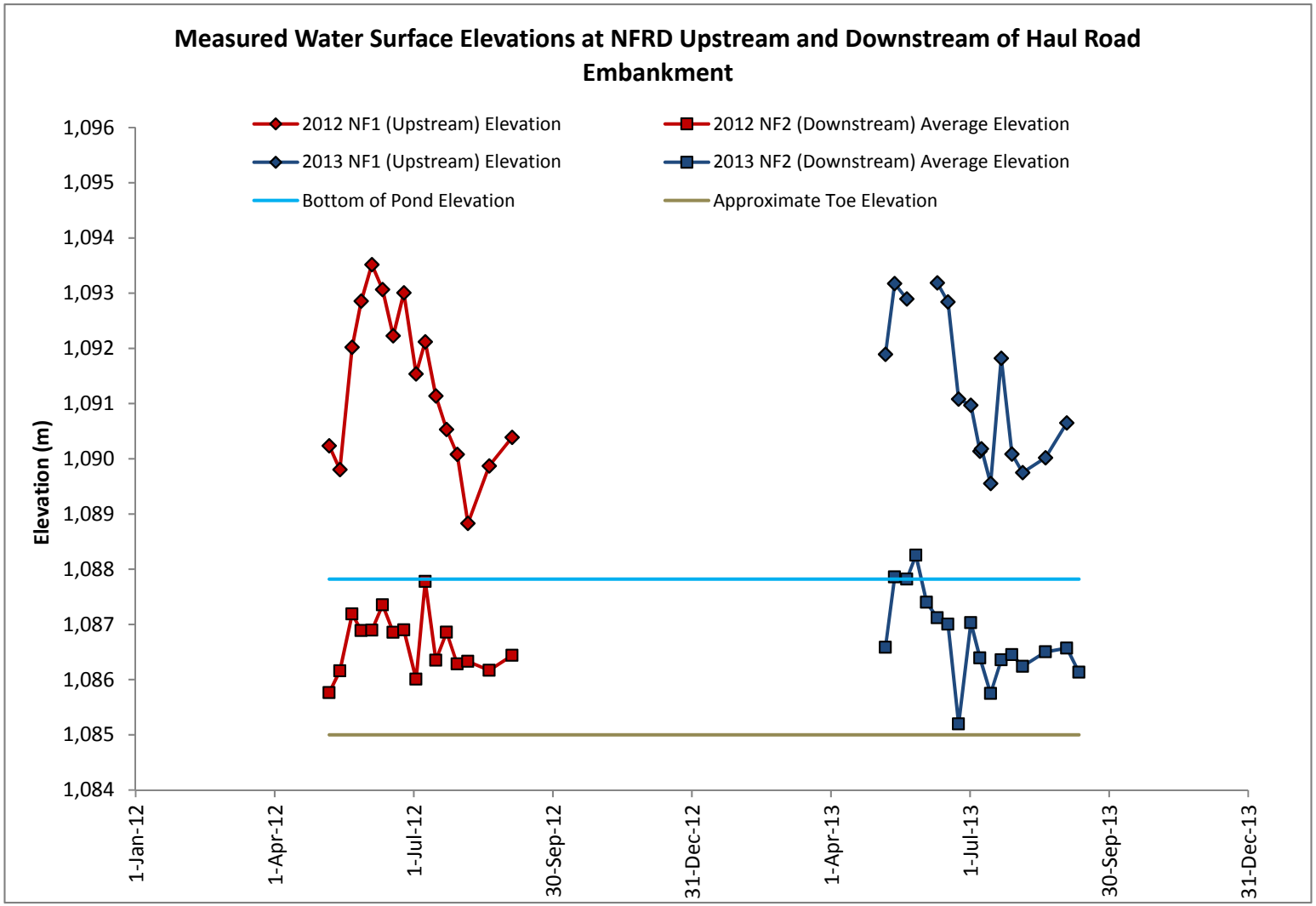

Figure 4-4

Measured Water Surface Elevations at NFRD Upstream and Downstream from Haul Road Embankment

Faro Mine Remediation Project

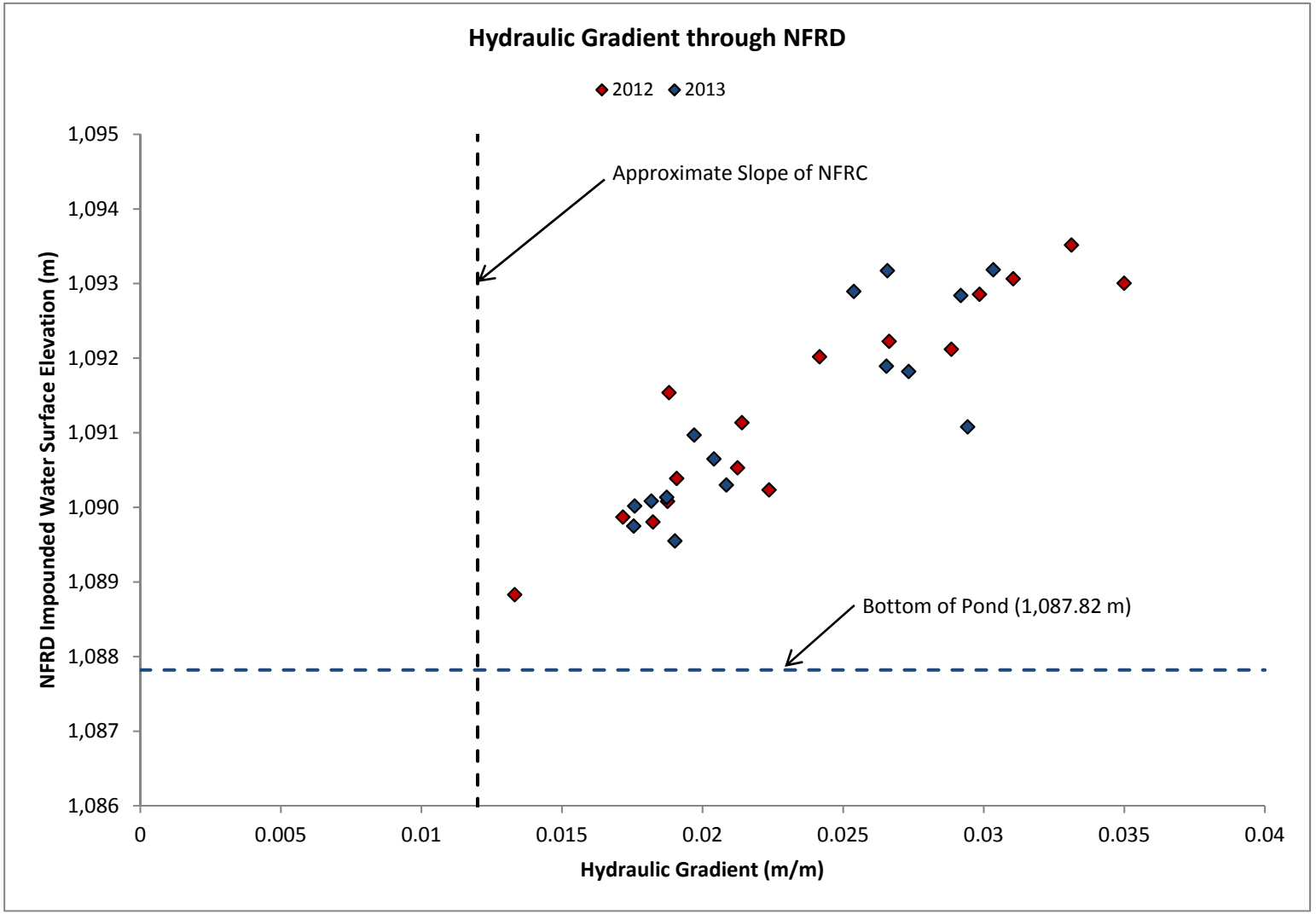

Figure 4-5

Average Hydraulic Gradient through the NFRD

Faro Mine Remediation Project

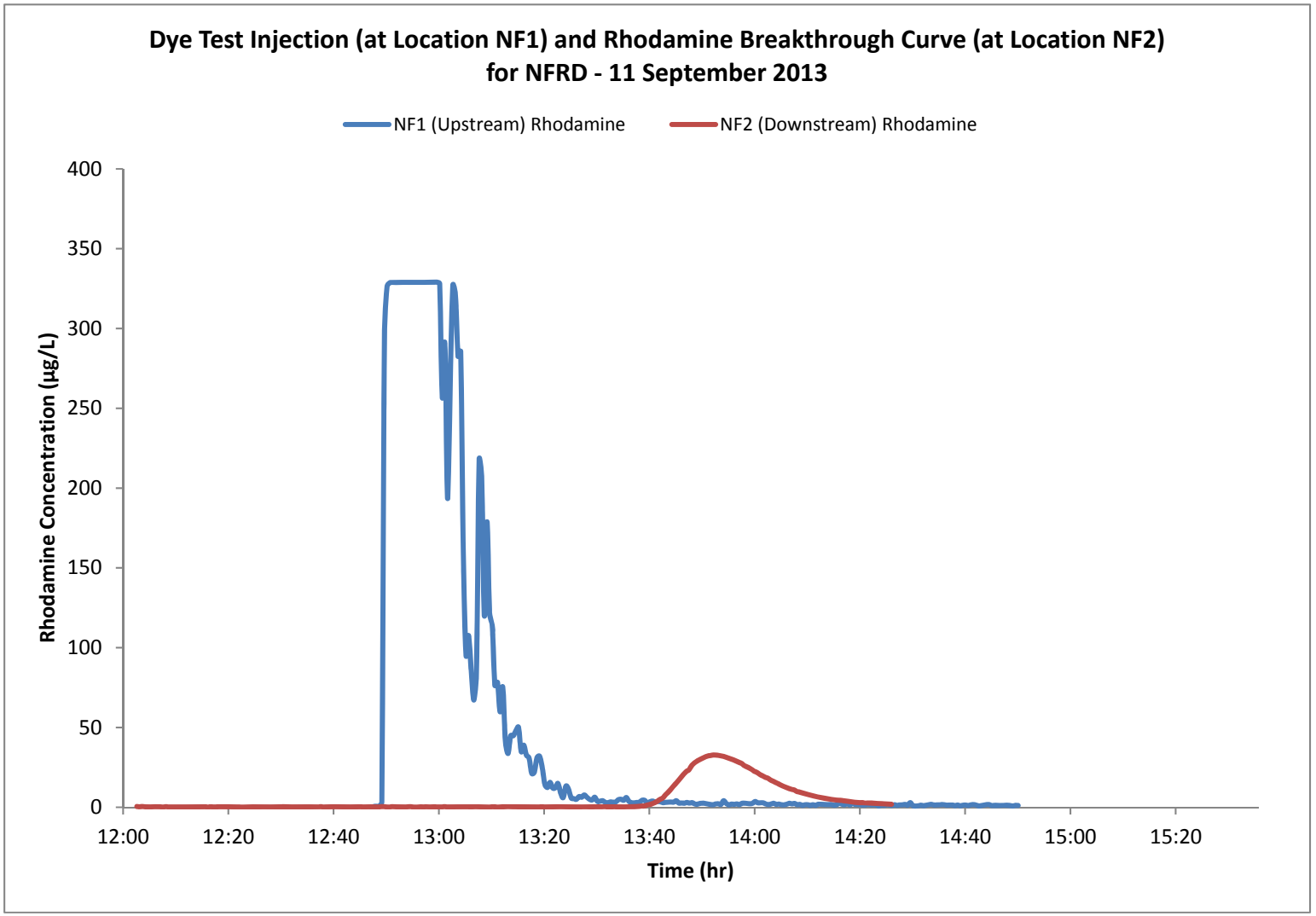

Figure 4-6

Dye Test Injection and Rhodamine Breakthrough Curves for NFRD (September 11, 2013)

Faro Mine Remediation Project

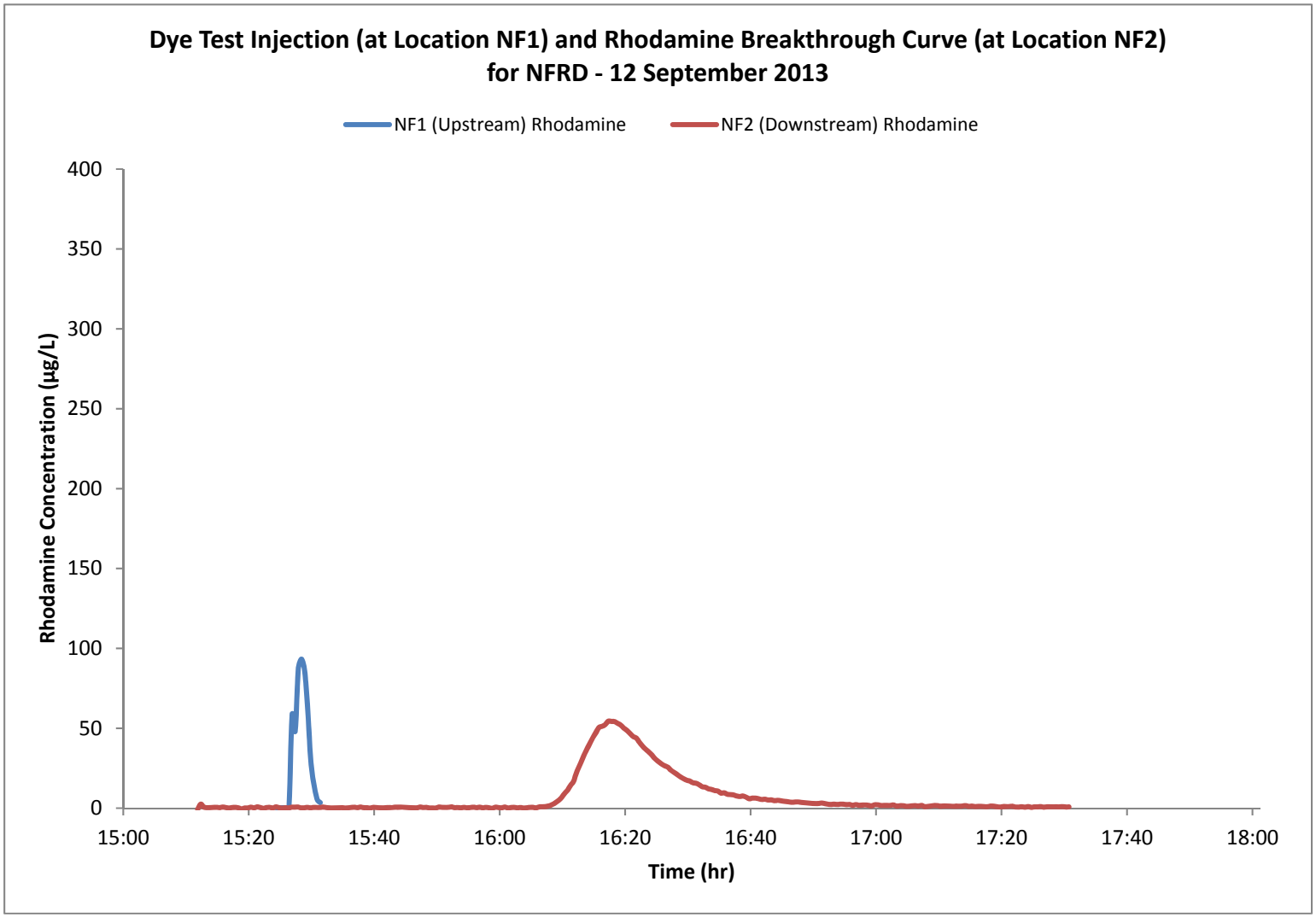

Figure 4-7
Dye Test Injection and Rhodamine Breakthrough Curves for NFRD (September 12, 2013)
Faro Mine Remediation Project

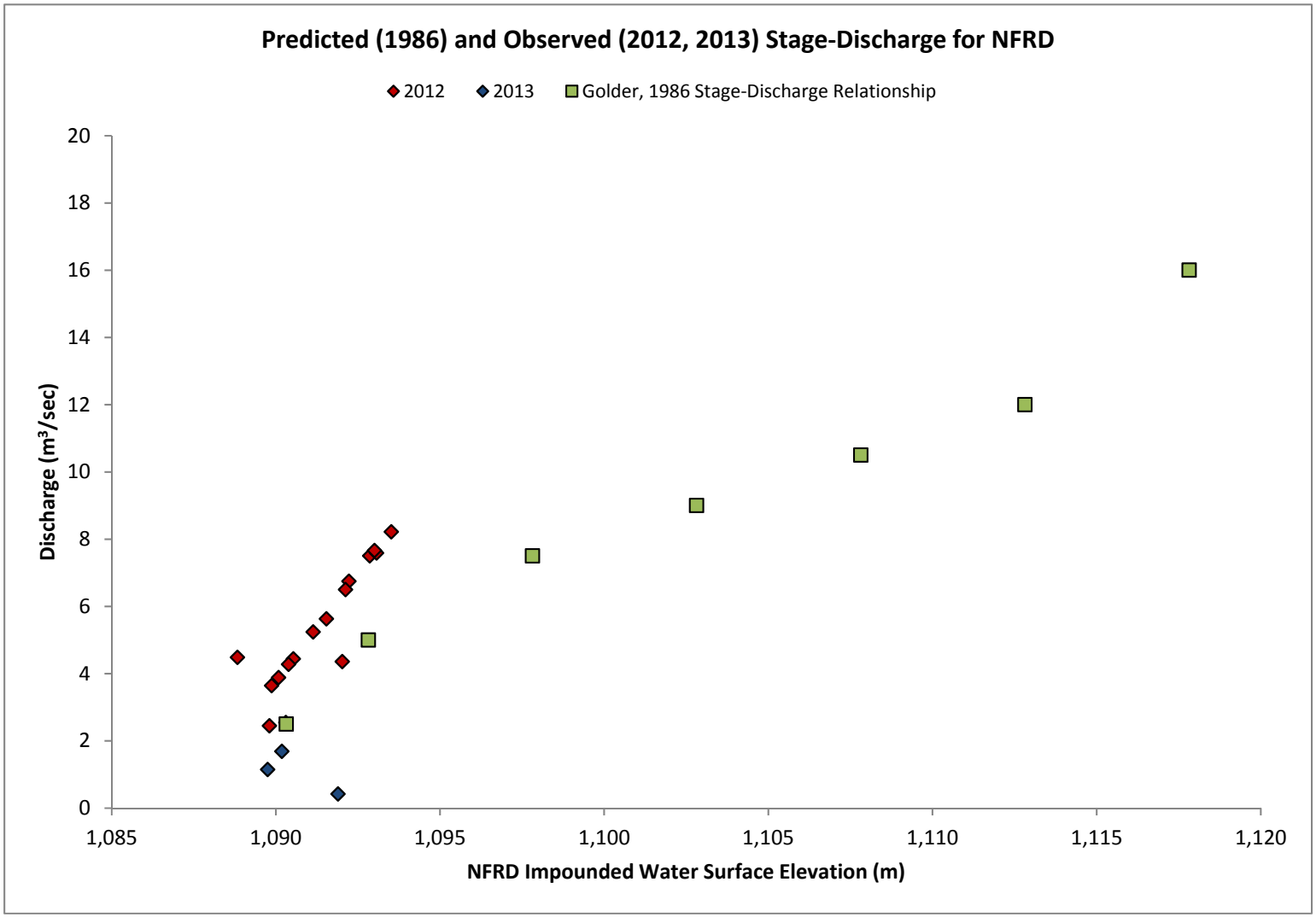

Figure 4-8
Predicted (1986) and Observed (2012, 2013) Stage-Discharge for NFRD
Faro Mine Remediation Project



VICINITY MAP



LEGEND

- NFRC - Upstream of NFRD
- NFRC - Haul Road Section
- NFRC - Downstream of NFRD
- NFRD Profile
- FMC - Water Lines
- FMC - Roads

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

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Metres

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CH2MHILL

FIGURE 4-9
NFRC and Haul Road Sections
Faro Mine Remediation Project

CH2MHILL

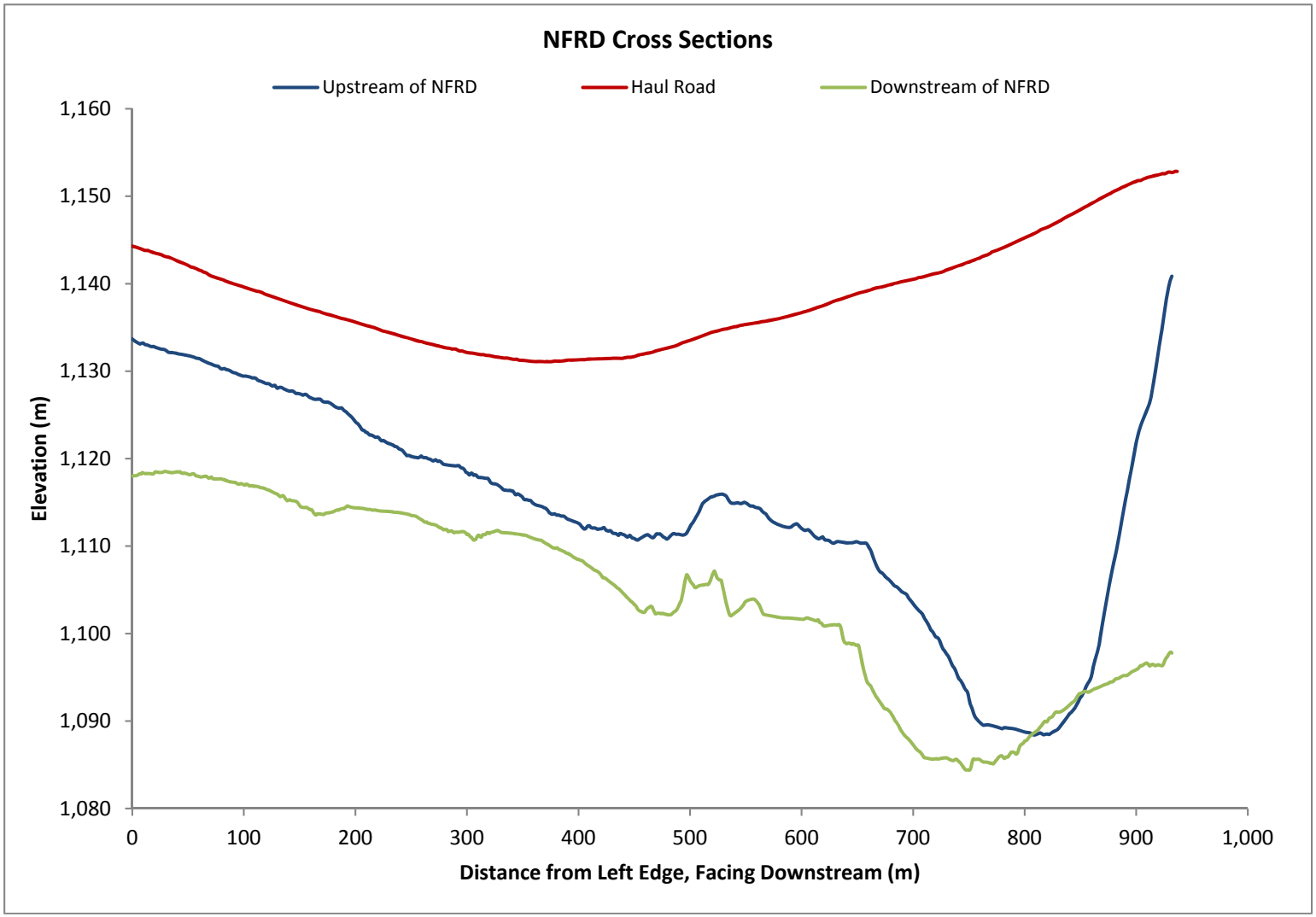


Figure 4-10

NFRD Cross Sections

Faro Mine Remediation Project

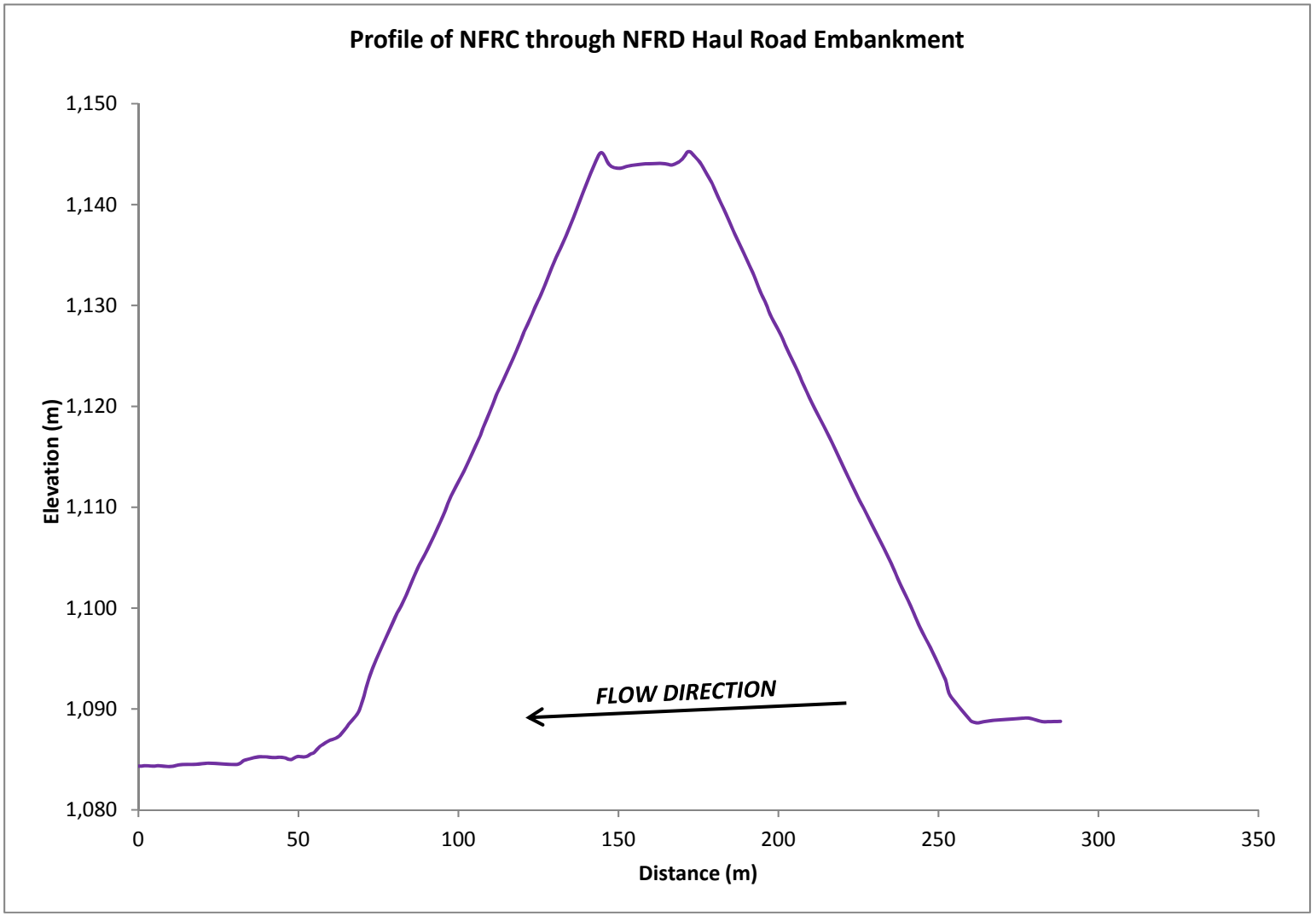


Figure 4-11
Profile of NFRC through NFRD Haul Road Embankment
Faro Mine Remediation Project

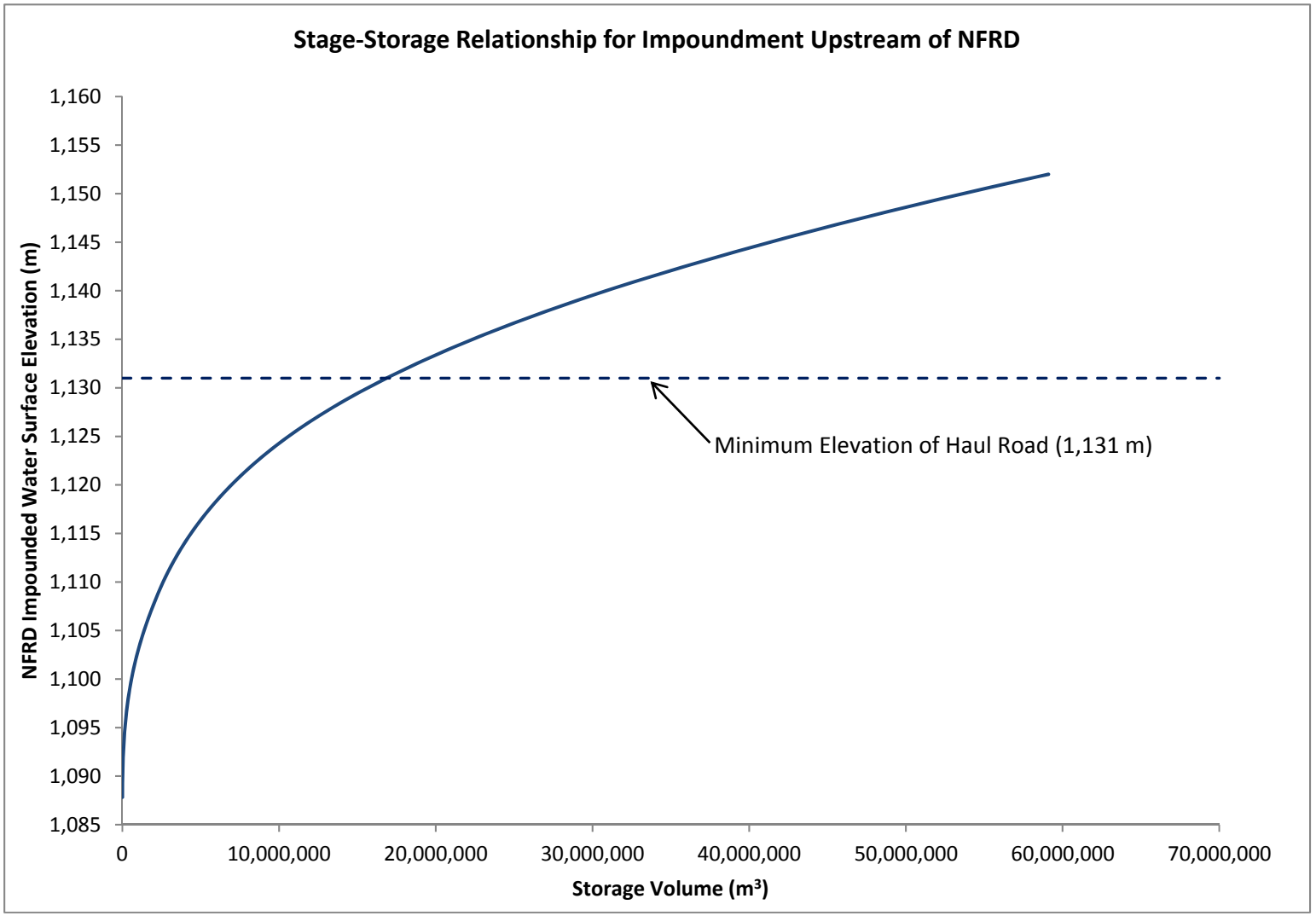


Figure 4-12
Stage-Storage Relationship for Impoundment Upstream from NFRD
Faro Mine Remediation Project

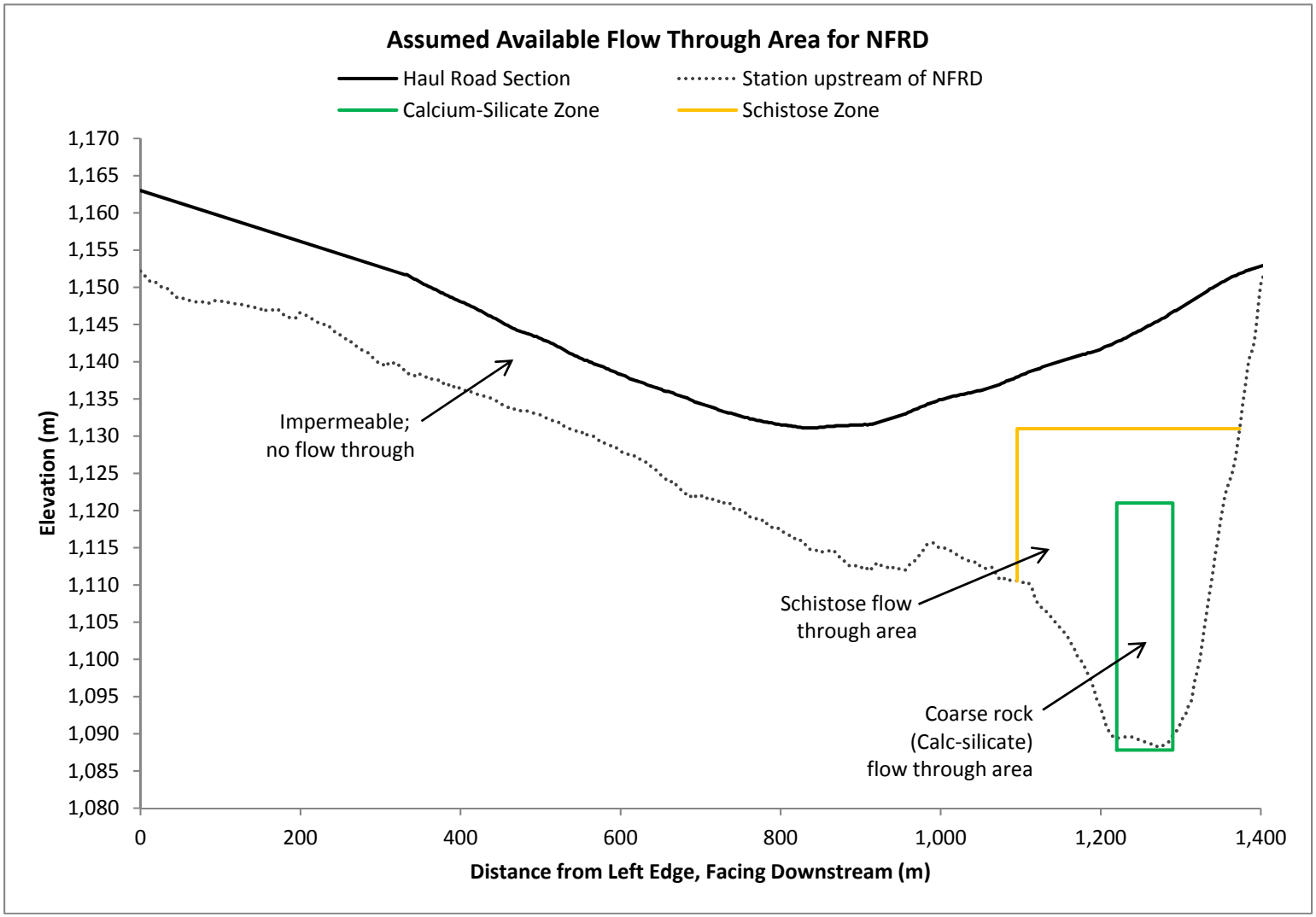


Figure 4-13
Assumed Available Flow Through Area for NFRD
Faro Mine Remediation Project

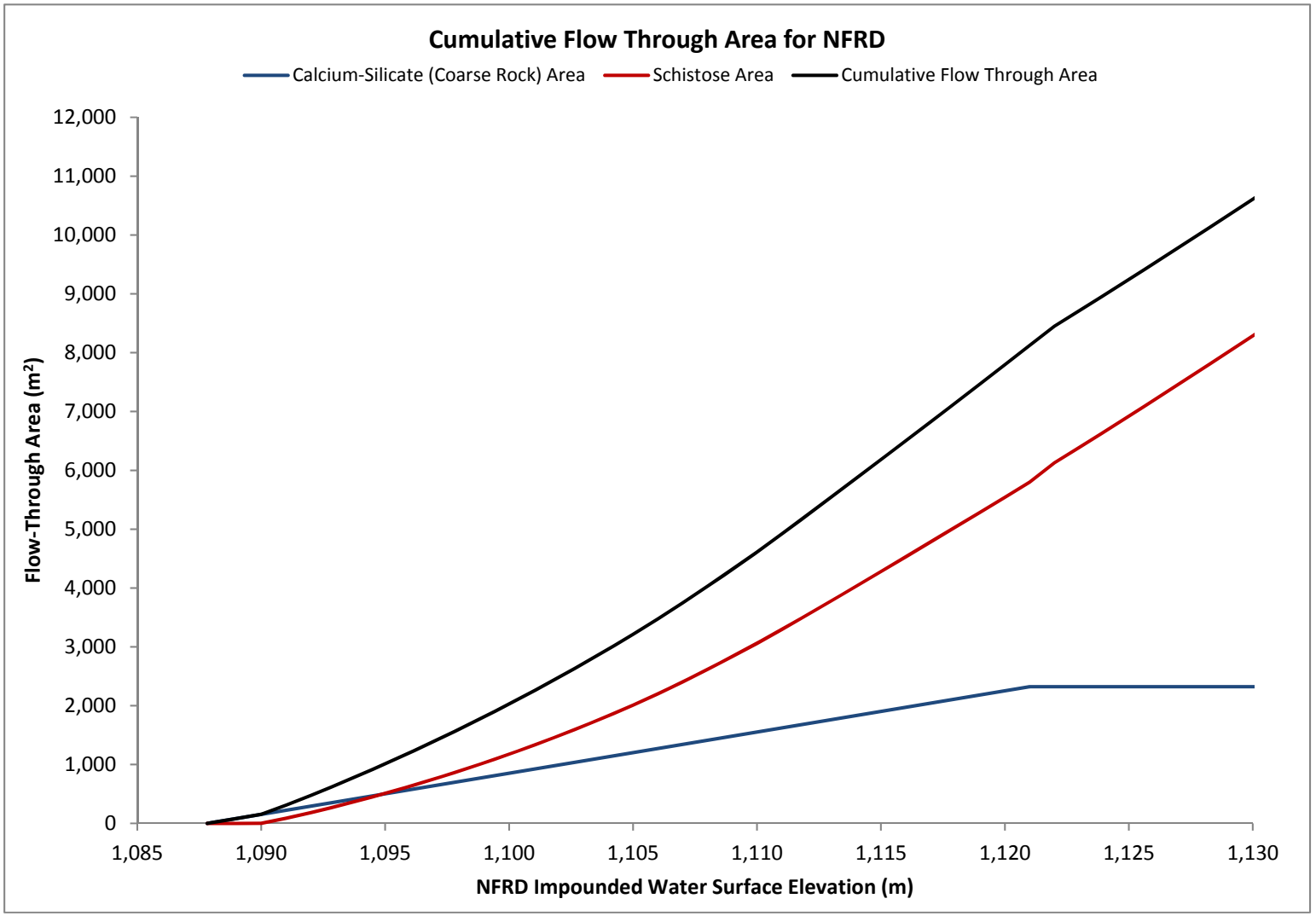


Figure 4-14

Cumulative Flow Through Area for NFRD

Faro Mine Remediation Project

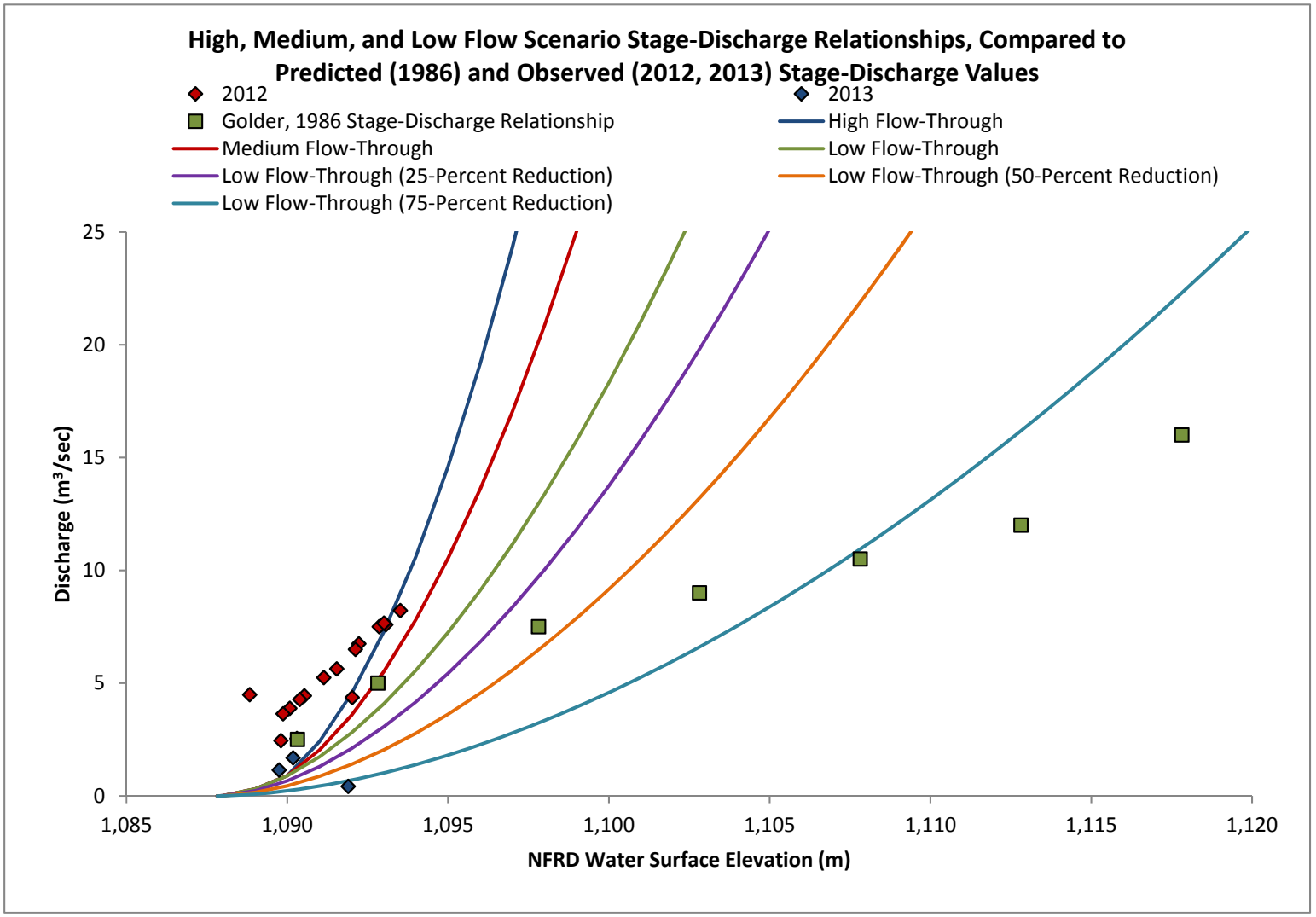


Figure 4-15

High, Medium, and Low Flow Scenario Stage-Discharge Relationships, Compared to Predicted (1986) and Observed (2012 and 2013) Stage-Discharge Values

Faro Mine Remediation Project

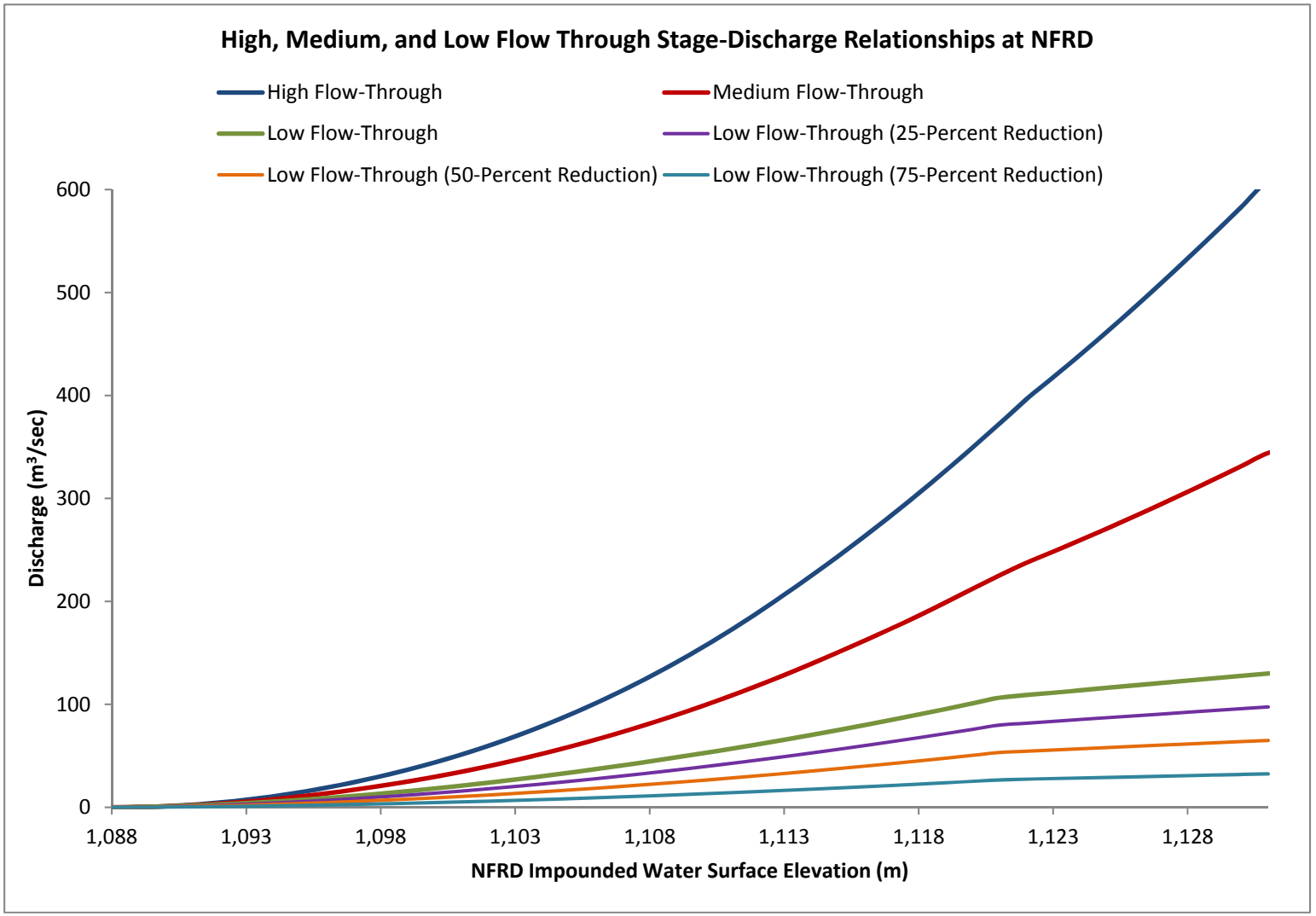


Figure 4-16
High, Medium, and Low Flow Scenario
Stage-Discharge Relationships at NFRD
Faro Mine Remediation Project

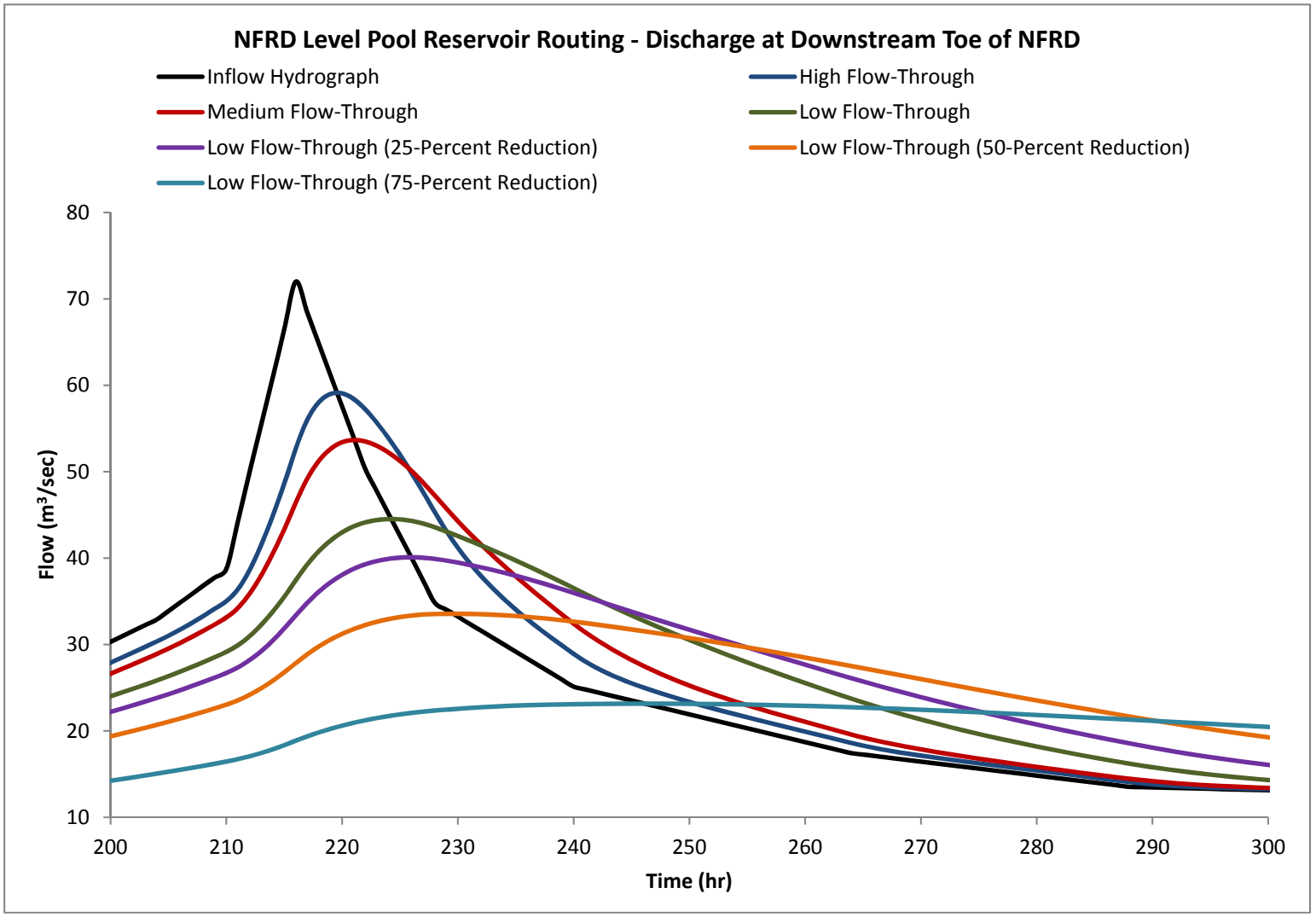


Figure 4-17
NFRD Level Pool Reservoir Routing - Discharge at Downstream Toe of NFRD
Faro Mine Remediation Project

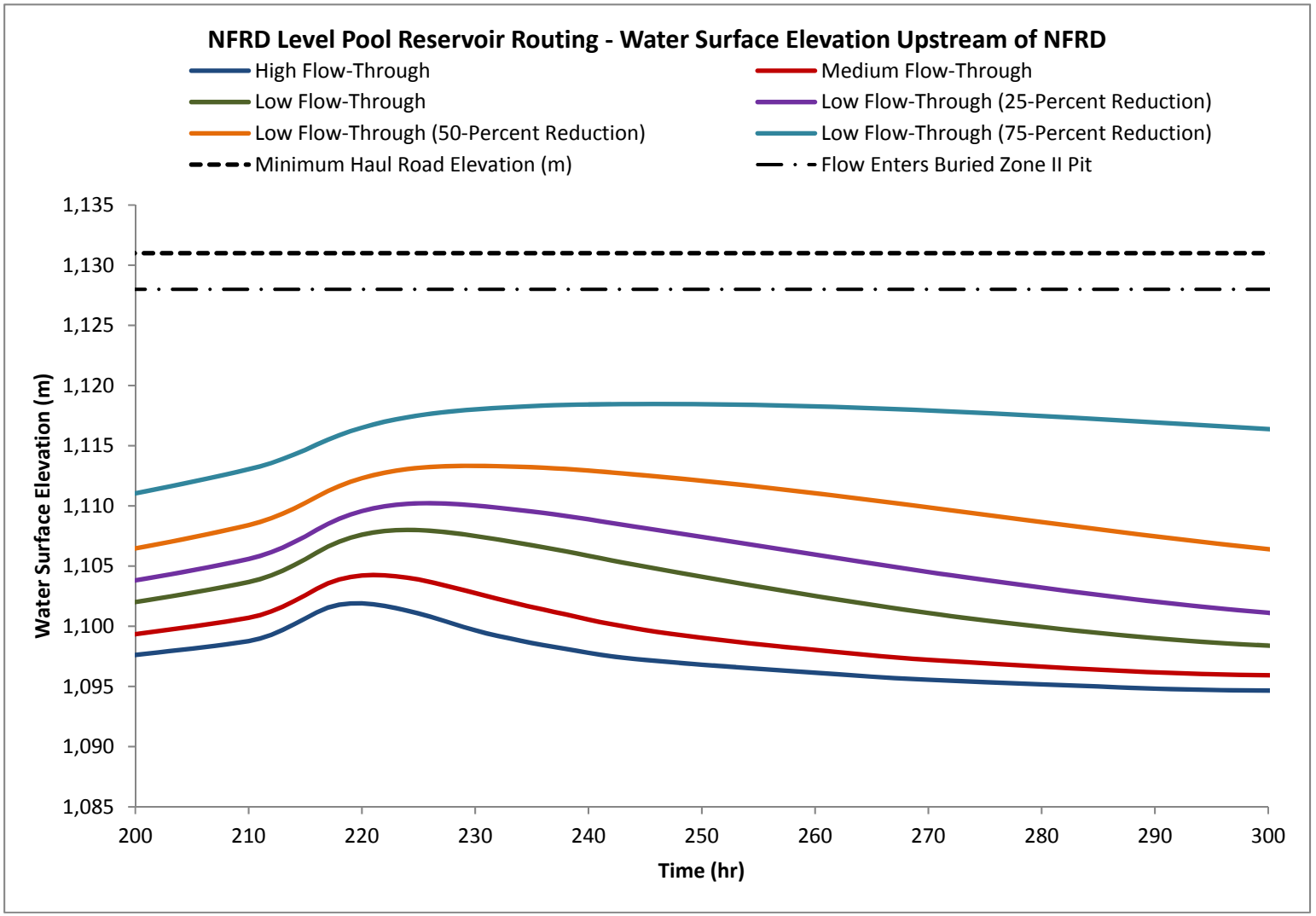
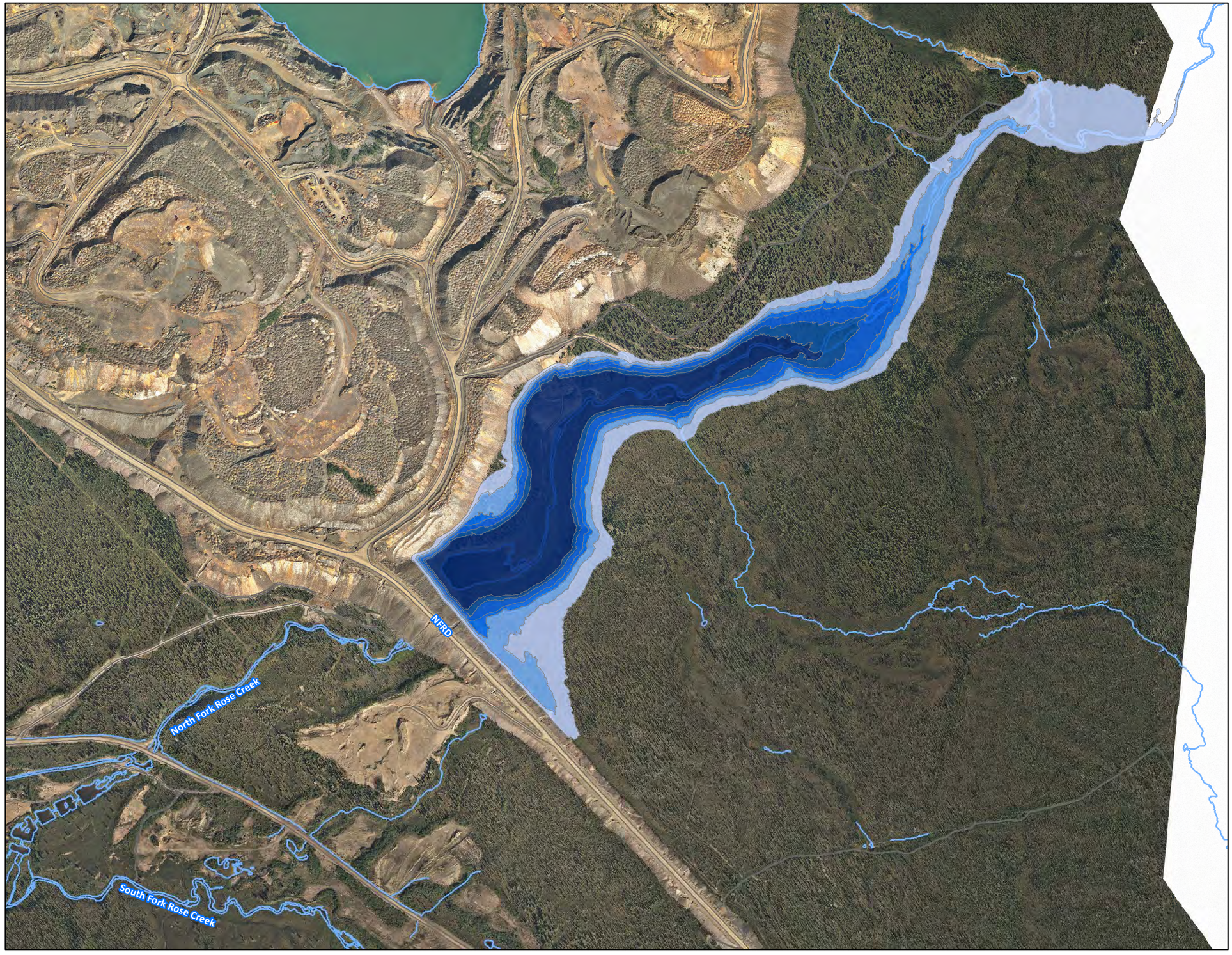
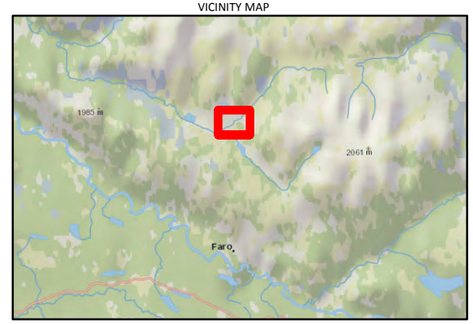


Figure 4-18
NFRD Level Pool Routing - Water Surface Elevation Upstream of NFRD
Faro Mine Remediation Project



VICINITY MAP



LEGEND

- High Flow Max WSEL = 1,101.9 m
- Medium Flow Max WSEL = 1,104.3 m
- Low Flow Max WSEL = 1,108.0 m
- Low Flow (25% Reduction) Max WSEL = 1,110.2 m
- Low Flow (50% Reduction) Max WSEL = 1,113.3 m
- Low Flow (75% Reduction) Max WSEL = 1,118.5 m

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

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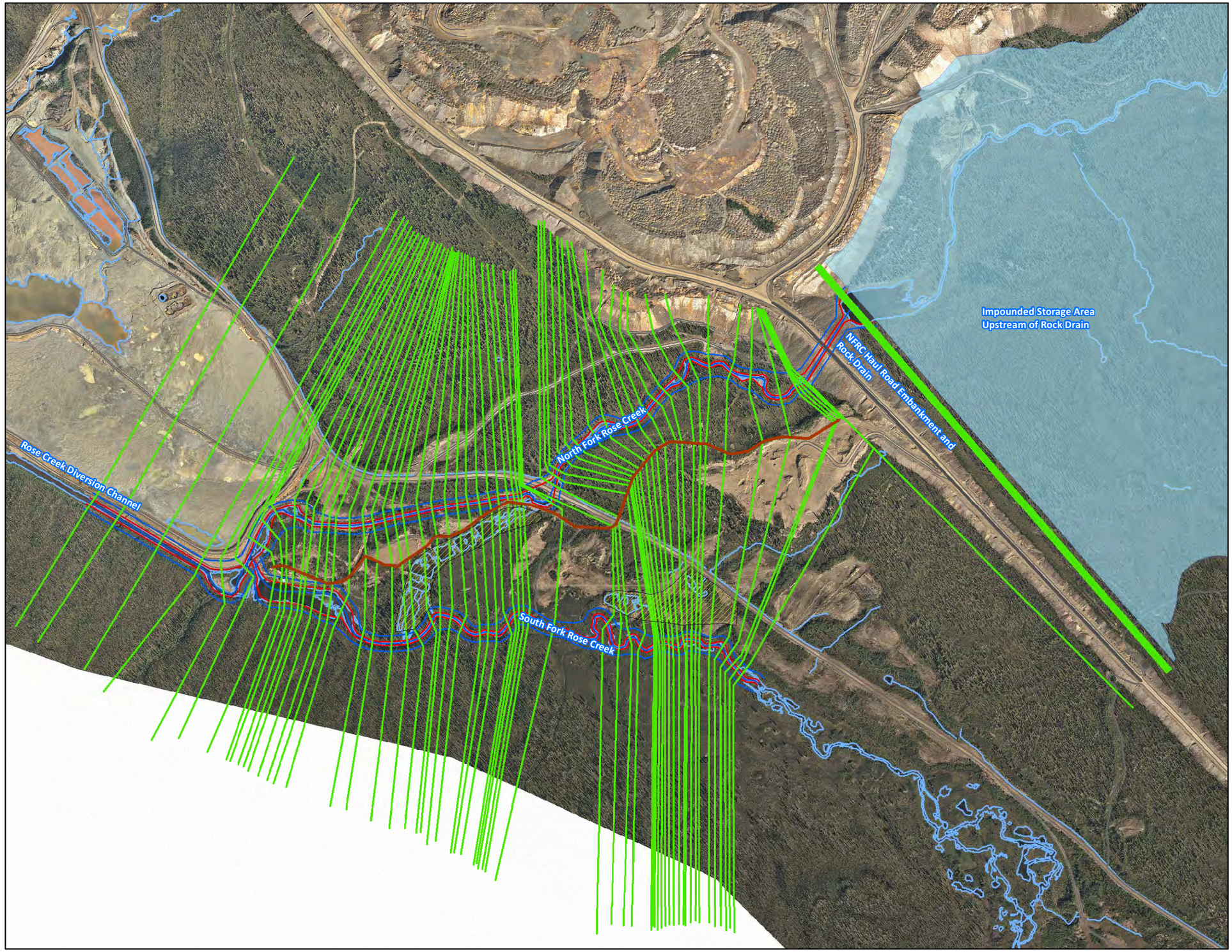
Metres

Created by:
CH2MHILL

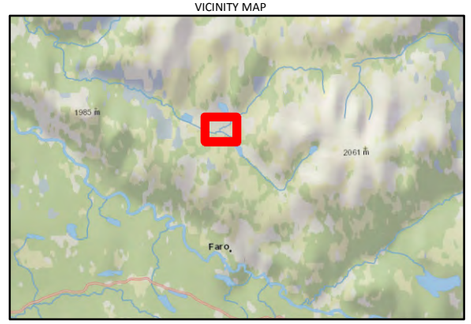
FIGURE 4-19
1-in-500-year Impounded Water Surface Extents Upstream of NFRD
Faro Mine Remediation Project

CH2MHILL

\\OSPREY\GROUPS\WATER_RESOURCES\FARO_MINE\GIS\MAPFILES\FIGURE4-19_IMPOUNDEDWATEREXTENTS.MXD FGARIGLI 1/14/2014 2:58:27 PM



VICINITY MAP



LEGEND

- Storage Area
- NFRC/SFRC Basin Divide
- Rock Drain
- Ineffective Flow Area
- Cross Section
- Stream Centerline
- Overbank Flowpath
- Stream Bank
- FMC - Roads
- FMC - Water Lines

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

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Metres

Created by:
CH2MHILL

FIGURE 4-20
HEC-GeoRAS 1D Hydraulic Model Geometry
Faro Mine Remediation Project

CH2MHILL

\\OSPREY\GROUPS\WATER_RESOURCES\FARO_MINE\GIS\MAPFILES\FIGURE4-20_HECGEORASGEOMETRY.MXD FGARIGLI 1/14/2014 1:42:01 PM

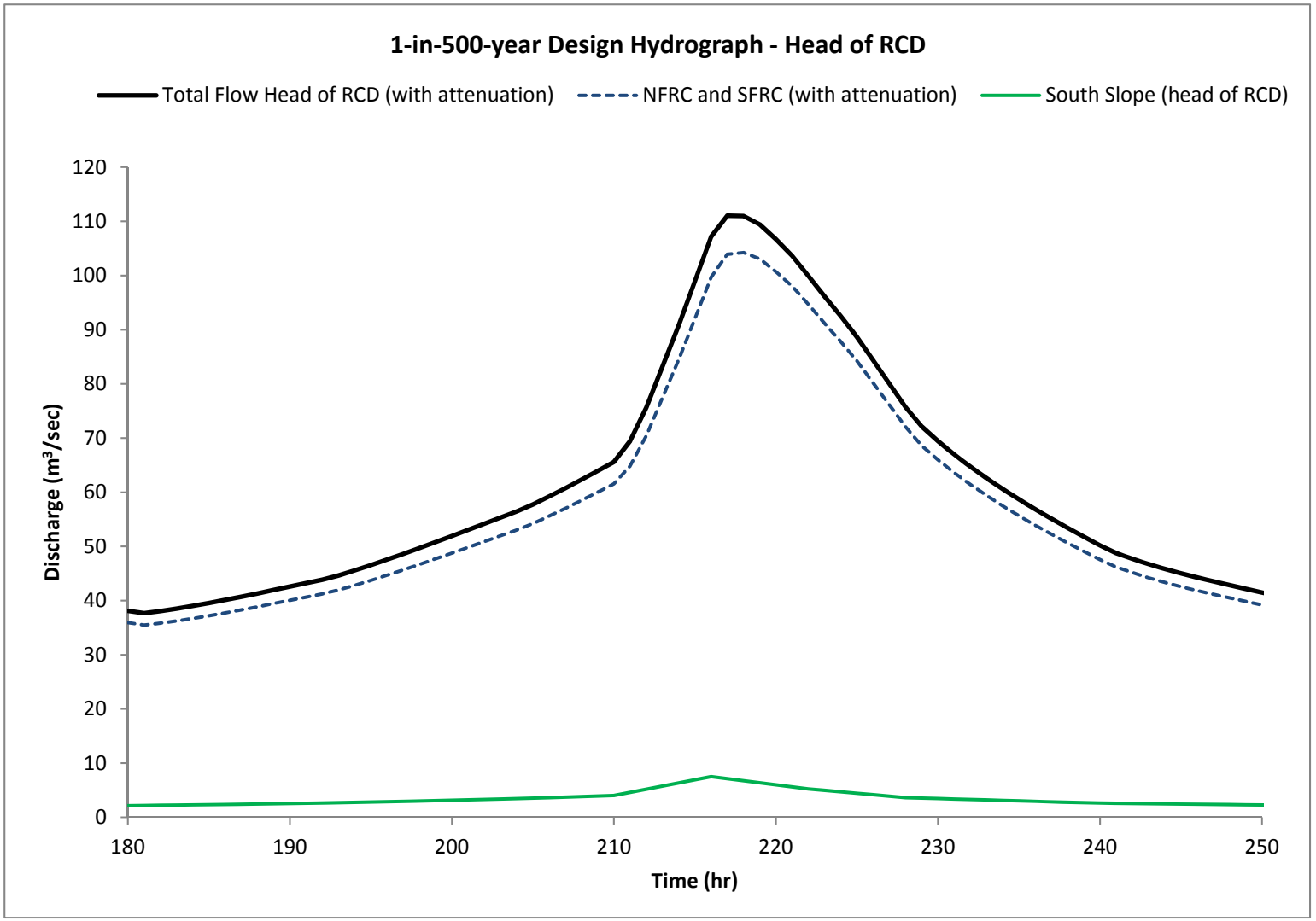


Figure 4-21

1-in-500-year Design Hydrograph - Head of RCD

Faro Mine Remediation Project

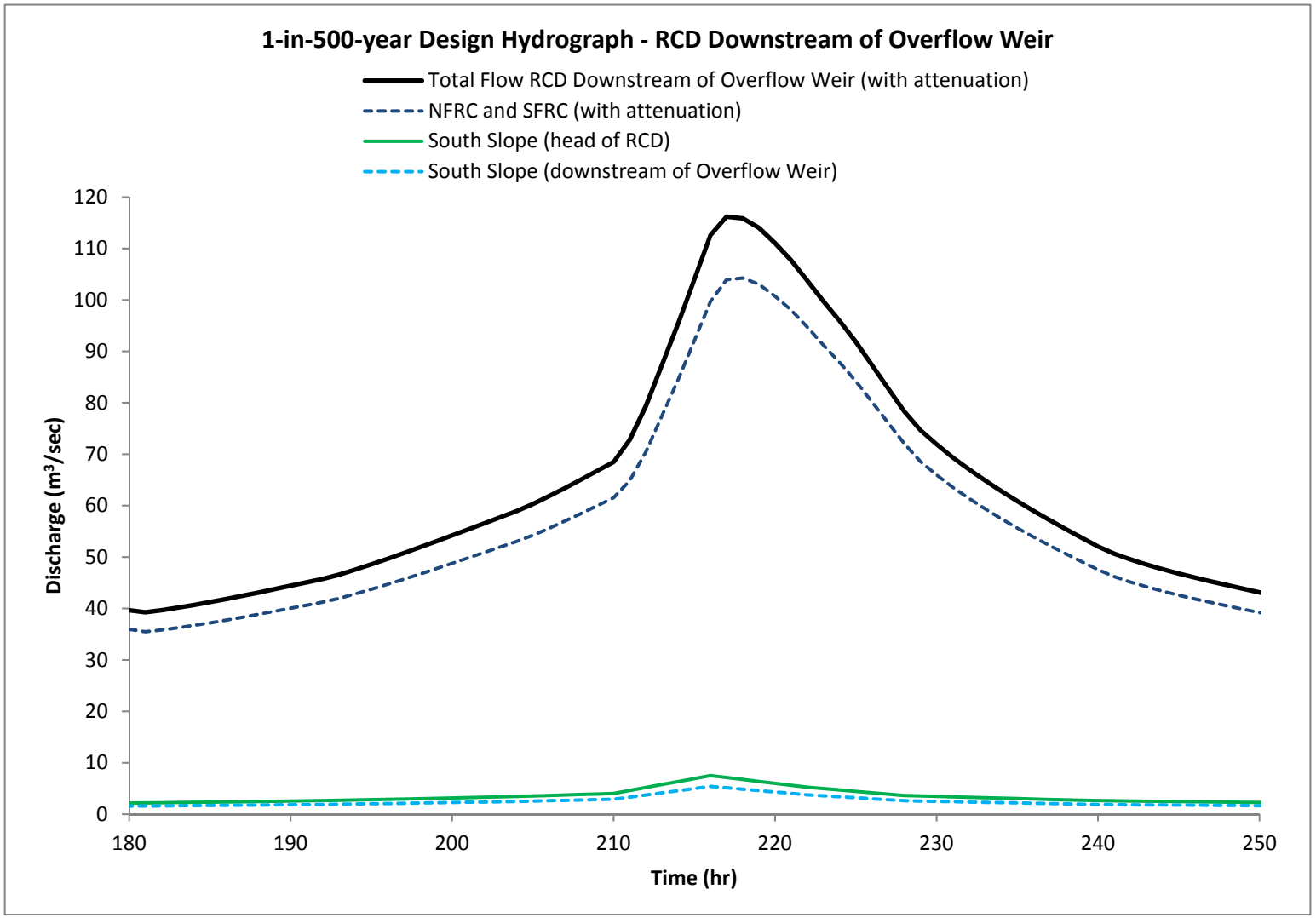


Figure 4-22
1-in-500-year Design Hydrograph - RCD Downstream of Overflow Weir
Faro Mine Remediation Project

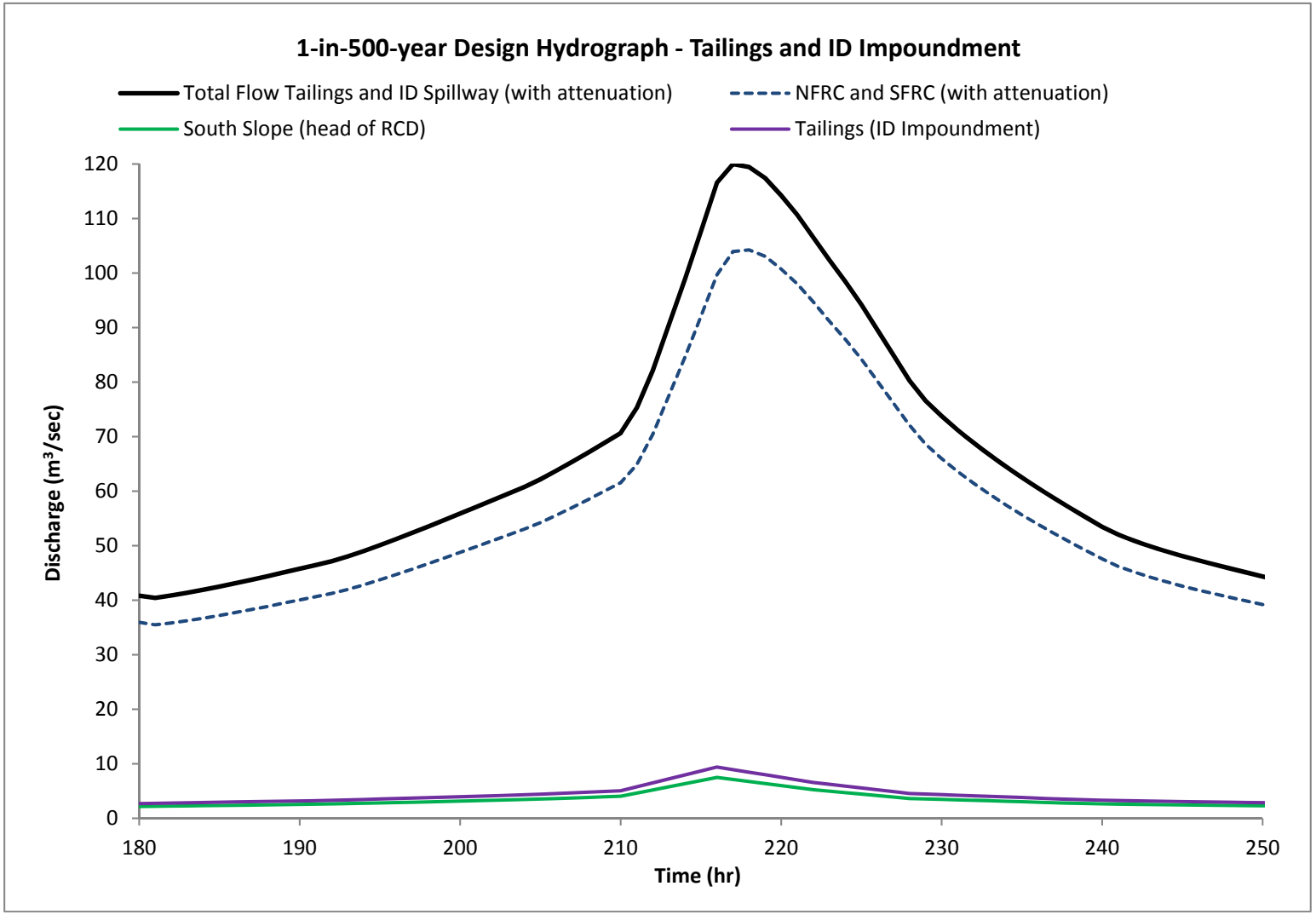


Figure 4-23
1-in-500-year Design Hydrograph - Tailings and ID Impoundment
Faro Mine Remediation Project

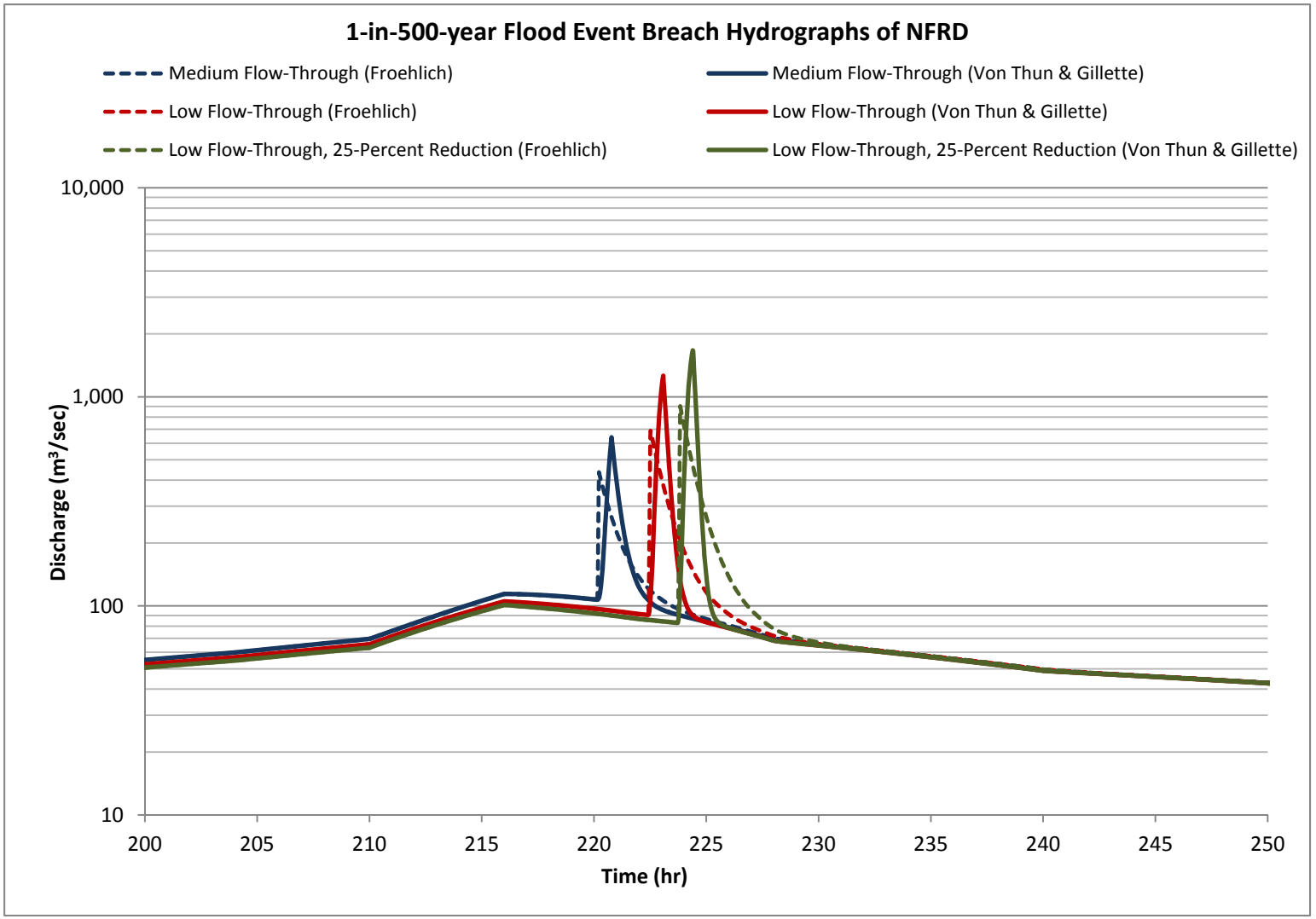


Figure 4-24
1-in-500-year Flood Event Breach Hydrographs of NFRD
Faro Mine Remediation Project

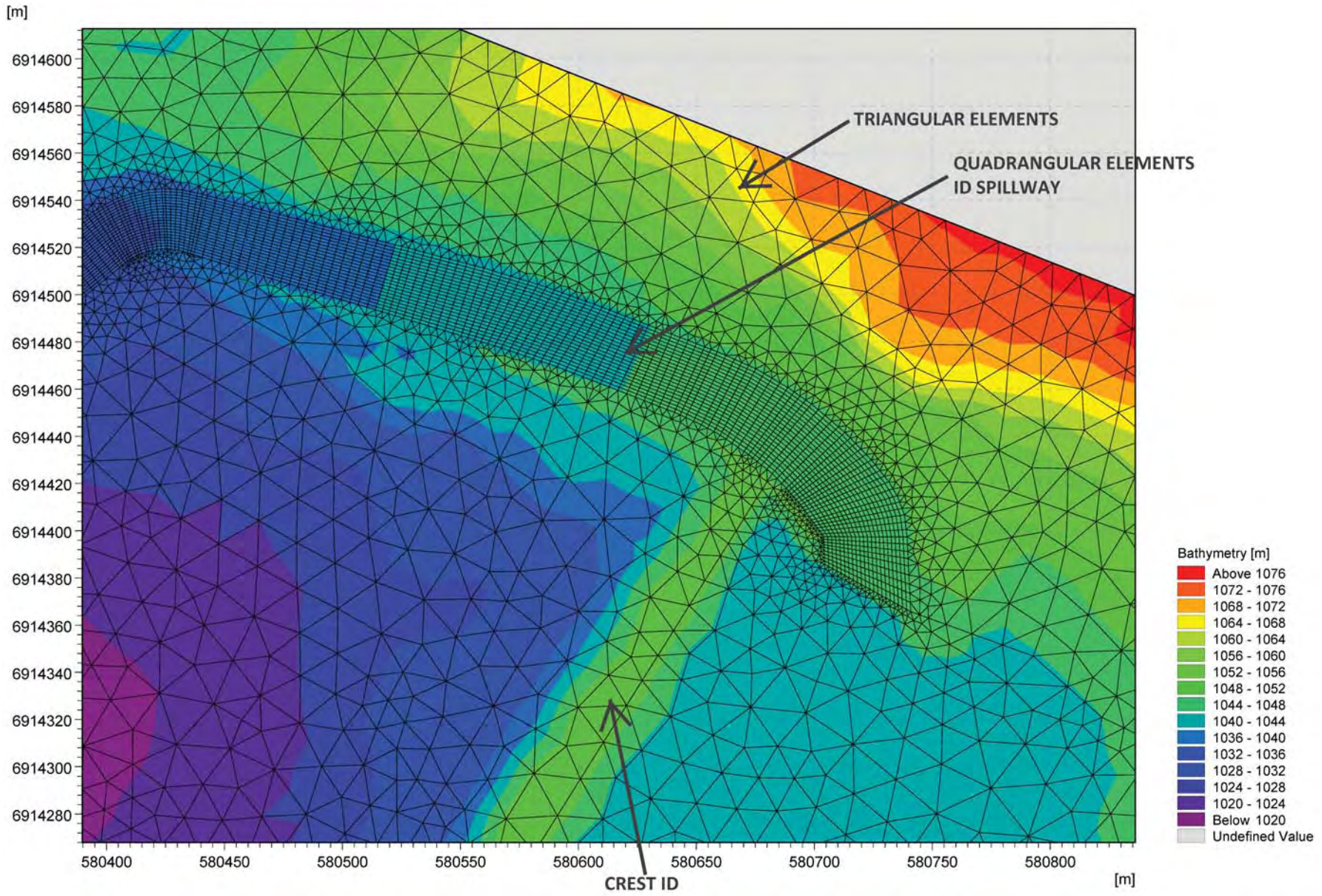
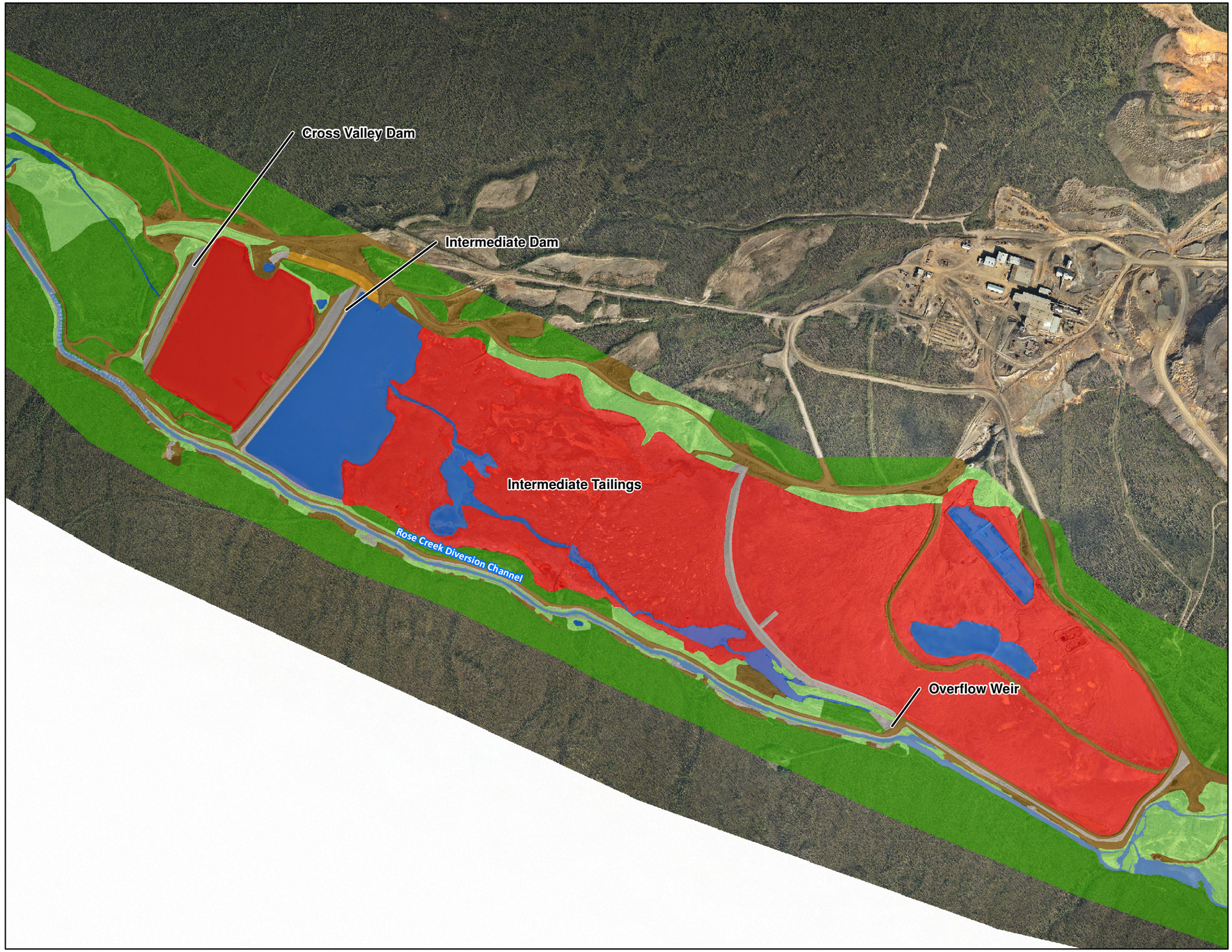
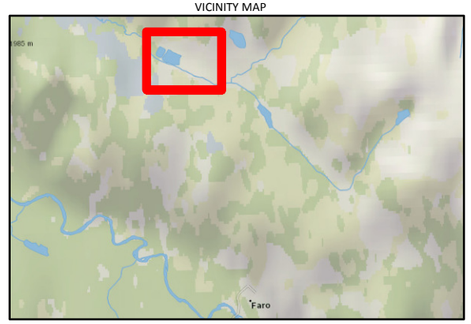


Figure 4-25
2D Model Computational Mesh at ID Spillway
Faro Mine Remediation Project



VICINITY MAP



LEGEND

Manning's Roughness Coefficient (Manning's n)

- Invert RCDC (submerged) (n=0.030)
- Submerged Tailings (n=0.016)
- Bare Rock (no vegetation) (n=0.047)
- Bare Soil (no vegetation) (n=0.030)
- ID Spillway (n=0.030)
- Tailings (n=0.016)
- Large Vegetation (n=0.120)
- Small Vegetation (n=0.080)

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

N

0 50 100 200 300
Metres

Created by:
CH2MHILL

FIGURE 4-26
Manning's n Values Used in 2D Model
Faro Mine Remediation Project

CH2MHILL

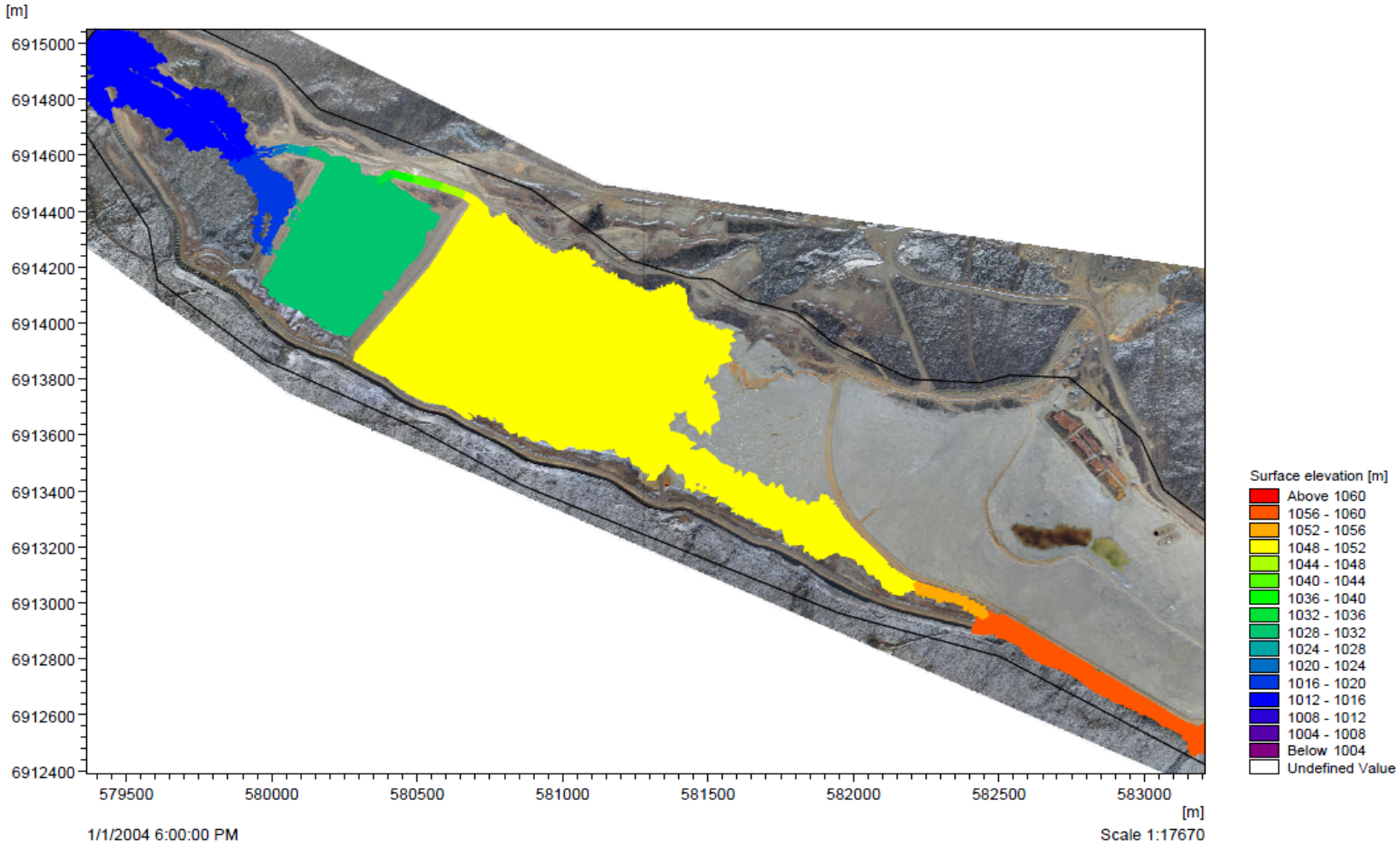


Figure 4-27

Extent of Inundation at 1-in-500-year Flood Event Flowrate

Faro Mine Remediation Project

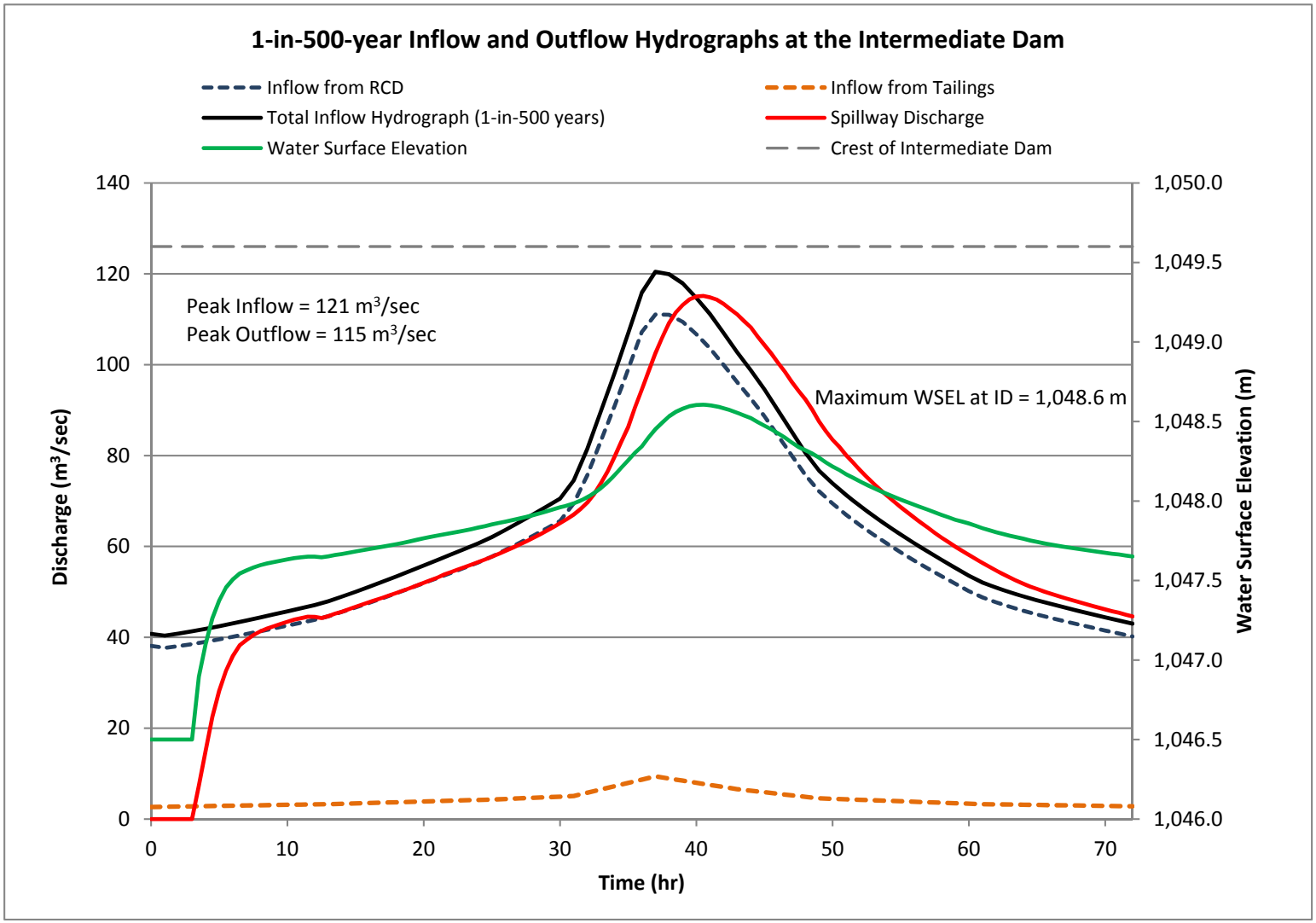
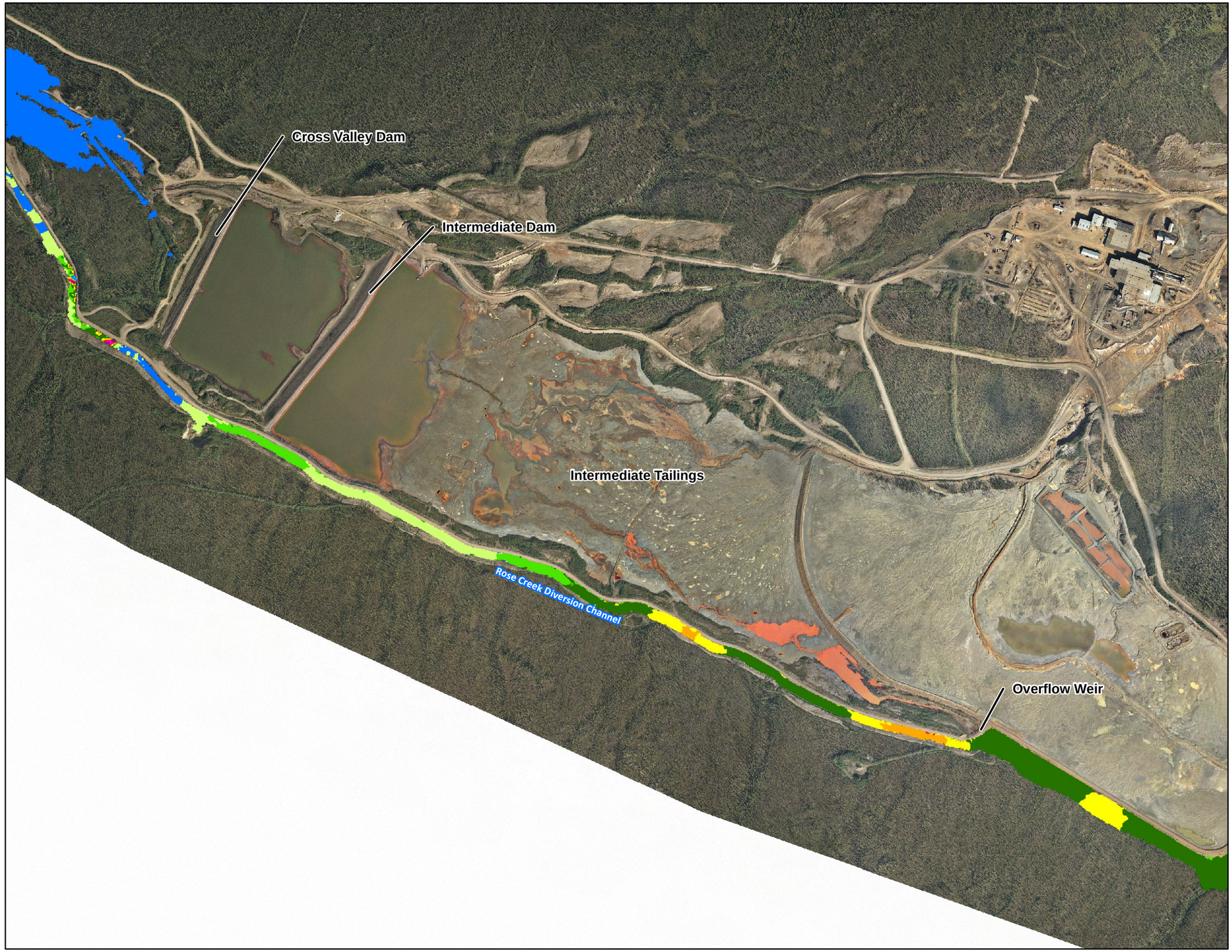
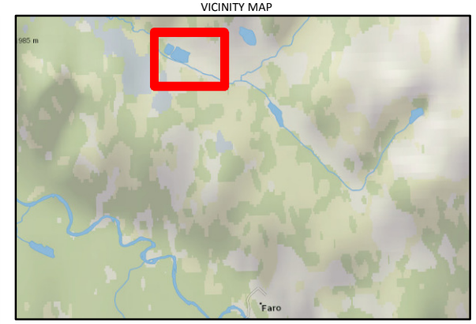


Figure 4-28
1-in-500-year Inflow and Outflow Hydrographs at the Intermediate Dam
Faro Mine Remediation Project



VICINITY MAP



LEGEND

Decrease in Water Surface From Removal of Vegetation on Right Bank (Dike Side)

- Above 0.175 m
- 0.150 - 0.175 m
- 0.125 - 0.150 m
- 0.100 - 0.125 m
- 0.075 - 0.100 m
- 0.050 - 0.075 m
- 0.025 - 0.050 m
- 0.000 - 0.025 m
- -0.100 - 0.000 m
- -0.200 - -0.100 m
- Below -0.200 m

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

N

0 50 100 200
Metres

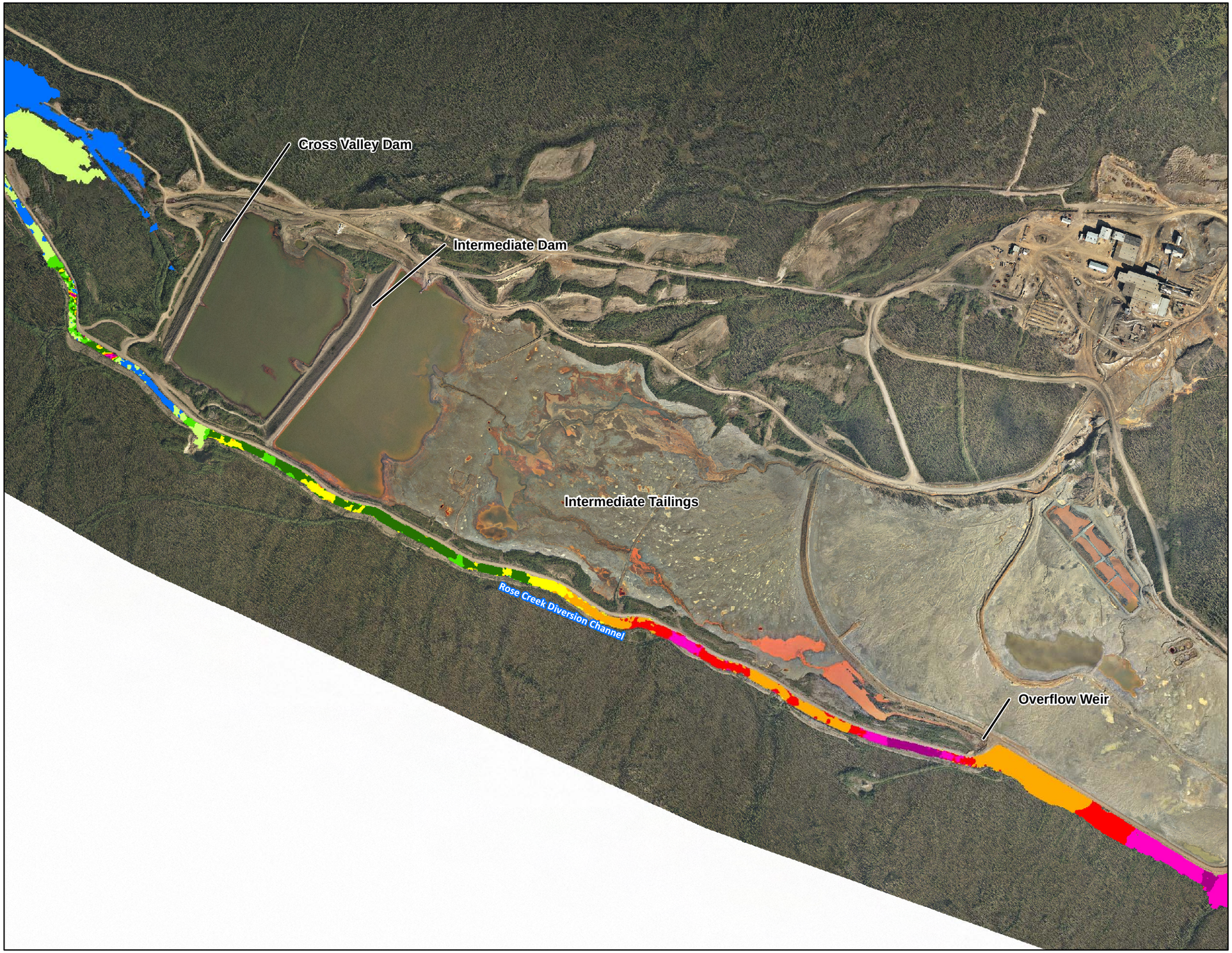
Created by:
CH2MHILL

FIGURE 4-29

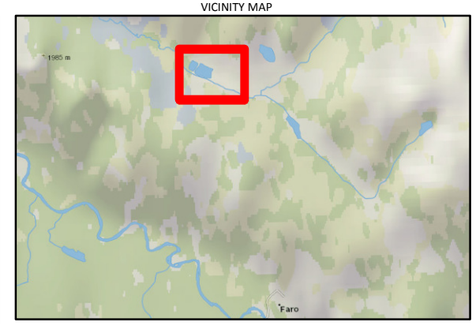
Estimated Reduction in WSEL due to Vegetation Removal on the Right Bank of the RCD

Faro Mine Remediation Project

CH2MHILL



VICINITY MAP



LEGEND

Decrease in Water Surface From Removal of All Vegetation (Left and Right Banks)

- Above 0.175 m
- 0.150 - 0.175 m
- 0.125 - 0.150 m
- 0.100 - 0.125 m
- 0.075 - 0.100 m
- 0.050 - 0.075 m
- 0.025 - 0.050 m
- 0.000 - 0.025 m
- -0.100 - 0.000 m
- -0.200 - -0.100 m
- Below -0.200 m

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

N

0 50 100 200
Metres

Created by:
CH2MHILL

FIGURE 4-30

Estimated Reduction in WSEL due to Vegetation Removal on the Right and Left Banks of the RCD

Faro Mine Remediation Project

CH2MHILL

\\osprey\GROUPS\Water_Resources\Faro_Mine\GIS\Figure4-44.mxd JKINDIG 11/11/2013 08:09:00 AM

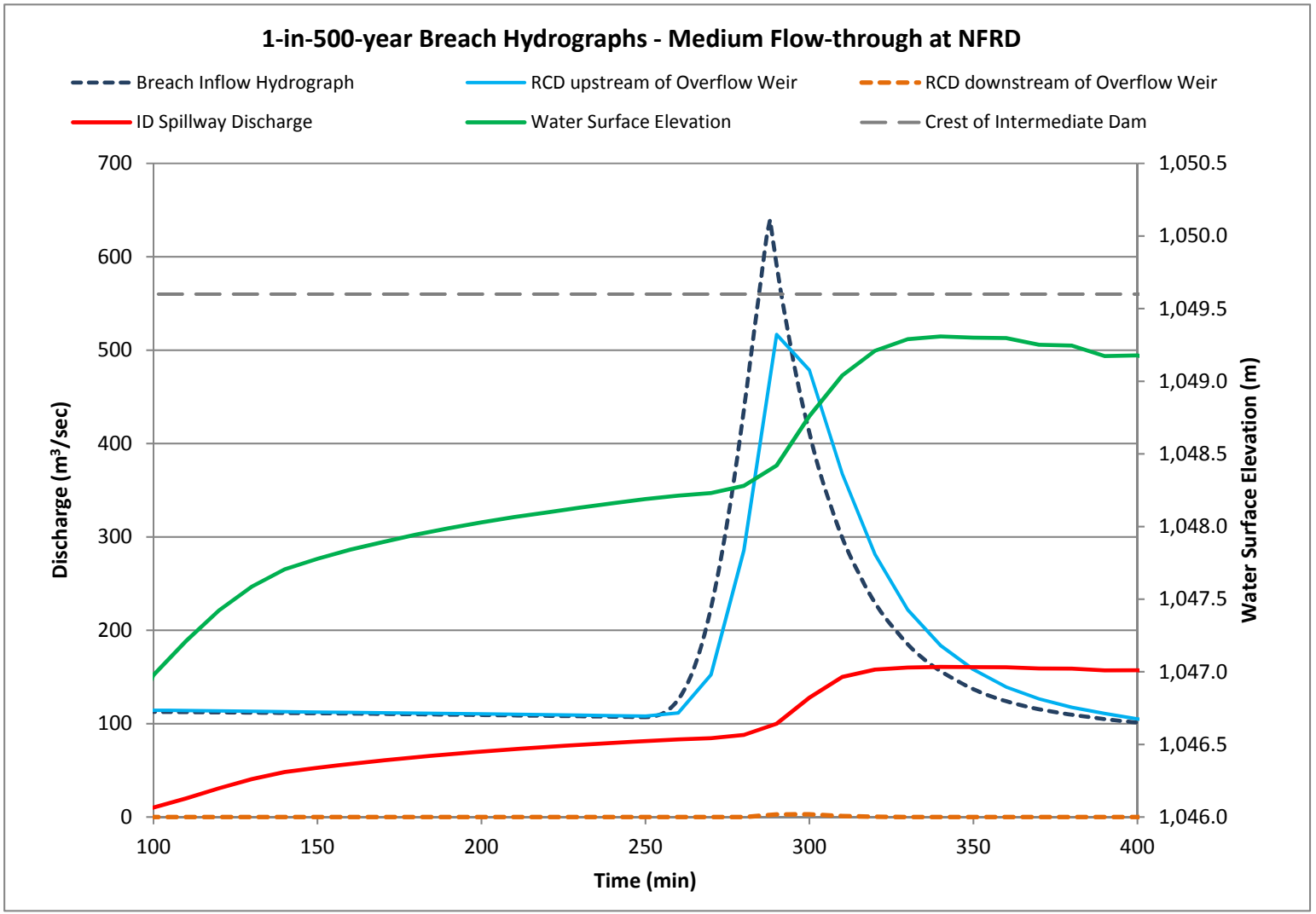


Figure 4-31
1-in-500-year Breach Hydrographs - Medium Flow-Through at NFRD
Faro Mine Remediation Project

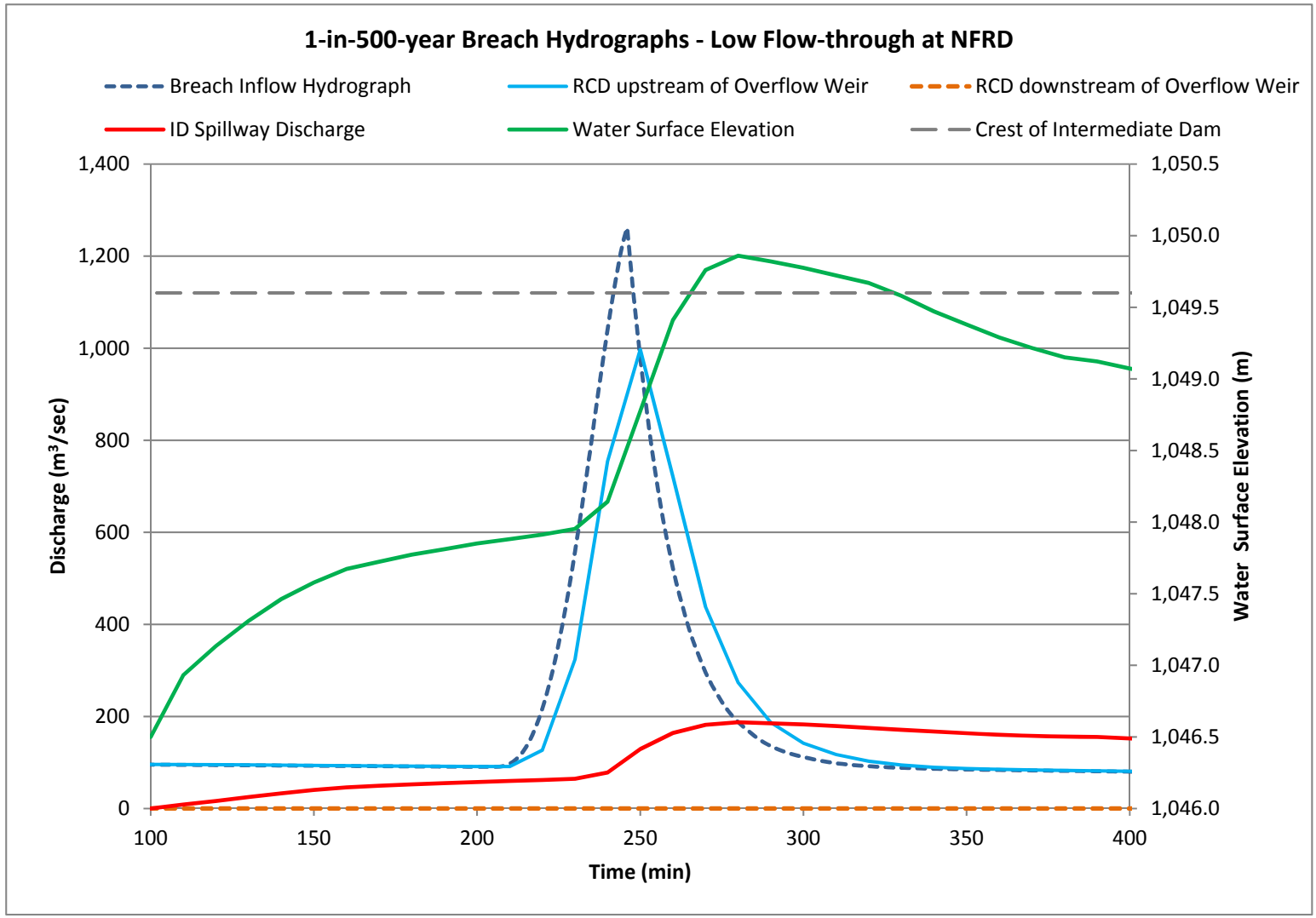


Figure 4-32
1-in-500-year Breach Hydrographs - Low Flow-Through at NFRD
Faro Mine Remediation Project

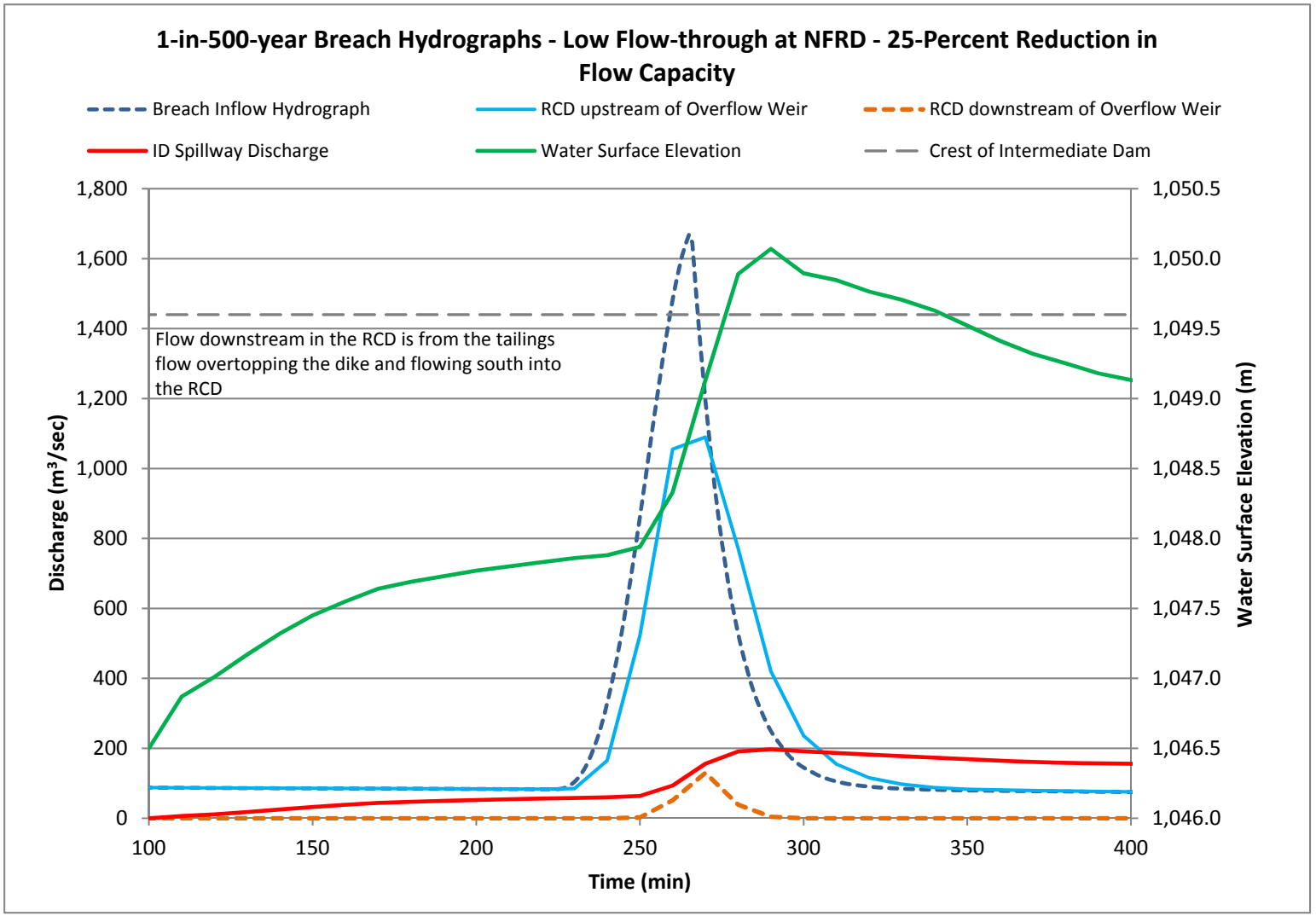
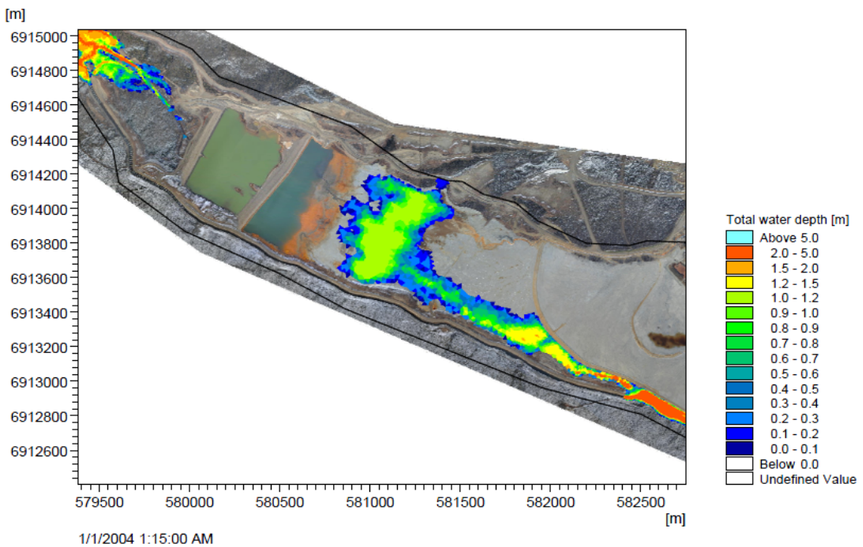


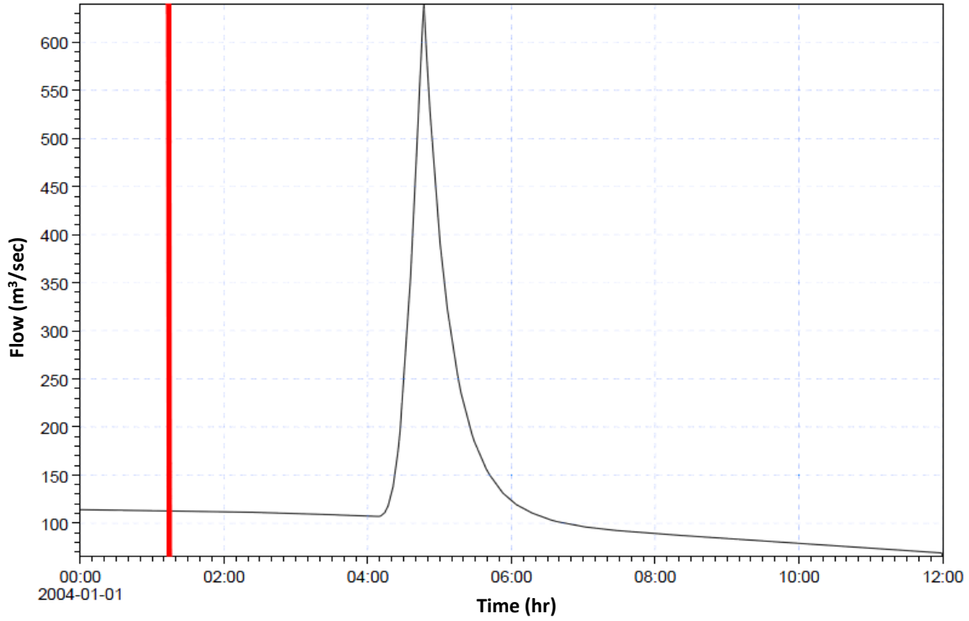
Figure 4-33

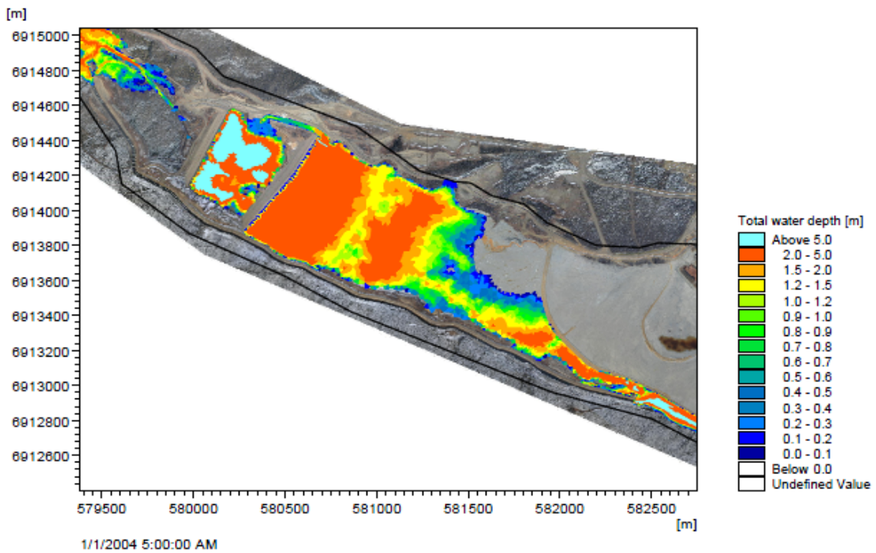
1-in-500-year Breach Hydrographs - Low Flow-Through at NFRD and 25-Percent Reduction in Flow Capacity

Faro Mine Remediation Project



Note - For areas in the ID impoundment, total water depth as indicated in the legend is the depth above the full pool elevation of 1046.5 m.





Note - For areas in the ID impoundment, total water depth as indicated in the legend is the depth above the full pool elevation of 1046.5 m.

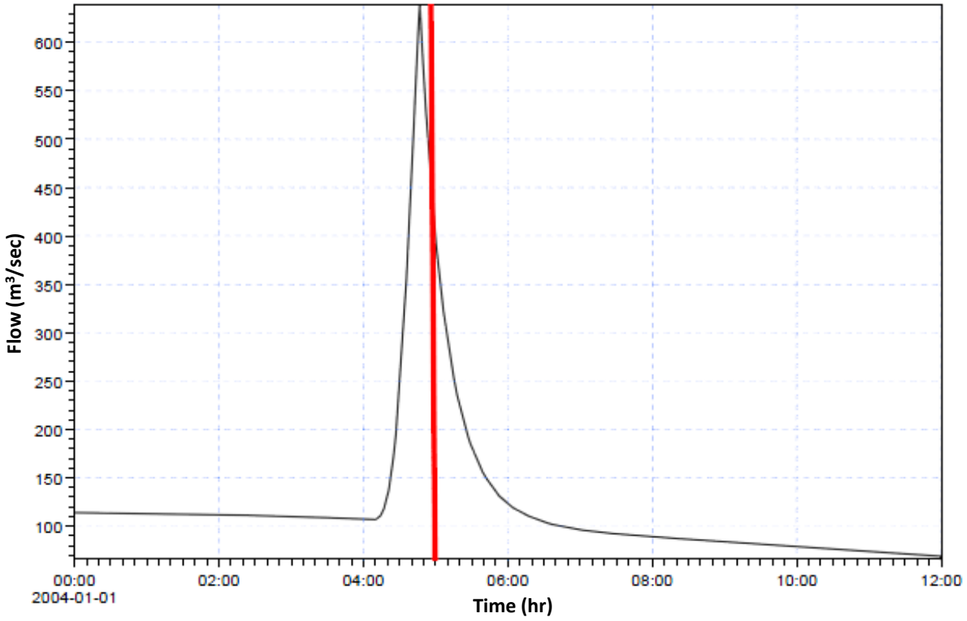
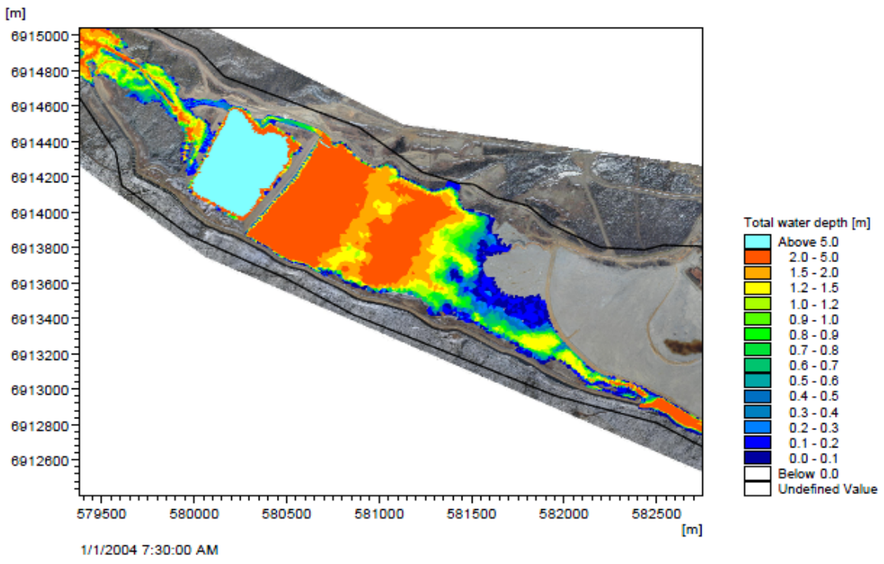
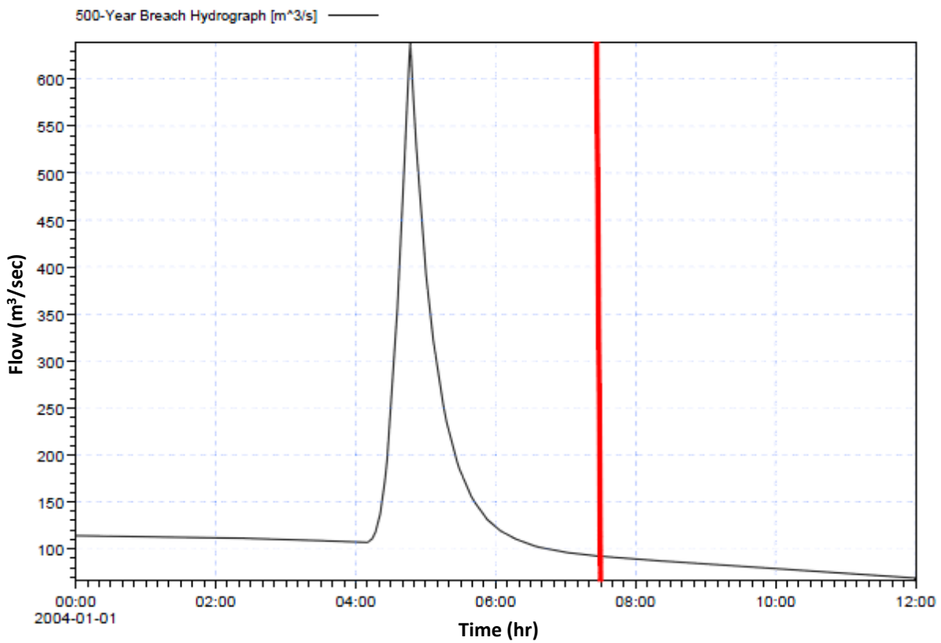
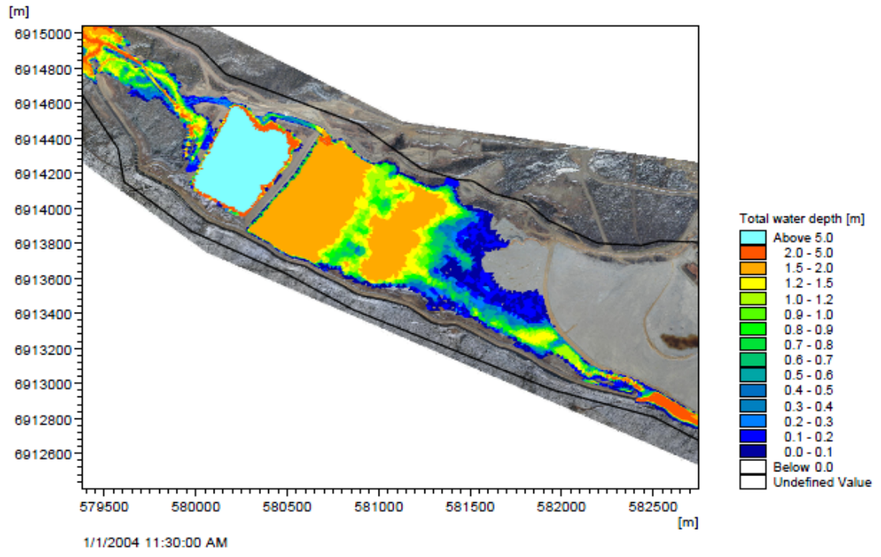


Figure 4-34
NFRD Breach Scenario 1 - Flood Inundation and Corresponding Flood Wave Hydrograph
Faro Mine Remediation Project



Note - For areas in the ID impoundment, total water depth as indicated in the legend is the depth above the full pool elevation of 1046.5 m.





Note - For areas in the ID impoundment, total water depth as indicated in the legend is the depth above the full pool elevation of 1046.5 m.

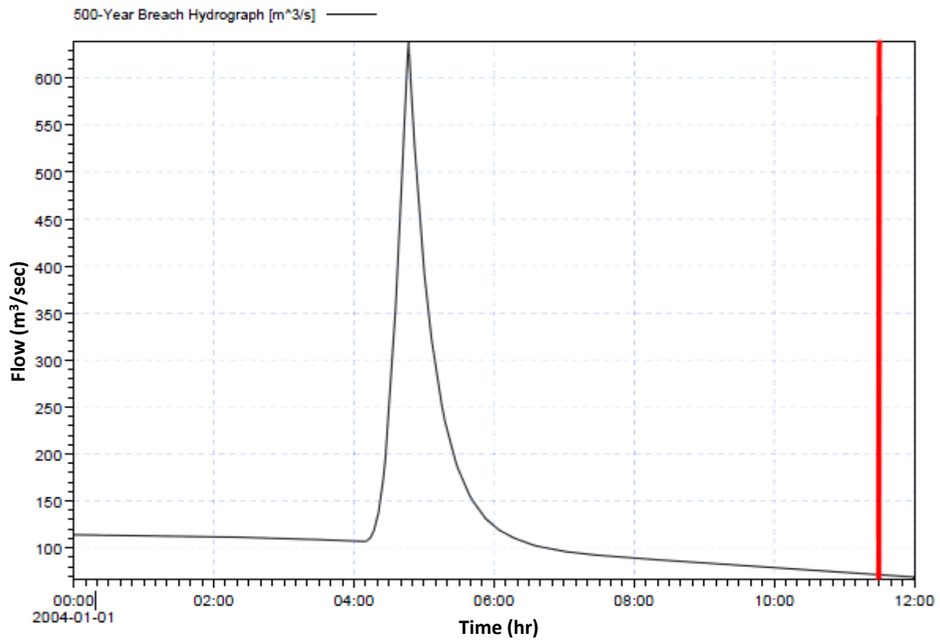


Figure 4-34 Continued
NFRD Breach Scenario 1 - Flood Inundation and Corresponding Flood Wave Hydrograph
Faro Mine Remediation Project

SECTION 5

Intermediate Dam Spillway and Crest Improvements

5.1 Required Intermediate Dam Spillway Capacity

The intent of the Down Valley Interim Hydraulic Upgrades is to provide a design which modifies the RCD and ID crest/spillway in order to safely pass a 1-in-500-year flood event through the RCTA, including attenuation of this flood on the NFRC by the NFRD. Apart from remediating spill capacity associated with large flood events, an increase in ID spillway capacity would also provide mitigation for other RCD failure mechanisms. These include (1) failure of the RCD dike by piping or slope instability during moderate flood events, (2) landslide or debris flow originating on the mountainous slopes to the south of the RCD that would block the RCD and cause overtopping of the RCD dike, and (3) icing buildup in the RCD resulting in overtopping of the RCD dike.

The 1-in-500-year flood event hydrograph has a peak flow of 121 m^3/sec, which could potentially be discharged over the ID spillway. However, it is unlikely that this flow rate would be reached over the ID spillway. Both of the following scenarios would have to occur at the same time in order for the full flow rate to be conveyed over the spillway:

- None of the flood flow would continue down the RCD and all of the flow would be conveyed onto the tailings. This would only occur if the right bank of the RCD totally breached at the overflow weir location, a new channel was formed because of erosion, and the flood flows completely abandoned the RCD. This would represent the classic pit capture scenario.
- The duration of the 1-in-500-year flood event peak flow would need to be of sufficient length to fill the ITA to about elevation 1,049.0 m. The amount of available storage in the impoundment at the beginning of the flood would determine the necessary duration of inflow to reach a WSEL of 1,049.0 m. As described in Section 4.2, hydraulic modelling assumed that the impoundment is at full pool with a beginning WSEL of 1,046.5 m. The 2D model includes the proposed improvements to the spillway and dam crest with flow input as a 72-hour duration hydrograph that represents the 1-in-500 year flood event. The peak flow of the input hydrograph is 121 m^3/sec and the attenuated peak flow that discharges over the spillway is 115 m^3/sec. Minimum freeboard is 1.0 m.

Based on these considerations, it is unlikely that the flow over the ID spillway will reach the same magnitude as the inflow into the RCD during a large flood event. However, because of uncertainty in the dike performance under large flood events, and based on the design criteria established by the expired water licence, the design ID spillway capacity was established as 115 m^3/sec, which is the 1-in-500-year flood event flow.

5.2 Field Investigations

The purpose of the field investigation was to collect geotechnical information to evaluate the feasibility of embedding a geomembrane in the existing compacted clay core of the ID and extending the geomembrane to provide a seepage cut-off to the crest of the ID. The top of the clay core in the existing ID is about 0.6 to 0.9 m below the crest of the existing dam. The geomembrane would limit the advancement of seepage through the upper portion of the existing ID; the single gabion row would further raise the crest of the ID, with the geomembrane extending over the top of the gabions.

To prevent seepage around the base of the geomembrane, it will need to be embedded some depth into the clay core. A trench will be excavated into the existing ID to allow embedment of the geomembrane.

Seven test pits were excavated in the crest of the existing ID to evaluate the depth and condition of the clay core and the stability of the trench walls in the dam material above the clay core. Three test pits were also excavated in the bottom of the existing ID spillway channel. The details and results of this investigation are described in detail in the CH2M HILL TAR-016 Data and Analysis Report. This document is in progress and will be bound and submitted separately.

The specific objectives of the test pit investigation were:

- Obtain depth of the compacted clay core in the existing ID and variability of the depth across the existing dam crest.
- Assess condition of the top zone of the existing clay core, including composition, width, relative moisture content and density, and presence of any cracks or other defects
- Determine nature of the material overlying the compacted clay core, including the composition and relative density, and the temporary stability of excavation side walls in this material, for construction purposes
- Determine the nature of the materials in the upper 2 m of the spillway channel, including particle size, relative density, and ease of excavation, for construction purposes

The dam core material generally consists of silty, clayey sand and gravel with cobbles. Near the centerline of the dam, the dam core material is within 0.3 m to 0.6 m of the ground surface. On the upstream side of the dam, the top of dam core material becomes deeper, up to a depth of about 1.2 m at a horizontal distance of 1.2 to 1.5 m from the top of the upstream slope. From design and as-built cross sections of the dam, the top surface of the upstream sloping dam core is approximately parallel to the upstream face of the dam, at an offset of approximately 0.9 meters horizontally. Based on these findings, the upstream edge of the installation trench will be located 1 m from the top of the upstream slope, with a depth of 1.5 m.

The subsurface material within the spillway consisted of coarse-grained alluvial soil that a CAT 345C excavator was able to excavate to a depth of more than 2 m. It is noted that there are abundant cobbles and boulders, up to a maximum size of about 60 cm (24 in) in dimension within the upper 0.9 m; this is the existing erosion protection material in the spillway channel. Based on the results of these three test pits, excavation of the bottom of the spillway channel could be easily accomplished with standard earthmoving equipment. Additional testing will be necessary to determine if the material excavated from the spillway is clean. There will be excess material from the excavation of the spillway. During the 90-percent phase, recommendations will be provided on where to stockpile this material and if it will be suitable earth fill material for this project.

5.3 Spillway Improvements

The improvements at the ID spillway consist of excavating the existing channel by a maximum of about 2 m, and placing a 0.45-m-thick gabion mattress on the excavated bottom of the spillway channel. The proposed channel will follow the same footprint of the existing channel, so there will not be any significant widening of the channel. Gabion cells that are 0.9 m by 0.9 m in cross section will be used on the sides of the channel, with configuration as shown on Drawing C-9 in Attachment A. A geotextile will be provided between the gabions and the excavated soil surface to provide separation and filtering.

It is proposed that cobbles screened from the Rose Creek borrow area be used to fill the gabion mattress and gabion cells. See Drawing C-1 in Attachment A.

5.4 Crest Improvements

To raise the effective ID crest, a geomembrane will be installed vertically in a trench between the dam core and the crest surface, and a single row of 0.9 m by 0.9 m gabions will be placed along this line to further raise the effective crest to an estimated elevation of 1,049.6 m. The gabions will be partially embedded (depth of about 0.2 m) in the upper portion of the excavated trench on top of the compacted backfill. It is noted that the ID crest is at an average elevation of about 1,048.9 m and based on the test pit exploration results the top of the dam core at the center of the dam crest varies with a low elevation of about 1,048.3 m. To tie the geomembrane into the existing core, the upstream edge of the installation trench will be located 1 m from the top of the upstream slope, with a depth of 1.5 m. Low-permeability glacial till material will be imported from a nearby borrow area and will be placed in the lower 0.5 m of the installation trench. The material excavated from the trench would be used for backfill in the upper 1.0 m. The crest surfacing will be reinstated as shown on the drawings, by placing a 0.2 m thick layer of gravel and sand at the crest.

Alternatives to the gabions were considered including use of concrete traffic barriers, or placing a 1-m-high soil or waste rock berm. Since no concrete batch plant would be in operation at the time of constructing the Down Valley Interim Hydraulic Upgrades, it was assumed that the barriers would have to be trucked in from Whitehorse. Given that gabion mattresses will be used to harden the spillway channel and that the contractor will already have a gabion installation process in place, a comparative cost estimate indicates that the gabions should be less expensive. In addition, it will be easier to reuse the materials in the gabions as compared to the traffic barriers when these structures are dismantled to implement final closure concepts such as raising the ID. A berm would have a larger footprint than the other two options, could limit vehicular access to the ID crest, and would potentially be more difficult to remove. Also a berm would have a flatter upstream slope with somewhat inferior performance against wave run-up compared to the vertical or near vertical upstream slopes of the other two options.

A freeboard analysis was performed in accordance with technical guidelines from CDA (2007) to determine minimum and normal freeboard requirements. Wind speeds representing the 1-in-2-, 1-in-10-, 1-in-100-, and 1-in-1,000-year annual peak wind were determined by analyzing weather records from the Faro Airport meteorological station (Climate ID 2100517). Normal freeboard was determined by assuming a still pool elevation of 1,046.5 m (inundation corresponding to spillway invert elevation) and accounting for increased water levels due to wave, wind setup, and wave runup conditions during a 1-in-1,000-year wind. Minimum freeboard was determined by assuming a still pool elevation of 1,048.6 m (approximate maximum water surface elevation during a 1-in-500-year flood event) and accounting for wind and wave action during a 1-in-10-year wind. Two wind frequency distributions were considered for determining normal and minimum freeboard due to a suspected statistical outlier in the wind data. The minimum required crest elevation to provide suitable freeboard was determined to be approximately 1,047.5 m (or 1,047.2 m without the outlier) for the normal freeboard case. The minimum required crest elevation for the minimum freeboard case was estimated to be 1,049.6 m (or 1,049.4 m without the outlier). The design crest elevation of 1,049.6 m provides suitable freeboard under both conditions. Additional information regarding the wind analysis and freeboard calculations can be found in Appendix H.

5.5 Replacement of Conflicting Pipeline Conveyance Systems

5.5.1 Existing Pipeline Conveyance systems

This section has been prepared to summarize the design intent and criteria for the relocation, protection, and removal of conflicting existing facilities prior to construction of the new interim emergency spillway. Requirements and parameters are identified for the final design team to execute the scope of work.

This portion of the project involves the replacement, protection, or removal of three existing pipeline conveyance and treatment systems located in or near the spillway construction zone (See Drawings). These are only operated during warm weather months and are as follows:

- The water treatment plant (WTP) effluent pipeline
- The Intermediate Pond conveyance system facilities
- The siphon lime mixing system

Based on conversations with the Yukon Government, the siphon lime mixing system is no longer in operation and will be removed by others before construction begins. Therefore, protection and relocation of the siphon lime mixing system is not required.

Existing WTP effluent pipeline: The existing WTP effluent pipeline in the construction zone is a 600 mm DR 32.5 HDPE gravity pipeline installed in approximately 2001 from the WTP to the beginning of the emergency spillway. The original alignment was on the south side of the access road based on 2004 Google Earth satellite imagery. Later the pipeline was moved to the north side and extended to discharge to the current CVD outlet structures. Two existing wafer type butterfly valves are located at a tee near the Intermediate Pond pump station valve house to divert water to the CVD or the Intermediate Pond depending on water quality. These valves are connected with fittings that allow the required internal disc separation from the thicker walled HDPE pipe and

HDPE fittings. The fittings and valves appear to be in relatively good condition and will be considered for relocation to a new valve location as shown on the drawings.

Existing Intermediate Pond conveyance system facilities: These facilities consist of a conveyance system that currently is used to pump Intermediate Pond water to the old WTP for treatment. Main components near or within the construction zone are:

- A floating barge pump station (2- vertical turbine pumps)
- A pipeline from the barge to a valve house structure. There are no known record-drawings of this pipe material. Based on photos, the pipe material appears to be reinforced high pressure dredge hose.
- A Motor Control Center structure adjacent to the valve house.
- An above ground/buried (under access road) 350 mm diameter DR 9 HDPE piping that is adjacent to the effluent pipeline.
- Overhead electrical power supply.

This facility was installed in approximately 2010 based on record drawings.

Proposed effluent pipeline replacement: A portion of the existing effluent pipeline will be removed, abandoned, and replaced to facilitate the new interim emergency spillway channel. The replacement segment is shown on the drawings. This replacement segment is located on the north side of the access road for the following reasons:

- To provide a perpendicular undercrossing of the new spillway and road while aligning with the existing downstream CVD polishing pond north effluent outlet structure.
- To keep any required excavation away from the ID footprint.
- To maintain a good horizontal and vertical alignment that will maintain the current open channel flow capacity.

Based on the attached profile the existing grade is flatter than the upstream grades. A minimum slope of one percent minimizes excavation and maintains system capacity. However the pipe size will need to be increased from 600 mm to 750 mm because of the flatter slope.

Main scope of work components are:

- Above grade and buried 750 mm DR 17 HDPE piping and associated fittings including but not limited to eccentric reducers
- An insulated trench design to mitigate frost heave and maintain capacity for 5 plus years
- An above grade valve assembly similar to the existing one
- Modifications to use the existing discharge pipeline to the Intermediate Pond
- Removal of the existing 600 mm above grade pipeline downstream from the existing valve assembly
- Abandonment of the existing 600 mm buried pipeline under the access road
- A 2100 mm precast drop manhole to provide the required drop and over 90 degree change in flow direction
- A cased crossing of the new spillway

Proposed Intermediate Pond Conveyance System Protection:

Spillway construction is approximately 20 m from the floating barge pump station. Spillway construction is assumed to occur while the pumps are operating during the warm months. Construction will cause additional silt in the water and a floating silt curtain will be required to protect the pumps.

5.5.2 Pipeline Design Criteria

5.5.2.1 Design Life

The design life for the relocated pipeline is 5 plus years.

5.5.2.2 Pipeline Alignment

Horizontal Alignment

The horizontal alignment is along the north side of the access for the reasons cited in Section 5.5.1.

Vertical Alignment

It is necessary to maintain a minimum one percent slope to maintain supercritical flow. This will prevent any hydraulic jumps which would reduce the maximum capacity.

Maximum Design Capacity

Maximum design capacity is 0.44 m^3/s (7,000 gallons per minute), based on the original 2001 design for an approximate half-pipe flow condition. See Appendix C for the original hydraulic design criteria.

5.5.2.3 Crossings

The pipeline alignment will cross under two roads and the existing ID Spillway. There are no known culverts or buried utility crossings.

5.5.2.4 Loading Conditions

i. Above grade

   1. The pipeline will need to be protected from traffic and occasional rock damage similar to the existing condition.

ii. Buried

   1. Live loads will be based on the Canadian H25 truck wheel load of 9072 kilograms (20,000 lbs).
   2. Earth loads are assumed to be 2243 kilograms per cubic metre (140 lbs/ft3) since we are along the existing access road. We may want to use the existing road backfill material.
   3. The Plastic Pipe Institute design standards will be followed for maximum HDPE pipe deflection, constrained buckling, and thermal movement and associated forces.

5.5.2.5 Trenching and Backfill Design

i. Location

   1. Similar to the existing effluent pipeline, open-cut trenching will be required at the road and emergency spillway crossings

ii. An insulated trench for bury depths less than 3.5 m (11.5 feet) using Styrofoam insulation is assumed to prevent frost upheaval and change in vertical alignment. Other means to prevent frost upheaval will be investigated in the advanced design (90 percent) phase.

iii. Bury depth

   1. Bury depth will vary since the pipeline invert slope must be maintained

iv. Trench Width

   1. Insulated trench width is pipe outside diameter plus 1.5 m to provide room for adequate frost prevention and compaction equipment loads over the pipe

v. Trench Pipe Zone Material

   1. As specified. Refer to Section 31 23 23 in Appendix F for material specification.
   2. Lean concrete, to anchor the HDPE pipeline, ends at the manhole inlet and outlet area

vi. Trench backfill above pipe zone

1. As specified. Refer to Section 31 23 23 in Appendix F for material specification.

5.5.2.6 Pipeline Materials

The HDPE pipeline material is assumed to be the latest PE4710 HDPE resin with either butt fused thermal, electrofused, or flanged joints. Similar to the existing pipeline, outside diameter controlled iron pipe size dimensions will be used.

5.5.2.7 Corrosion Protection

Assume corrosion protection will be required for any above or below grade metal components.

5.5.2.8 Pipeline Appurtenances

Valves

Assume we can use the existing wafer valve assemblies (valves plus fittings) since they have not been in service long.

Drop Manhole

1. Size: A similar (including flow rates) cast-in-place rectangular structure design has been in service for about 20 years. The inside dimensions were a 1.8 m (6.0 foot) square to allow adequate flow equalization for the drop and more than 90-degree change in direction. Therefore, assume a 2,100 mm (84 inch) diameter precast manhole. A vent pipe will be provided to allow air exchange from the interior top of the manhole to the outlet pipe.
2. At grade traffic rated top.

5.5.2.9 Surface Restoration

Roadway surfaces for the buried pipe portions will be restored in-kind.

5.5.2.10 Traffic Control

Assume traffic can be detoured around the construction zones.

5.5.2.11 Ambient Temperature Range

HDPE pipe has a large coefficient of thermal expansion and contraction. Both ambient temperature and associated soil temperature changes will result in either movement or large thermal forces if anchored. The design ambient temperature range is -45° Celsius to 30° Celsius.

5.5.3 Preliminary Wall Thickness Calculations

Pipe Wall Thickness Calculations: Preliminary wall thickness calculations were performed using the latest Plastic Pipe Institute calculator.

5.5.3.1 Purpose and Need

Wall thickness calculations were performed to determine the pipe internal diameter for the hydraulic analysis. HDPE pipe is outside diameter controlled. A 600 mm nominal iron pipe size pipe is manufactured to a 600 mm outside diameter. For solid wall HDPE gravity pipelines, wall thickness is typically controlled by dead and live loads.

5.5.3.2 Modelling Software

The polyethylene piping- calculator by the Plastic Pipe Institute was used to determine pipe wall thickness to resist wall crushing and constrained buckling.

5.5.3.3 Modelling Runs and Results

An assumed 750 mm pipe size was used since the grade was flatter. This was later verified in the hydraulic calculations in Section 5.5.4. The following three different wall thicknesses were used as initial inputs for the

750mm -diameter pipe: DR 32.5, DR 21 and DR 17.The results indicated that a DR 17 wall thickness would resist the heavier Canadian H25 wheel loads and not buckle at a minimum standard safety factor of 2. A minimum pipe cover of 3 feet was assumed. For pipe covers less than 3 feet the pipe will need to be protected. See Appendix D for detailed output results.

5.5.4 Pipeline Hydraulic Analysis

5.5.4.1 Purpose and Need

A hydraulic analysis was performed to verify that the existing pipeline capacity was maintained at the flatter one percent slope. This analysis utilized the original 2001 design criteria presented in Appendix C.

5.5.4.2 Modelling Software

Modelling software for this pipeline gravity flow condition was performed by the Haestad Methods Solutions FlowMaster V8i (Select Series 1) program by Bentley Systems Inc. The original 2001 design calculations were first validated with this program.

5.5.4.3 Modelling Runs and Results

The program validation gave the same results as in 2001, with approximate 37 to 50 percent full-pipe flow conditions. It was discovered that the original calculations were competed for a 600 mm DR17 HDPE pipe. Apparently, the DR was later changed to 32.5 which would give a higher flow capacity but lower resistance to deflection when buried. Results for the minimum one percent slope indicated that a 750 mm nominal diameter DR 17 pipe would perform well. The DR 17 wall thickness was determined from loading calculations as indicated above. See Appendix E for detailed output results.

SECTION 6

Rose Creek Diversion Improvements

6.1 Diversion Flow Capacity

Design criteria require that the crest elevation of the overflow weir be high enough to prevent overtopping for flows less than 111 m^3/sec(the 1-in-500-year flood event flows), and the dike crest downstream from the overflow weir not overtop for flows less than 116 m^3/sec (the un-attenuated 1-in-500-year flood event flows). Hydraulic modelling results for the RCD predict that the existing configuration does not provide adequate capacity to convey the 1-in-50-year flood event flow of 71 m^3/sec before overtopping the overflow weir. Using these results, it was determined that the crest of the overflow weir will have to be raised by about 0.8 m to an elevation greater than 1,058 m to prevent overtopping of the structure for flows of less than 111 m^3/sec in the RCD. As flood flows exceed 111 m^3/sec, the newly-raised overflow weir will begin to overtop. For the purposes of evaluating the RCD capacity, it is conservatively assumed that the overflow weir will not erode during overtopping, and flood waters in excess of the 1-in-500-year flood flows will spill at this location as the flood levels continue to rise. Hydraulic modelling results were used to determine how high the dike will have to be raised downstream from the overflow weir so that overtopping does not occur during a 1-in-500-year flood event; the right bank of the dike will have to be raised by a maximum of about 0.8 m till plus 0.2m of road surface to prevent overtopping.

6.1.1 Geologic Hazards

It is considered possible that mass wasting, slope wash, activation of existing alluvial fans, forest fires, melting of permafrost, earthquakes, and other phenomena are all plausible mechanisms for initiation of coarse sediment deposition into the RCD channel, and that such events could initiate a breach. Such phenomena could coincide with a 1-in-500-year flood event or could occur more frequently. In 2006, BGC performed a natural hazards assessment for the slopes south of the RCD. In this review, BGC identified the alluvial fans near the downstream weir section of the RCD channel as the primary geologic hazard, but also noted that no significant debris accumulation occurred in this area during the period reviewed (1979 to 2003). BGC (2006) also noted the mechanisms previously mentioned.

For Down Valley Interim Hydraulic Upgrades purposes, mitigation of these hazards is not deemed practical. It is noted, instead, that the redundancy provided by maintaining adequate capacity to pass the 1-in-500-year flood flows through the ID and CVD spillways is expected to be an adequate safeguard against RCD breach. Initiation of this breach is expected to occur at the overflow weir section. Because of the unpredictability of these geologic events, CH2M HILL recommends regular inspection and maintenance of the RCD during the interim period to maintain adequate channel capacity.

6.2 Historical Performance of the Rose Creek Diversion Dike

6.2.1 Diversion Construction

Construction of the RCD began in early October 1980 and was completed 12 months later. Most excavation for the diversion can be classified as common excavation and included frozen and unfrozen soil as well as fractured rock. A smaller amount (about 10 percent of total excavation volume) was classified as rock excavation defined as any material that had to be blasted before it could be excavated.

Details of the diversion construction are detailed by Golder (1982) and BGC (2005a). Common excavation took place from November to April, when temperature records show that average daily temperatures were below freezing. This timing was deliberate to prevent thawing of ice rich materials in the cut slope along the south side of the diversion. A gravel thermal liner was placed over the exposed cut slope before spring to reduce the risk of thaw-induced slope instability.

Winter construction, however, presents disadvantages for dike construction and engineered fill placement. During construction it was very difficult to ascertain the extent of permafrost in the native material. It was noted that

significant volumes of unfrozen material were encountered at depth, but that the excavation surfaces usually froze within 24 hours. Snow also masked the excavation surface and complicated construction inspection. A significant portion of the fill for the RCD dike was placed during March and April, when average air temperatures were below freezing. Additionally, foundation preparation activities at several locations for the dike encountered pockets of organic soils several metres thick. Such soils commonly have low strengths, high water contents, and are prone to high degrees of consolidation (settlement). Golder (1982) reported that stripping activities did not remove all of the organic soils, and unknown extents existed below the prepared subgrade.

6.2.2 Diversion Performance

Golder (1982) details the performance of the diversion during the period from May to September 1981, which was the first thaw season after construction. Their report indicates that virtually no thaw settlements or instability occurred on the south cut slope during the first summer after construction. However, some erosion of the thermal blanket materials occurred as surface water runoff flowed over the top of the cut slope. Subsequently, drainage swales were installed along the crest of the cut slope to direct surface water to rock filled drainage channels placed at selected locations along the diversion.

Instability on the south cut slopes have been observed over the years, and evidence of active sloughing and repaired former sloughs was noted in the recent RCD Inspection Memorandum (CH2M HILL, 2013c). The rock slopes that are more prevalent in the downstream section of the diversion have remained stable since construction.

BGC (2005a) noted that cracking and settlements on the dike were observed in a few localized areas and that there was some seepage along the north toe of the dike during the first thaw season after construction. Dike settlements were thought to be either the result of inadequate compaction of the fill materials during the previous winter, the presence of organic silts in the foundation, or thaw settlement of ice rich permafrost within the foundation soils. In the decades since construction, the crest of the north dike settled a total of about 1 m starting about 300 m upstream from the ID and extending upstream over a 1 kilometre-distance. In the summer of 2004, additional fill was placed along this section of the RCD dike to raise it back to its initial design elevation (BGC, 2005b).

6.3 Field Investigation and Mapping

CH2M HILL performed a field inspection of the existing RCD on July 26 and 27, 2013. The inspection was performed by a CH2M HILL geotechnical engineer who walked the entire length of the RCD from the upper end of diversion to the confluence of the diversion with Rose Creek, a distance of approximately 5 kilometres. During the inspection the conditions of the channel and dike were observed and documented. The purpose of the work was to delineate areas where vegetation removal is needed as well as delineate areas of raveled riprap slopes, erosion, oversteepened slopes, or any other areas that may need maintenance or repair commensurate with the Down Valley Interim Hydraulic Upgrades design criteria. Locations where these conditions were observed were geo-referenced using a handheld Garmin model GPSMap 60CSx global positioning unit, to collect Universal Transverse Mercator coordinates and elevations at the locations. The accuracy of this device varies, but is estimated as ±3 to 4 m during the inspection. All Universal Transverse Mercator coordinates reference the WGS 84 datum. The details and extent of this work are described in detail in the RCD Inspection Memorandum (CH2M HILL, pending), which will be an attachment to the TAR 16 Data and Analysis Report.

A summary of the inspection observations follows in Sections 6.3.1 through 6.3.5.

6.3.1 Vegetation

Significant vegetative growth was noted along the RCD during the inspection. Vegetation sizes observed varied from young forbs to small trees up to approximately 100 mm (4 inch) caliper diameter. Woody vegetation was observed on both the left (diversion side), and right (tailings side) of the diversion dike, and also on the left side of the diversion. The type, distribution, and size of vegetation vary widely along the diversion. In some places, large thickets cover the slopes of the dike and complicate inspection. In other places, the vegetation exists at an acceptable level that is not harmful to the integrity of the dike. There is evidence of pockets of recent vegetation

removal activities, but it is apparent that a thorough vegetation removal program is necessary, along with corrective measures and routine maintenance.

6.3.2 Berm Crest Grading

During the inspection, it was observed that the berm crest was generally uniform without obvious signs of settlement or subsidence. A slight dip less than 0.3 m was observed at a location that is approximately the starting point of a 1-kilometre-section extending upstream where the dike crest was raised in 2004 (BGC, 2005b). At this location, the RCD is higher than the adjacent tailings ponds.

At multiple locations along the dike crest or other access roadways adjacent to the RCD, ruts or puddles were observed in the roadway surface. The grading of the berm crest should be maintained to prevent development of these water-collecting depressions which can serve to soften and destabilize the dike and promote additional rutting. The crest should be graded to direct water off from the dike. Additional crest elevation deficiencies are apparent from review of survey information relative to the predicted 1-in-500-year flood event WSEL, see Appendix A, Drawings C-12, Table 1 for details.

6.3.3 Slope Stability

The RCD dike exhibits evidence of slope instability occurring frequently. Long sections of the dike have tension cracks, slides, scarps, riprap deficiencies, toe bulges, and debris accumulations which are indicative of slopes which have failed or are in the process of failing. Generally, most evidence supports that these failure are relatively shallow. The cause for the instability is likely due to a number of factors, including freeze-thaw, rapid-drawdown stresses following high-water events, low strength (organic) materials in the foundation, poor material compaction during dike construction, and other factors. Many slide areas appear to have been repaired, both for discrete slides as well as for long sections of the dike; monitoring instrumentation such as a slope inclinometer casing appears to have been installed by others. Still, many slides appear active and require corrective action. It is important to note that the presence of thick vegetation in some locations prevents detailed inspection of the diversion slopes. In these areas, vegetation should be removed and maintenance performed.

Geotechnical characterization of the dike strengths and evaluation of dike stability has not been performed. However, slides and sloughs observed in the field generally appear to be relatively shallow and non-threatening with respect to deep-seated failure or reduction of dike freeboard, and further do not appear to appreciably compromise the function of the Class II seepage control liner. Dike slopes exhibit signs of ongoing (active) instability, which is expected to continue into the future. These slides are generally regarded as maintenance issues; active maintenance would prevent problems from advancing and would help maintain uniform erosion protection necessary to pass the design flood.

The potential hazards presented by the observed slope instability include:

- Large slides could compromise the existing seepage control liner and allow seepage into or out of the channel
- Debris accumulations could contribute to channel constriction and reduced flood flow capacity
- Sloughing of erosion protection material could leave dike fill exposed to erosive flows during flood events

6.3.4 Riprap and Large-Diameter Riprap Erosion Protection Material

The riprap and large-diameter riprap armoring of the RCD is not uniform and not consistent. In places, it is apparent that slope instability (discussed in Section 6.3.3) has carried riprap downwards and left portions of the slope exposed; elsewhere, riprap appears to be completely absent. Previous slope repairs included placement of riprap of varying size, shape (rounded vs. angular), and lithology. In some locations, riprap sloughing has impinged somewhat on channel capacity.

The higher-gradient portions of the channel are armored with large-diameter riprap (i.e. large diameter rip rap). The condition of these sections of channel generally appear more uniform than the conventionally-armored channel sections and have fewer signs of distress. There are several locations, however, where these large stones have moved downwards and into the channel, or have left portions of the channel unprotected. Additionally, many locations armored with large diameter riprap have significant vegetative growth. In some cases large voids have been identified behind the large-diameter riprap, and the underlying embankment fill could be subjected to

erosion and scour. The higher-gradient areas on the downstream portion of the RCD have a higher concentration of dense willow growth.

In places where this large diameter riprap has moved downward into the RCDC, there are several channel constrictions or large prominent boulders with a tendency to collect debris.

6.3.5 Overflow weir

The overflow weir portion of the RCD is a depressed section of the berm which permits flow of excess water into the intermediate tailings pond. The structure is referred to as a fuse plug; however, a section is heavily reinforced with large diameter stone, and does not appear to be readily "fusible" in a high water event. The depressed section of the overflow weir is slightly lower than the surrounding berm and would more realistically function as an armored overflow spillway during a high water event. The dike slopes upstream from the overflow weir were observed to be un-armored.

6.4 Rose Creek Diversion Improvements

6.4.1 Vegetation Removal

As described in Section 4.3.6.3, hydraulic modelling was performed to evaluate improvements in RCD capacity by removal of vegetation. Modelling results indicate that removal of vegetation from the left bank of the RCD could result in an average reduction in the WSEL from 0.05 to 0.10 m. Removal of vegetation from both banks would reduce the WSEL from about 0.10 to 0.15 m. Removal of vegetation is estimated to reduce the WSEL through the total length of the RCD channel.

The predicted improvement in diversion capacity by vegetation removal is too modest to warrant removal of vegetation based only on such a criterion. Given the difficult access to the left bank of the diversion, the fact that the vegetation on the left side of the channel is generally shrubby and not prone to toppling into the channel, and that the left bank is not a critical seepage barrier between diversion water and tailings impoundments, it is recommended that vegetation does not need to be removed from the left bank of the diversion.

Trees and other woody vegetation on the dike slopes can have a detrimental effect on the stability and function of the dike, somewhat akin to the impact of vegetation on levee dikes. It is therefore recommended that this type of vegetation be removed from the dike. Policies and criteria regarding the removal of trees and other woody vegetation on levees are evolving and will change in the future as a result of ongoing and future research.

Reasons for vegetation removal are cited in USACE (2009), including:

- Allow proper inspection, surveillance, and monitoring for seepage, cracking, displacement, and any other signs of distress in the embankment or its foundation.
- Allow access for operations and maintenance activities.
- Prevent root-related damage, such as shortened seepage paths through the dike and its foundation; voids in the dike and its foundation due to decayed roots or fallen trees; clogged seepage collector systems; and expansion of cracks in canal linings.
- Limit those habitat characteristics that encourage the creation of animal burrows.

Criteria for this project have been developed by considering the following guidelines:

1. Best Management Practices for Works Affecting Water in Yukon, YG, May 2011
2. Guidelines for Management of Flood Protection Work in British Columbia, British Columbia Ministry of Environment, Lands and Parks, March 1999
3. Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment, British Columbia Ministry of Environment, Lands and Parks, March 1999
4. Urban Levee Design Criteria, May 2012 (California Department of Water Resources, 2012)

5. USACE Guidelines for Vegetation Management (USACE, 2009)

Based on a review of these guidelines (with more consideration given to the Canadian guidelines), the recommended criteria are as follows:

- Provide a zone free of woody vegetation that extends from the water surface in the channel to a minimum distance of 5 m from the downstream (landward) toe of the dike. Note that the BC guidelines require a minimum 3-m strip beyond the landside toe, but states that the strip could be increased as necessary to facilitate maintenance. Extending the width of the vegetation-free zone to 5 m is consistent with the United States guidelines referenced previously.
- All trees or woody vegetation that are more than 50 mm (2 inch) in caliper diameter or that are more than 2-m tall shall be removed from the vegetation-free zone. This suggested criterion is more lenient than suggested by the guidelines, of which all require that no vegetation, other than trimmed grasses, be allowed to grow in the vegetation-free zone.
- Roots of woody vegetation should generally remain in place to prevent undue disturbance of the slope material, except if determined to be potentially detrimental to the stability of the dike as determined by the Engineer in the field during construction. Where root removal is directed, any excavation or voids in the dike resulting from the above actions shall be backfilled with engineered fill similar to the original dike fill, and shall be compacted to the original compaction specifications, or if no specifications exist, match adjacent compaction.

Further coordination with the YG is needed to refine these suggested criteria and to develop appropriate site-specific vegetation monitoring and removal.

6.4.2 Rose Creek Diversion Dike Crest and Overflow Weir Raise

Hydraulic modelling results were used to determine the locations and extents of dike and overflow weir raises necessary to prevent overtopping of the overflow weir during a 1-in-500-year flood event (zero freeboard condition) and to prevent overtopping of the dike during a 1-in-500-year flood event (0.5 metre freeboard downstream of the overflow weir). Appendix A, Drawing C-12, Table 1 shows the required raise heights with a maximum required raise of about 0.8 m. The raise will be performed using native sand and gravel for the upper 0.5 m, which is the freeboard distance. Compacted glacial till material should be used to extend the seepage barrier to the 1-in-500-year flood event elevation, and appropriate riprap erosion protection should be extended to the top of the raised dike. It is noted that the overflow weir will be raised with low permeability material (glacial till) to the 1-in-500-year flood event elevation (1,058.0 m), with a 200 mm-thick layer of native sand and gravel covering the crest to provide a road surface, i.e., the structure will have a freeboard of 0.2 m.

6.4.3 Slope Repair and Riprap Augmentation

Visual inspection of the existing RCD slopes and comparison with hydraulic modelling results confirmed the need for restoration of the existing channel slope geometry and establishment of uniform erosion protection in order to safely pass the 1-in-500-year flood event. The predicted inundation levels and RCD channel velocities which were considered in the riprap augmentation recommendations are shown in Figure 6-1.

As noted previously, visual observations indicate that the RCD dike is plagued with shallow slides and sloughs occurring frequently. These slides have occurred in the past, are presently moving, and are likely to continue in the foreseeable future. To thoroughly stabilize the dike and minimize the potential for future slides would require re-compaction of dike fill materials, possible flattening of dike slopes, and replacement of channel armour. The time and cost of this level of repair would be prohibitive and not reasonable for the Down Valley Interim Hydraulic Upgrades improvements. As an alternative, it is recommended that some selected problem areas be repaired, and a proactive monitoring and maintenance approach be adopted for the remainder of the dike.

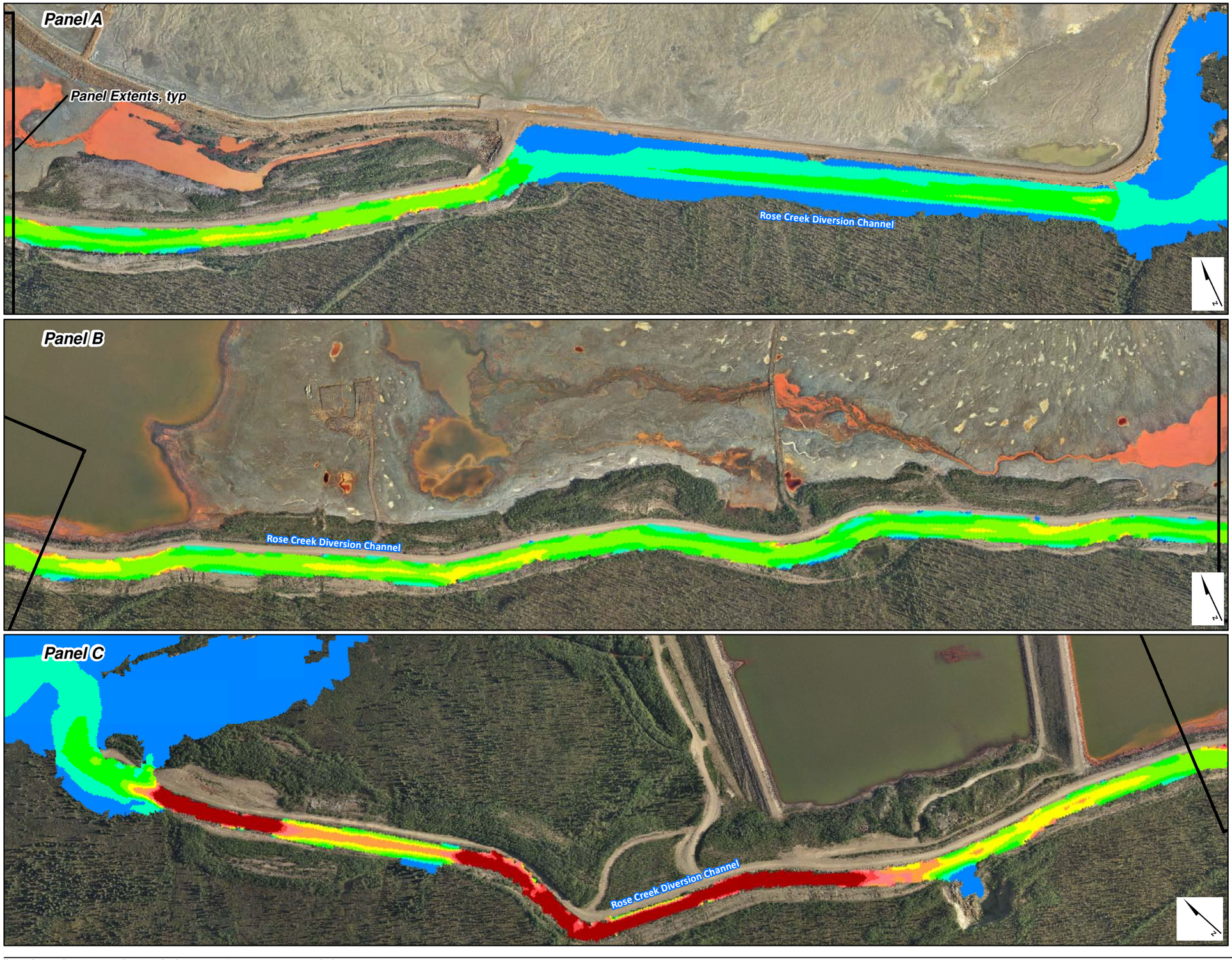
The shallow sloughs on the RCD banks have resulted in deformed cross sections with oversteepened slopes and areas of dike fill which are unprotected by riprap armoring. The nearly 5-kilometre long channel has a multitude of relatively minor deficiencies which are vulnerable to the design flood event, and if left uncorrected, could

continue to worsen. For the purposes of the Down Valley Interim Hydraulic Upgrades, the locations and nature of the various dike deficiencies have been characterized and simplified for purposes of remediation. The necessary remediation techniques will not be the same everywhere, and will require adaptive site-specific field assessment to apply the appropriate construction technique to stabilize the channel for the design event. The field implementation of this solution will require a cooperative field oversight program which assesses the problems at a particular dike section and prescribes an appropriate remediation technique.

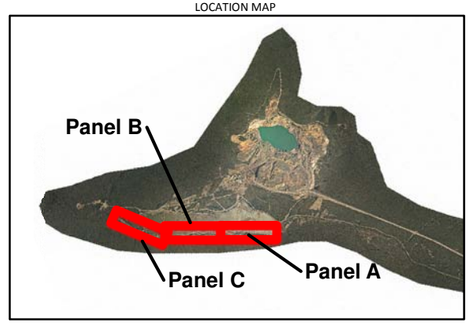
The dike deficiencies have been characterized and several generic fixes have been proposed in the advanced design drawings (60 percent) in Appendix A. It is anticipated that the most-common remediation technique will first require the removal of vegetation and accumulated organic matter as described above, localized minor regrading of the dike berm, and placement or augmentation of riprap erosion protection material. Details of these proposed repairs are shown schematically in the drawings.

Several other isolated problems require specific corrective action, which is also called out specifically in the advanced design drawings (60 percent) in Appendix A:

- A few lowered sections of the dike crest must be re-graded to provide adequate freeboard of 0.5 m for the 1-in-500-year flood event and to improve surface drainage, as described in detail in the previous section.
- A few locations which have unnecessary stockpiles of random fill near the top of the slopes should be removed and hauled off the dike crest, to reduce driving forces/weight on top of the slopes.
- In some places, the removal or relocation of boulders or accumulated debris that could potentially collect debris is required. In most (but not all) cases, these boulders are located in the high-gradient sections of channel with large-diameter riprap, and appear to have been moved from their original locations as a result of large flows.



LOCATION MAP



LEGEND

1-in-500 year event velocity (m/sec)

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- > 4

Note:
Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.

0 25 50 100
Metres

Created by:
CH2MHILL

FIGURE 6-1
Velocity in RCD for 1-in-500 year flow
Faro Mine Remediation Project

CH2MHILL

\\osprey\GROUPS\Water_Resources\Faro_Mine\GIS\Figure5-XX_VelocityRCD.mxd FGARIGLI 11/11/2013 08:25:00 AM

SECTION 7

On-Site Borrow

A total of four potential on-site borrow areas were investigated during the 2013 Field Season as potential borrow sources for the Down Valley Interim Hydraulic Upgrades project. The Calcium-Silicate Waste Rock Borrow area, The Rose Creek Haul Road Borrow Area, and the Rose Creek Borrow Area, and the Granitic Outcrop Borrow Area (see Drawing C-1 in Appendix A for locations). Given the irregular shape of the calcium-silicate waste rock, high sulfate content, and the fact that borrow material in the Rose Creek Borrow Area will already be processed to generate other materials needed for this project, only the Rose Creek Borrow Area is considered a cost-effective and suitable source of cobbles for the gabions. Minor riprap is needed to repair the slopes along the RCD. The riprap needs to be angular and therefore the Rose Creek Borrow Area is not a suitable borrow source. The Granitic Outcrop Borrow Area has been investigated as a riprap source for the Vangorda Creek Diversion project, and is planned to be developed and processed at the same time that the material is needed for this project. Therefore, we are considering Granitic Outcrop Borrow Area the riprap source for the Down Valley Interim Hydraulic Upgrades project. Based on the laboratory results, the borrow areas will be suitable for processing the following materials:

- Rose Creek Haul Road Borrow Area: Glacial Till
- Rose Creek Borrow Area: Cobbles for gabions, pipe zone material, small to intermediate riprap, sand, and gravel
- Granitic Outcrop Borrow Area: Riprap

Several material types will be required for construction of the Down Valley Interim Hydraulic Upgrades project. For the RCD improvements, a well-graded sand and gravel mixture will be used to raise the crest of the dike, with some smaller amounts of glacial till where the low permeability seepage liner needs to be extended to the 1-in-500-year flood event elevation. The sand and gravel mixture would also be used as riprap bedding where riprap repairs need to be performed on the diversion banks. Some of the material excavated from the ID spillway may be able to be re-used for raising the RCD dike crest. The remainder of the material can be stockpiled for later use. It is anticipated that a modest amount of riprap will be required to repair sloughed areas or to augment existing sparse rip rap; as discussed above this riprap is anticipated to come from the Granitic Outcrop Borrow Area.

For construction of the ID spillway improvements, the main borrow material source required would be the cobbles needed in the gabion mattresses and gabion baskets. It is proposed that this material be obtained by processing (screening) the alluvial and glaciofluvial deposits from the Rose Creek Borrow sites. These materials consist mainly of poorly graded gravel with sand and silty gravel with sand. Glacial till to backfill the geomembrane installation trench to raise the ID crest could be obtained from the Rose Creek Haul Road Borrow Area.

A rock processing plant, with a conveyor system, screening plant, and generator, along with excavating equipment are anticipated. All of these processed materials will be used in the elements to be constructed in Down Valley Interim Hydraulic Upgrades. Any excess material will be stock piled at the Rose Creek Borrow Area for later use.

SECTION 8

Cost Estimate

A Class II capital cost estimate has been developed for the 60 percent Design. This type of estimate is based on a 60 percent design level of project definition. This type of estimate is generally prepared to develop a preliminary budget and schedule. The estimate would have semi detailed unit costs with line item descriptions. Expected accuracy would be -5 percent to -15 percent on the low side and + 5 percent to +20 percent on the high side. The Class II capital cost estimate will be submitted and bound separately from the BODR.

The capital cost estimate will be updated to a Class I and submitted with the Detailed Design (90 percent).

SECTION 9

Specifications

CH2MHILL Standard Specification will be used for this project. Detailed specifications are included as part of this Advanced Design (60 percent) and will be included in the Detailed Design (90 percent) deliverables. See Appendix F for the Advanced Design Specifications (60 percent).

SECTION 10

Summary and Recommendations

The work performed for the design of the Down Valley Interim Hydraulic Upgrades, including the results of engineering evaluations performed can be summarized as follow:

10.1 Rose Creek Diversion Design

- Design criteria require that the RCD dike crest has minimum 0.5 m freeboard for a flow of 111 m^3/sec upstream of the overflow weir and 116.2 downstream of the overflow weir, which approximates the 1-in-500-year flood event flows.
- Hydrotechnical analyses were performed to establish the 1-in-500-year flood event elevations in the diversion. The existing conditions model was modified in the location of the overflow weir to allow only flood flows in excess of the 1-in-500-year flood event flow rate (111 m^3/sec upstream and 116 m^3/sec downstream) to discharge through the overflow weir.
- The crest elevation of the overflow weir in this design was set to elevation 1058.2 m, which corresponds to the water surface elevation predicted for the 1-in-500-year flood event flow rate (elevation 1,058.0 m) plus a 200 mm-thick layer of native sand and gravel covering the crest to provide a road surface (i.e., the structure will have a freeboard of 0.2 m). This implies that the overflow weir will have to be raised by about 0.95 m.
- The model results indicate that the existing crest elevation is deficient to contain the predicted 1-in-500-year flood event flows. Over some portions of the dike, it would overtop and at other locations there would not be adequate freeboard. To mitigate this deficiency, the dike crest needs to be raised over some sections of the dike, resulting in a maximum required dike raise of about 0.95 m.
- Apart from the required raise of the dike crest and overflow weir, it is also proposed to remove woody vegetation from the dike and to perform some repairs of slope sloughing and riprap, and to add riprap where slopes are unprotected.

10.2 Intermediate Dam Spillway Improvements

- Because of uncertainty in the RCD dike performance under large flood events, and based on the design criteria established by the expired water licence, the required design ID spillway capacity was established as 115 m^3/sec, which is the 1-in-500-year flood event flow (including attenuation through the NFRD and in the ID impoundment). The existing ID spillway (with a capacity of 32 m^3/sec) cannot safely pass a moderate or major flood event without potentially failing the dam.
- The improvements at the ID spillway consist of excavating the existing channel by a maximum of about 2 m, and placing a 0.45-m-thick gabion mattress on the excavated surface. Gabion cells will be used on the sides of the channel, with a geotextile between the gabions and the excavated soil surface.
- To raise the effective ID crest, a geomembrane will be installed vertically in a trench between the dam core and the crest surface, and a single 0.9 m by 0.9 m gabion row will be placed along this line to further raise the effective crest to an estimated elevation of 1,049.6 m.
- The 2D model was used to evaluate the proposed ID spillway improvements. Model simulations assume that the overflow weir would be completely breached, resulting in the entire design flow conveyed onto the tailings. Model simulations with the 1-in-500-year flood event flow rate routed down the RCD, discharged through the overflow weir, and conveyed over the tailings predict the following:
  - Flow over the spillway = 115 m^3/s
  - Headwater elevation = 1048.6 m
  - Freeboard at ID = 1.0 m

10.3 North Fork Rock Drain Recommendations

The main objective of the interim improvements is to prevent overtopping and breach of the ID during the 500-year flood. Based on a review of the design and construction records of the NFRD, this objective cannot be met with a sufficiently high degree of confidence by relying on the haul road embankment to act safely and reliably as a flood retarding structure during a 500-year flood event. To achieve a high confidence level, more positive measures will have to be implemented to pass large flood events safely at the Haul Road embankment and NFRD. One such measure might include installation of culverts or tunnels under the embankment.

In the absence of such measures, a risk analysis might be helpful in determining acceptability of the Haul Road embankment and NFRD in the interim period. The probability of failure of the structure is less than 2 percent over a 10-year period, but the consequences of failure of the NFRD are potentially large. Breach analyses performed for low flow-through assumptions indicate that an NFRD breach could result in overtopping of the ID.

A risk analyses would not only consider the 500-year flood, but would combine the probability of failures during the interim period with the consequence of failure for the full range of flood loading up to the 500 year event to estimate the risk. It is recommended that such a risk analysis be performed if: (1) it is not possible for the YG to take more positive measures to ensure the reliability of the Haul Road embankment, or (2) if the YG is not willing to accept a risk (not well understood at this time) that could exceed generally accepted tolerable risk guidelines.

Monitoring of the Haul Road embankment and NFRD should continue and maintenance measures should include prevention of blockage of the inlet to the NFRD by removing any buildup of debris.

SECTION 11

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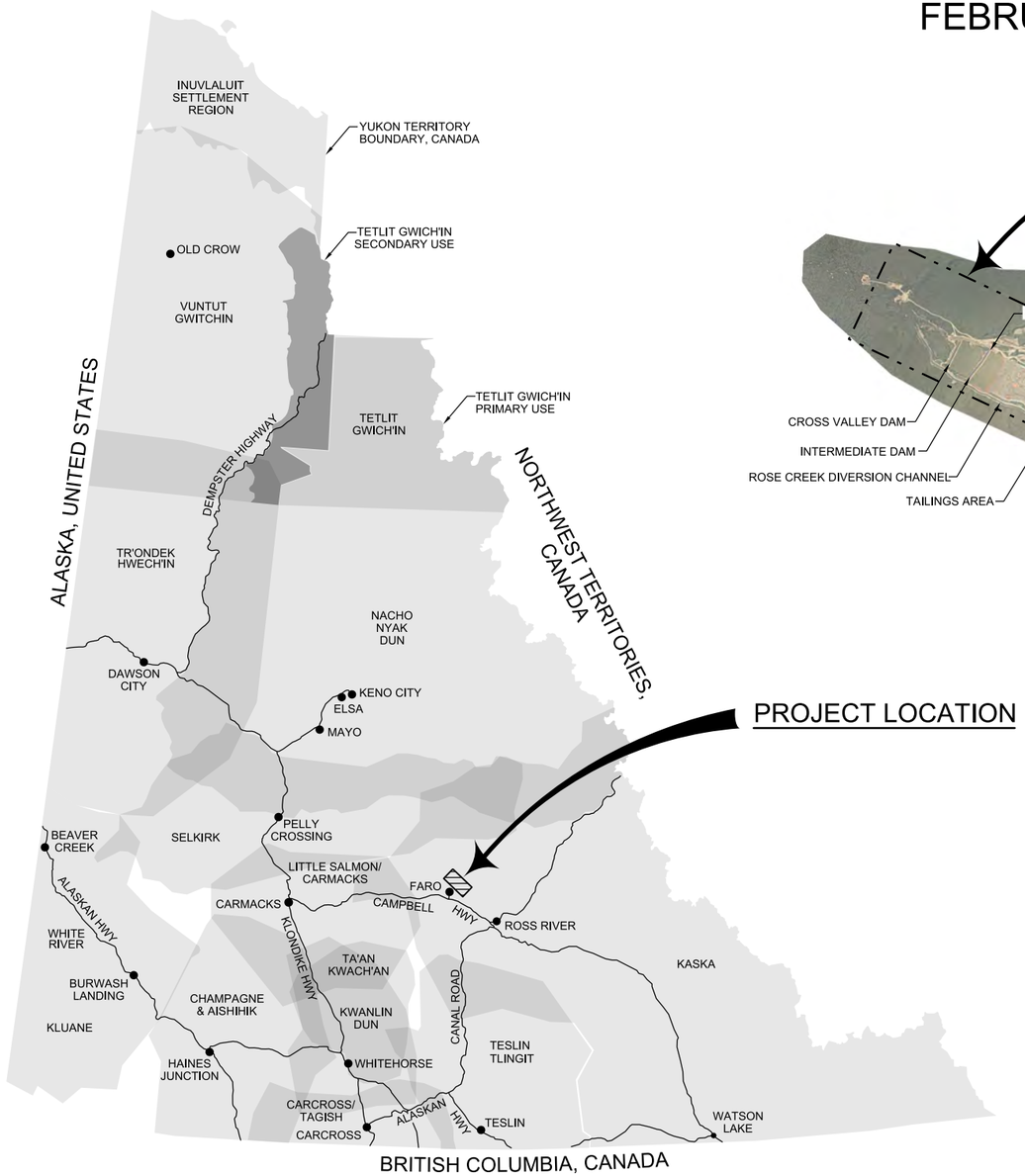
Appendix A
Advanced Design Drawings (60 percent)

FARO MINE REMEDIATION PROJECT
DOWN VALLEY INTERIM HYDRAULIC UPGRADES (DVIHU)

TASK AUTHORIZATION NO. (TAR) 16
ADVANCED DESIGN (60%)
FEBRUARY 2014



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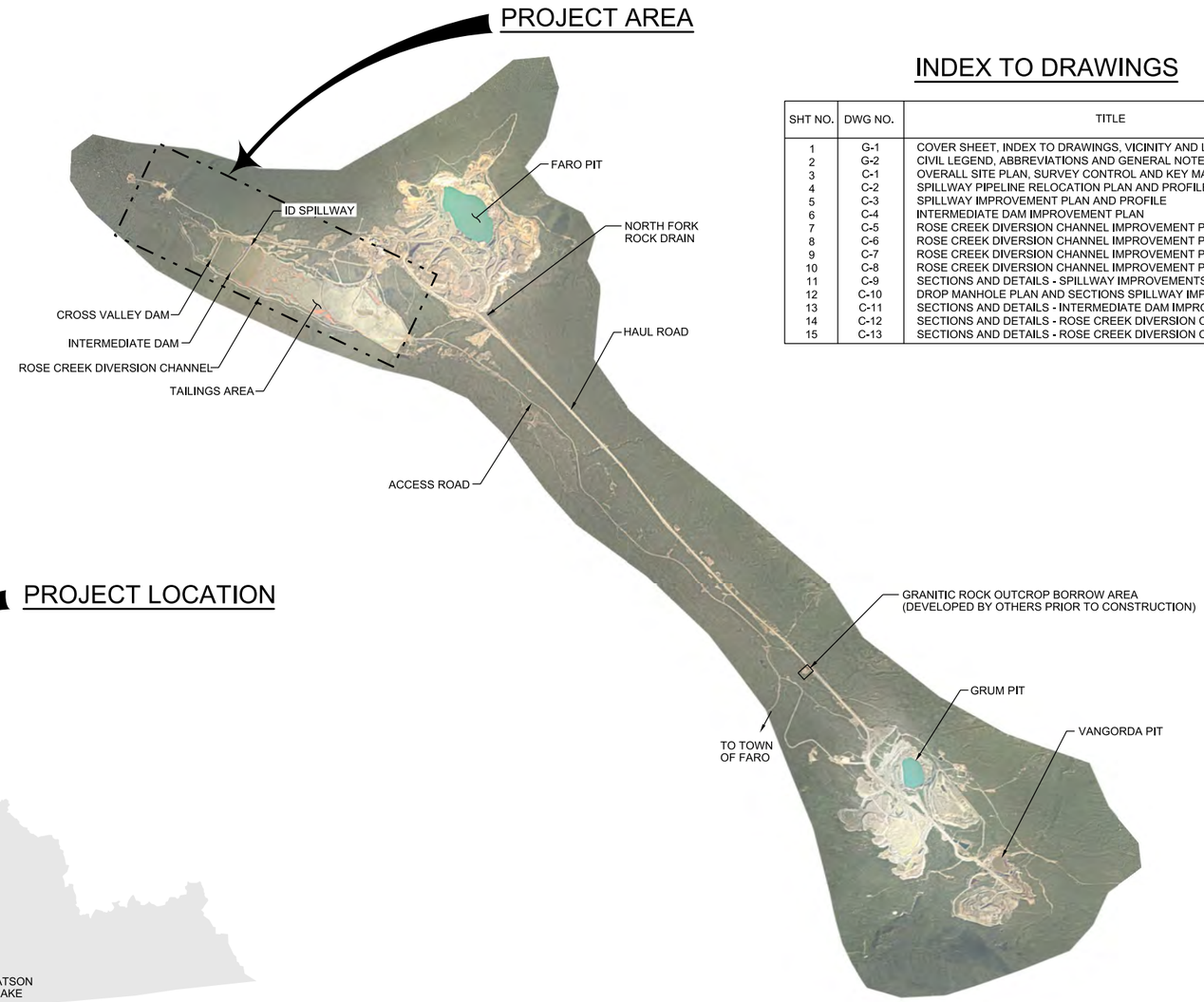
VICINITY MAP

NTS



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LOCATION MAP

NTS

PREPARED FOR GOVERNMENT OF CANADA AND THE GOVERNMENT OF YUKON AS REPRESENTED BY ABORIGINAL AFFAIRS AND NORTHERN DEVELOPMENT OF CANADA.

INDEX TO DRAWINGS

SHT NO.	DWG NO.	TITLE
1	G-1	COVER SHEET, INDEX TO DRAWINGS, VICINITY AND LOCATION MAPS
2	G-2	CIVIL LEGEND, ABBREVIATIONS AND GENERAL NOTES
3	C-1	OVERALL SITE PLAN, SURVEY CONTROL AND KEY MAP
4	C-2	SPILLWAY PIPELINE RELOCATION PLAN AND PROFILE
5	C-3	SPILLWAY IMPROVEMENT PLAN AND PROFILE
6	C-4	INTERMEDIATE DAM IMPROVEMENT PLAN
7	C-5	ROSE CREEK DIVERSION CHANNEL IMPROVEMENT PLAN STA 1+500 TO 3+100
8	C-6	ROSE CREEK DIVERSION CHANNEL IMPROVEMENT PLAN STA 3+100 TO 4+500
9	C-7	ROSE CREEK DIVERSION CHANNEL IMPROVEMENT PLAN STA 4+500 TO 5+900
10	C-8	ROSE CREEK DIVERSION CHANNEL IMPROVEMENT PLAN STA 5+900 TO 6+573
11	C-9	SECTIONS AND DETAILS - SPILLWAY IMPROVEMENTS
12	C-10	DROP MANHOLE PLAN AND SECTIONS SPILLWAY IMPROVEMENTS
13	C-11	SECTIONS AND DETAILS - INTERMEDIATE DAM IMPROVEMENTS
14	C-12	SECTIONS AND DETAILS - ROSE CREEK DIVERSION CHANNEL IMPROVEMENTS
15	C-13	SECTIONS AND DETAILS - ROSE CREEK DIVERSION CHANNEL IMPROVEMENTS

NO.	DATE	REVISION	BY
DSGN		LAA	APVD
		DR	
		JPS	checker
		CHK	APVD

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FARO MINE REMEDIATION PROJECT
DOWN VALLEY INTERIM HYDRAULIC UPGRADES
GOVERNMENT OF YUKON
DESIGN

CH2MHILL®

GENERAL
COVER SHEET, INDEX TO DRAWINGS
VICINITY AND LOCATION MAPS

60% DESIGN - NOT FOR CONSTRUCTION

AS SHOWN	
VERIFY SCALE	
BAR IS 25mm ON ORIGINAL DRAWING. 0 25mm	
DATE	FEBRUARY 2014
PROJ	427716
DWG	G-1
SHEET	1 of 15

FILENAME: 200-016-G-001_427716.dgn PLOT DATE: 2/12/2014 PLOT TIME: 5:15:48 PM

GENERAL NOTES

1. CONTOURS SHOWN ON DRAWINGS WERE PREPARED BY CRITIGEN CORPORATION FROM LIDAR DATED OCT 2011. PLANIMETRIC MAPPING PREPARED BY CRITIGEN CORPORATION FROM AERIAL PHOTOS DATED AUGUST 2012.
2. EXISTING TOPOGRAPHY, STRUCTURES, AND SITE FEATURES ARE SHOWN SCREENED AND OR LIGHT-LINED. NEW FINISH GRADE, STRUCTURES, AND SITE FEATURES ARE SHOWN HEAVY-LINED.
3. HORIZONTAL DATUM: NAD83, CSRS EPOCH 2002.
4. VERTICAL DATUM: CGVD 28 (HTV 2.0).
5. MAINTAIN, RELOCATE, OR REPLACE EXISTING SURVEY MONUMENTS, CONTROL POINTS, AND STAKES WHICH ARE DISTURBED OR DESTROYED. PERFORM THE WORK TO PRODUCE THE SAME LEVEL OF ACCURACY AS THE ORIGINAL MONUMENT(S) IN A TIMELY MANNER AND AT THE CONTRACTOR'S EXPENSE.
6. EXISTING UTILITIES, PIPELINES, STRUCTURES, AND CONNECTION POINTS ARE SHOWN ON DRAWINGS IN ACCORDANCE WITH AVAILABLE RECORDS. CONTRACTOR SHALL NOTIFY ALL UTILITY OFFICES WHICH ARE AFFECTED BY THE CONSTRUCTION OPERATION AT LEAST TWO WEEKS PRIOR TO COMMENCING EXCAVATION.
7. CAUTION: THERE ARE OVERHEAD UTILITIES IN THE WORK AREA. CONTRACTOR SHALL MAINTAIN REQUIRED CLEARANCE BETWEEN EQUIPMENT AND UTILITIES TO PROTECT ALL PERSONNEL, EQUIPMENT, AND UTILITIES. COORDINATE WITH UTILITY COMPANIES AS NECESSARY.
8. STATIONING AND DISTANCES SHOWN ON THE DRAWINGS ARE BASED ON HORIZONTAL MEASUREMENTS. REFERENCES TO LEFT OR RIGHT ON THE DRAWINGS ASSUME THE DIRECTION OF INCREASING STATION ALONG THE PIPELINE ALIGNMENT.
9. CONTRACTOR SHALL LIMIT CONSTRUCTION ACTIVITIES WITHIN THE WORK LIMITS SHOWN OR SPECIFIED. THIS SHALL INCLUDE, BUT NOT BE LIMITED TO, VEHICLES AND EQUIPMENT, LIMITS OF EXCAVATION, EXCAVATED MATERIAL AND BACKFILL MATERIAL STORAGE. WHERE WORK LIMITS ARE NOT SHOWN LIMIT CONSTRUCTION ACTIVITIES WITHIN ROAD RIGHT-OF-WAYS, UNLESS OTHERWISE SHOWN.
10. IT IS THE CONTRACTOR'S RESPONSIBILITY TO EXPLORE SUBSURFACE CONDITIONS AS NECESSARY PRIOR TO CONSTRUCTION IN ORDER TO DESIGN TRENCH DEWATERING AND SHORING SYSTEMS.
11. CONTOURS ARE TO BE RESTORED TO THE PRE-CONSTRUCTION CONDITION UNLESS OTHERWISE SHOWN.
12. REPAIR OR REPLACE ALL PROPERTY DAMAGED BY CONSTRUCTION.
13. SYMBOLS, LEGENDS, AND PIPE USE IDENTIFICATIONS SHOWN SHALL BE FOLLOWED THROUGHOUT THE DRAWINGS, WHEREVER APPLICABLE. NOT ALL OF THE VARIOUS PIPING COMPONENTS ARE NECESSARILY USED IN THE PROJECT.
14. SYMBOLS SHOWN ON LEGEND ARE GENERIC ONLY. REFER TO PIPING SPECIFICATIONS FOR SPECIFIC END CONNECTIONS.

ABBREVIATIONS

AC	ASPHALT CONCRETE
APPROX	APPROXIMATE
APVD	APPROVED
BC	BEGIN CURVE
BF	BLIND FLANGE
BO	BLOW OFF
BLDG	BUILDING
BP	BACKFLOW PREVENTER
CGVD	CANADIAN GEODETIC VERTICAL DATUM
CHK	CHECKED
CL	CENTER LINE
CARV	COMBINATION AIR RELEASE VALVE
CLSF	CONTROLLED LOW STRENGTH FILL
CONC	CONCRETE
CSRS	CANADIAN SPACIAL REFERENCE SYSTEM
CU	CUBIC, COPPER
DIA	DIAMETER
DR	DRAWN BY, DRIVE, DIMENSIONAL RATIO
DSGN	DESIGNED BY
DWG	DRAWING
E	EAST, EASTING
EC	END CURVE
EF	ELECTROFUSION
EL	ELEVATION
E(OH)	ELECTRIC OVERHEAD
EXST	EXISTING
FCA	FLANGE COUPLING ADAPTOR
FHY	FIRE HYDRANT
FLG	FLANGE
FT	FEET, FOOT
GALV	GALVANIZED
H	HORIZONTAL
HDPE	HIGH DENSITY POLYETHYLENE
ID	INTERMEDIATE DAM
INV	INVERT
IP	INTERMEDIATE POND
LBS	POUNDS
LF	LINEAR FEET
M	METRES
mm	MILIMETRES
MAX	MAXIMUM
MFR	MANUFACTURER
MIN	MINIMUM
MJ	MECHANICAL JOINT
N	NORTH, NORTHING
NAD83	NORTH AMERICAN DATUM OF 1983
NO.	NUMBER
NTS	NOT TO SCALE
OD	OUTSIDE DIAMETER
OG	ORIGINAL GROUND
OH	OVERHEAD
PE	PLAIN END, POLYETHYLENE
PEP	HDPE PIPE
PET	HDPE TUBING
PI	POINT OF INTERSECTION
POB	POINT OF BEGINNING
POC	POINT OF CONNECTION
POE	POINT OF ENDING
PROJ	PROJECT
PVC	POLYVINYL CHLORIDE
REQD	REQUIRED
RCD	ROSE CREEK DIVERSION
RD	ROAD
R/W	RIGHT OF WAY
S	SLOPE
SC	SERVICE CONNECTION
SD	STORM DRAIN
SIM	SIMILAR
SQ	SQUARE
SR	SURFACE RESTORATION
ST	STREET
STA	STATION
TYP	TYPICAL
UG	UNDERGROUND
UNK	UNKNOWN
V	VERTICAL
VC	VERTICAL CURVE
WTP	WATER TREATMENT PLANT
W/	WITH
WS	WATER SURFACE

LEGEND

CIVIL

- ABOVE GROUND PIPELINE
- EDGE OF UNPAVED ROAD
- WORK LIMITS AND/ OR BOUNDARY
- CENTERLINE
- CULVERT
- 2+000 — NEW PIPELINE W/ STATIONING
- COMBINATION AIR RELEASE VALVE (PLAN)
- BLOWOFF (PLAN)
- GATE VALVE
- REDUCER
- POWER POLE
- FIRE HYDRANT
- TEST PIT
- W — MONITORING WELL
- SURVEY CONTROL MONUMENT

PIPE, FITTING, AND VALVE SYMBOLS

- FLANGED JOINT
- ELBOW UP
- ELBOW DOWN
- TEE UP
- TEE DOWN
- CONCENTRIC REDUCER
- ECCENTRIC REDUCER
- UNION
- CAP
- ELBOW, 90 DEGREE
- TEE
- ELBOW, 45 DEGREE
- LATERAL
- REGULATED SIDE PRESSURE CONTROL VALVE
- CHECK VALVE
- BUTTERFLY VALVE
- GLOBE VALVE
- BALL VALVE
- AIR AND/ OR VACUUM RELEASE VALVE

DETAIL AND SECTION DESIGNATION

DETAIL (NUMERAL) DESIGNATION

ON DRAWING WHERE DETAIL IS TAKEN: 1 / C-1 — DRAWING NUMBER WHERE SHOWN (REPLACED WITH A LINE IF TAKEN AND SHOWN ON SAME SHEET)

ON DRAWING WHERE DETAIL IS SHOWN: 1 DETAIL 1/2"=1'-0" / C-1 — DRAWING NUMBER WHERE TAKEN (REPLACED WITH A LINE IF TAKEN AND SHOWN ON SAME SHEET)

SECTION (LETTER) DESIGNATION

ON DRAWING WHERE SECTION IS TAKEN: A / C-1 — SECTION DIRECTION; DRAWING NUMBER WHERE SHOWN (REPLACED WITH A LINE IF TAKEN AND SHOWN ON SAME SHEET)

ON DRAWING WHERE SECTION IS SHOWN: A SECTION 1/2"=1'-0" / C-1 — DRAWING NUMBER WHERE TAKEN (REPLACED WITH A LINE IF TAKEN AND SHOWN ON SAME SHEET)

PIPE AND VALVE DESIGNATIONS

PIPES

3" PW-PEP
- PIPE MATERIAL
- SERVICE
- PIPE NOMINAL DIAMETER

STANDARD DETAIL DESIGNATION

SHOWN ON STANDARD DETAIL DRAWING: 3123-110 — STANDARD DETAIL DESIGNATION (NUMERAL)

NOTE:

1. ALL STANDARD DETAILS ARE TYPICAL AND MUST BE USED EVEN IF STANDARD DETAIL DESIGNATION IS NOT SHOWN.

VALVES

V301
- VALVE TYPE, SEE SPECIFICATIONS
- VALVE DESIGNATION

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GOVERNMENT OF YUKON
DESIGN

GENERAL
CIVIL LEGEND, ABBREVIATIONS AND GENERAL NOTES

60% DESIGN - NOT FOR CONSTRUCTION

AS SHOWN
VERIFY SCALE
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SHEET	2 of 15

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SURVEY CONTROL MONUMENTS

POINT ID	LOCATION	NORTHING (m)	EASTING (m)	ELEVATION (m)
2010-P4	MAIN ROAD	6914202.677	582192.825	1118.245
2010-P5	NORTH OF CROSS VALLEY POND	6914557.921	580635.174	1060.480
2010-P7	FARO WEST	6915185.357	583895.571	1255.613
2010-P9	ROSE CREEK DIVERSION CHANNEL	6913817.662	580089.029	1084.706

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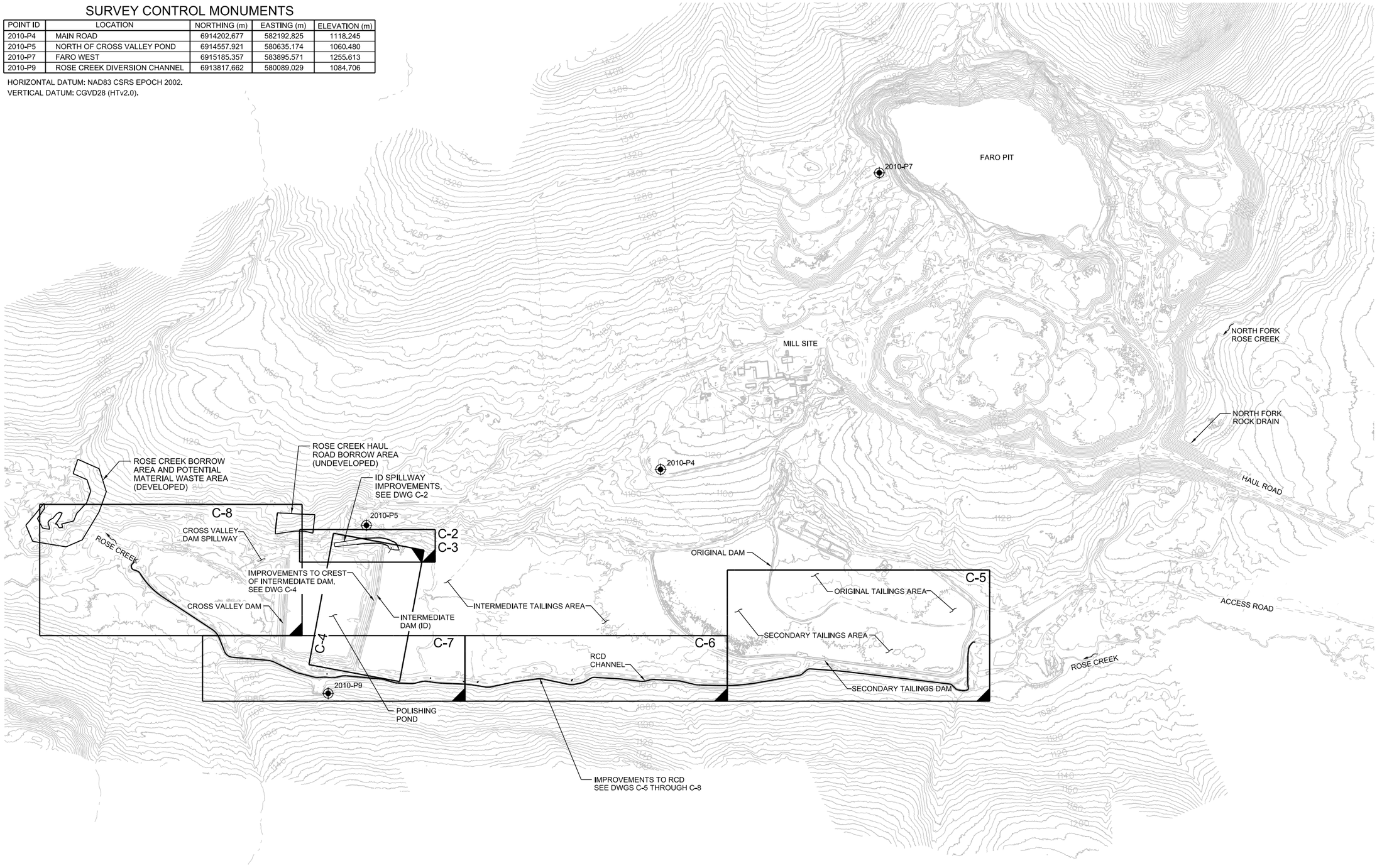
VERTICAL DATUM: CGVD28 (HTv2.0).



NOTE:

1. GRANITIC ROCK OUTCROP BORROW AREA NOT SHOWN. SEE DWG G-1

PLAN

SCALE: 1:10000 (FULL SIZE)
1:20000 (HALF SIZE)
CONTOUR INTERVAL 5m

N

NO.	DATE	DSGN	DR	CHK	APVD	BY
		LAA	KIS	checker	APVD	approver

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GOVERNMENT OF YUKON
DESIGN

CIVIL
OVERALL SITE PLAN, SURVEY CONTROL AND KEY MAP

60% DESIGN - NOT FOR CONSTRUCTION

1:1000
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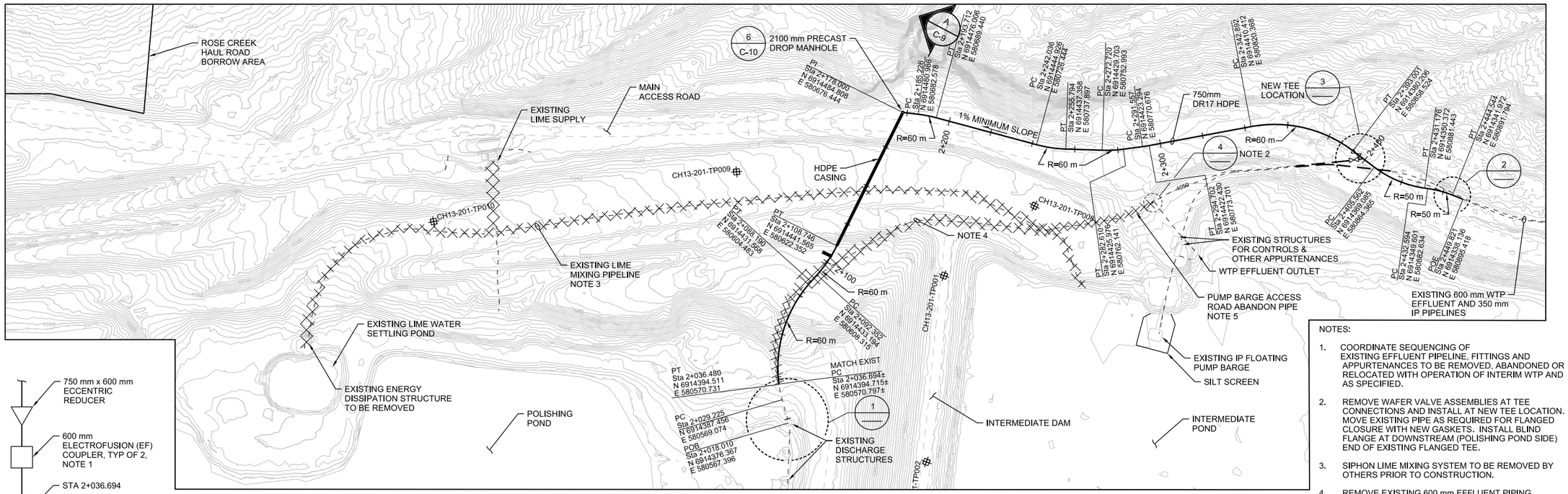

NOTES:

1. COORDINATE SEQUENCING OF EXISTING EFFLUENT PIPELINE, FITTINGS AND APPURTENANCES TO BE REMOVED, ABANDONED OR RELOCATED WITH OPERATION OF INTERIM WTP AND AS SPECIFIED.
2. REMOVE WAFER VALVE ASSEMBLIES AT TEE CONNECTIONS AND INSTALL AT NEW TEE LOCATION. MOVE EXISTING PIPE AS REQUIRED FOR FLANGED CLOSURE WITH NEW GASKETS. INSTALL BLIND FLANGE AT DOWNSTREAM (POLISHING POND SIDE) END OF EXISTING FLANGED TEE.
3. SIPHON LIME MIXING SYSTEM TO BE REMOVED BY OTHERS PRIOR TO CONSTRUCTION.
4. REMOVE EXISTING 600 mm EFFLUENT PIPING BETWEEN PUMP BARGE ACCESS ROAD AND STA 2+036.480 AFTER A SUCCESSFUL HYDROSTATIC TEST AND AS SPECIFIED.
5. ABANDON EXISTING PIPE UNDER PUMP BARGE ACCESS ROAD.

PLAN

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1:2000 (HALF SIZE)

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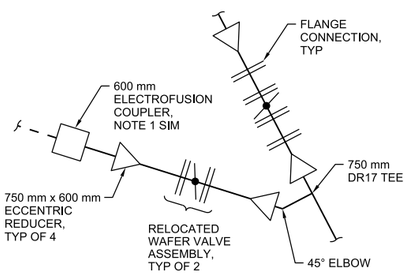
2 DETAIL NTS



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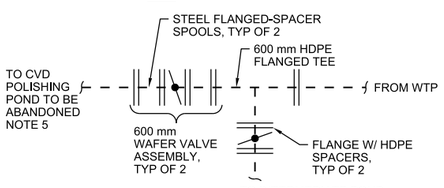
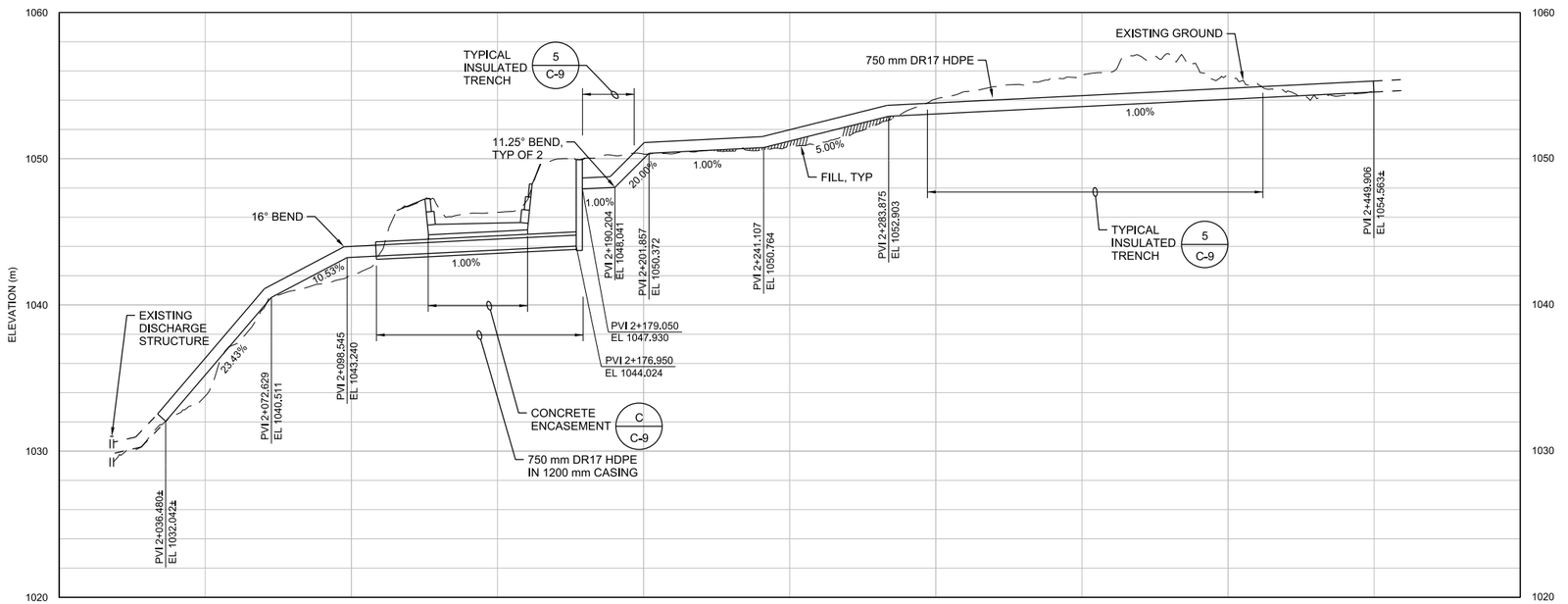


EXISTING VALVED TEE

4 DETAIL NTS



PROFILE

SCALE: HORIZ: 1:1000 VERT: 1:200 (FULL SIZE)
HORIZ: 1:2000 VERT: 1:400 (HALF SIZE)

NO.	DATE	REVISION	BY	APVD
DSGN	LAA	DR KIS	CHK	checker

2525 AIRPARK DR.
REDDING, CA 96001
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FARO MINE REMEDIATION PROJECT
DOWN VALLEY INTERIM HYDRAULIC UPGRADES
GOVERNMENT OF YUKON
DESIGN

CH2MHILL®

CIVIL
SPILLWAY PIPELINE RELOCATION
PLAN AND PROFILE

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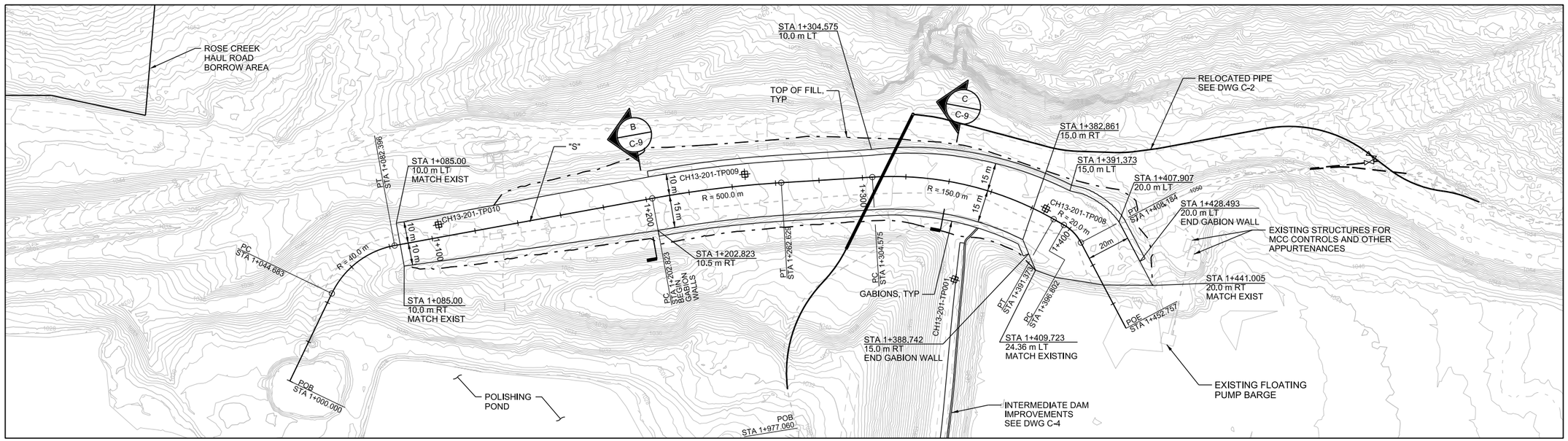
60% DESIGN - NOT FOR CONSTRUCTION

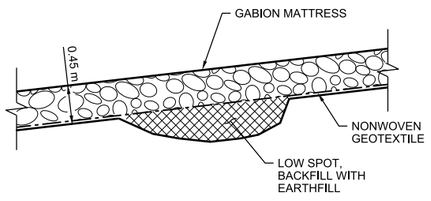
AS SHOWN	
VERIFY SCALE	
BAR IS 25mm ON ORIGINAL DRAWING. 0 25mm	
DATE	FEBRUARY 2014
PROJ	427716
DWG	C-2
SHEET	4 of 15

FILENAME: 200-016-C-202_427716.dgn PLOT DATE: 2014\02\12 PLOT TIME: 11:57:41 AM



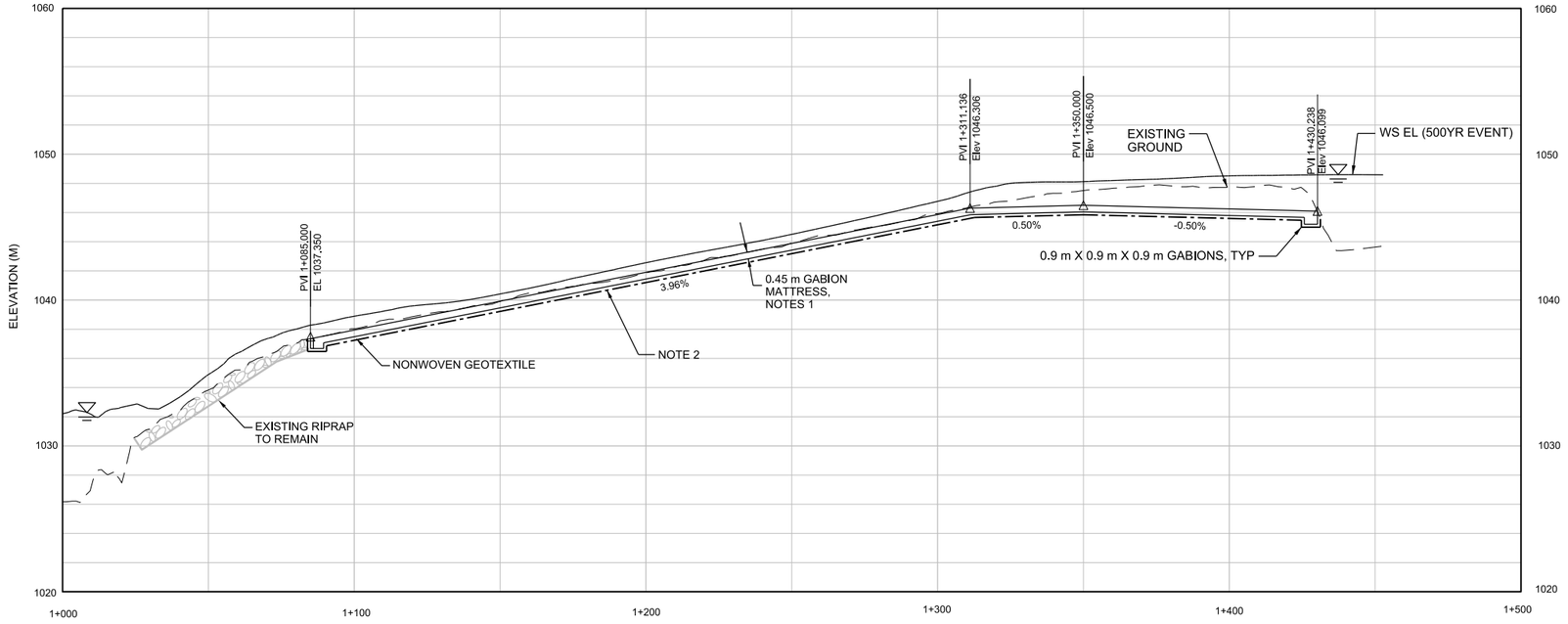
PLAN

SCALE: 1:1000 (FULL SIZE)
1:2000 (HALF SIZE)



1 DETAIL

NTS



PROFILE "S"

SCALE: HORIZ: 1:1000 VERT: 1:200 (FULL SIZE)
HORIZ: 1:2000 VERT: 1:400 (HALF SIZE)

NOTE:

1. EXCAVATE SPILLWAY TO GRADE SHOWN ON PROFILE AND INSTALL GABION MATTRESS (0.45m THICK MACCAFERRI GABION MAT OR EQUAL).
2. BOTTOM OF GABION MATTRESS TO CONFORM TO EXCAVATION BOTTOM. IF LOW SPOTS ARE ENCOUNTERED REFER TO DETAIL 1.

NO.	DATE	DR	REVISION	CHK	APVD	BY
DSGN		LAA		KIS	checker	approver

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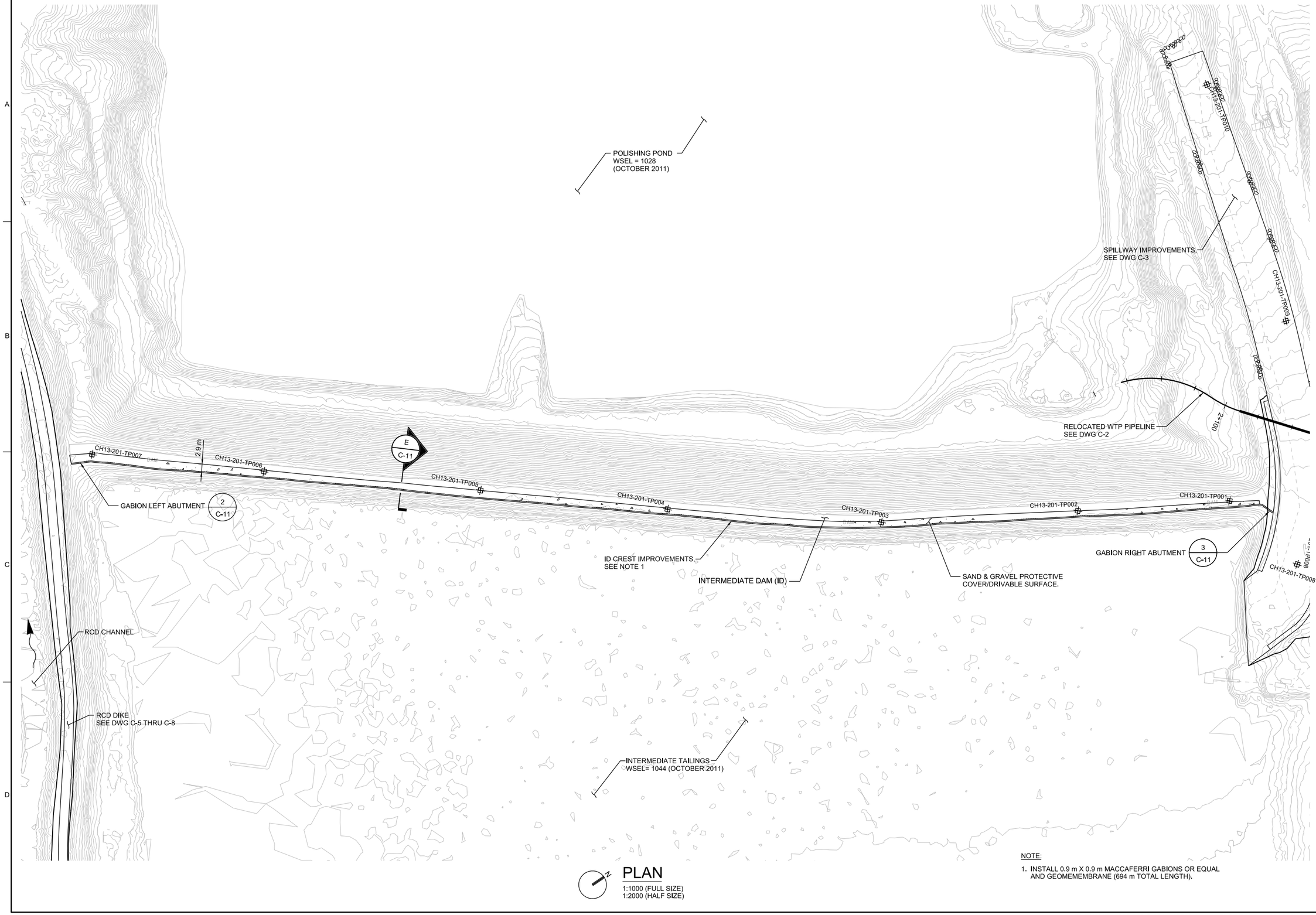
FARO MINE REMEDIATION PROJECT
DOWN VALLEY INTERIM HYDRAULIC UPGRADES
GOVERNMENT OF YUKON
DESIGN

CIVIL
SPILLWAY IMPROVEMENT
PLAN AND PROFILE

AS SHOWN	
VERIFY SCALE	
BAR IS 25mm ON ORIGINAL DRAWING. 0 25mm	
DATE	FEBRUARY 2014
PROJ	427716
DWG	C-3
SHEET	5 of 15

FILENAME: 200-016-C-203_427716.dgn PLOT DATE: 2014\02\12 PLOT TIME: 4:25:14 PM



PLAN

1:1000 (FULL SIZE)
1:2000 (HALF SIZE)

NOTE:

1. INSTALL 0.9 m X 0.9 m MACCAFERRI GABIONS OR EQUAL AND GEOMEMEMBRANE (694 m TOTAL LENGTH).

NO.	DATE	REVISION	BY	APVD
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FARO MINE REMEDIATION PROJECT
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GOVERNMENT OF YUKON
DESIGN

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CIVIL
INTERMEDIATE DAM IMPROVEMENT PLAN

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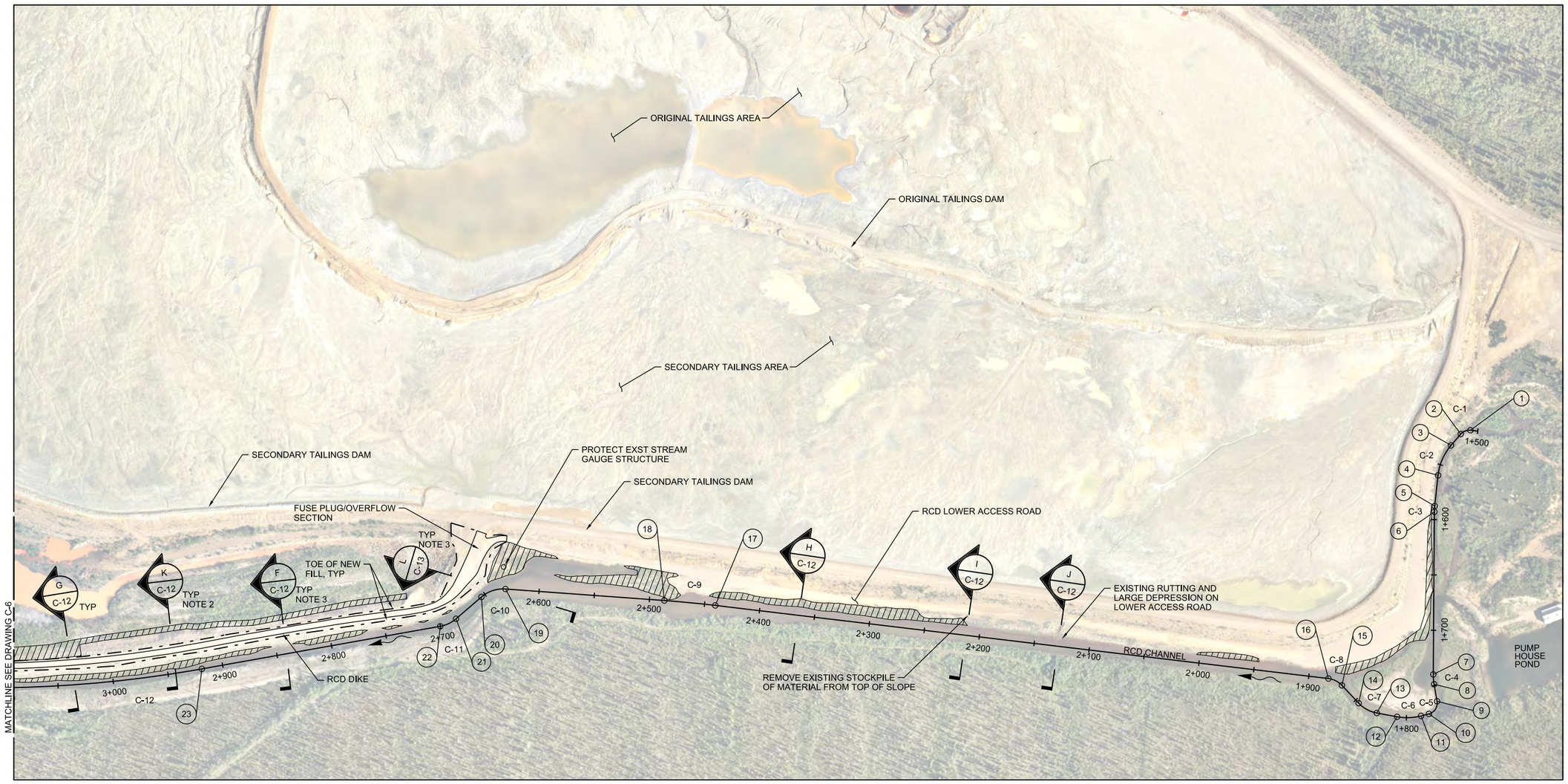
VERIFY SCALE
BAR IS 25mm ON ORIGINAL DRAWING.
0 25mm

DATE	FEBRUARY 2014
PROJ	427716
DWG	C-4
SHEET	6 of 15

FILENAME: 200-016-C-204_427716.dgn PLOT DATE: 2014\02\02 PLOT TIME: 1:14:51 PM



PLAN

SCALE: 1:2000 (FULL SIZE)
1:4000 (HALF SIZE)

"RCD" ALIGNMENT POINT CONTROL

POINT NO.	DESCRIPTION	STATION	NORTHING	EASTING
1	PC	1+506.687	6912689.377	583356.773
2	PT	1+516.442	6912689.725	583347.408
3	PC	1+529.904	6912683.863	583335.289
4	PT	1+559.824	6912663.777	583313.717
5	PC	1+587.733	6912639.583	583299.804
6	PT	1+592.904	6912634.974	583297.462
7	PC	1+739.879	6912500.679	583237.744
8	PT	1+748.781	6912492.267	583234.868
9	PC	1+764.404	6912477.093	583231.149
10	PT	1+779.287	6912469.598	583219.863
11	PC	1+786.651	6912470.756	583212.592
12	PT	1+808.487	6912478.717	583192.444
13	PC	1+827.164	6912489.180	583176.973
14	PT	1+846.152	6912503.935	583165.529
15	PC	1+868.214	6912524.710	583158.105
16	PT	1+882.155	6912535.231	583149.391
17	PC	2+440.224	6912817.602	582668.031
18	PT	2+486.525	6912840.096	582627.567
19	PC	2+630.461	6912907.101	582500.177
20	PT	2+653.951	6912909.221	582477.381
21	PC	2+684.176	6912900.324	582448.495
22	PT	2+700.195	6912899.821	582432.673
23	PC	2+919.041	6912950.824	582219.854

"RCD" ALIGNMENT CURVE DATA

CURVE NO.	RADIUS	DELTA	LENGTH	TANGENT
C1	10.000	55°53'19"	9.754	5.305
C2	50.000	34°17'09"	29.92	15.423
C3	50.000	5°55'36"	5.172	2.588
C4	50.000	10°12'05"	8.902	4.463
C5	10.000	85°16'31"	14.883	9.208
C6	50.000	25°01'23"	21.837	11.095
C7	30.000	36°15'50"	18.988	9.824
C8	20.000	39°56'19"	13.941	7.267
C9	1000.000	2°39'10"	46.301	23.154
C10	30.000	44°51'41"	23.489	12.384
C11	30.000	30°35'41"	16.019	8.206
C12	1100.000	11°55'52"	229.063	114.947

NOTES:

1. ALL TREES OR WOODY VEGETATION GREATER THAN 50 mm CALIPER DIAMETER OR HIGHER THAN 2 m SHALL BE REMOVED. ROOTS ARE GENERALLY TO REMAIN IN PLACE, BUT SOME ROOTS CONSIDERED DETRIMENTAL TO THE STABILITY OF THE DIKE SHALL BE REMOVED AT THE DIRECTION OF THE ENGINEER.
2. FREQUENT PREVIOUSLY REPAIRED, DISTRESSED OR INADEQUATELY ARMORED DIKE SLOPES IN THIS REACH. REPAIR SLOPES AND AUGMENT RIPRAP AS SHOWN.
3. RAISE CREST ELEVATION TO GRADES SHOWN IN TABLE 1 ON C-12 AND EXTEND RIPRAP EROSION PROTECTION TO DIKE CREST.

LEGEND:

- WOODY VEGETATION REMOVAL, NOTE 1
- TOE OF NEW FILL
- EDGE OF RCD DIKE CREST RAISE
- (1) CURVE PC/PT NUMBER

NO.	DATE	DSGN	DR	CHK	APVD	REVISION	BY	APVD
			LAA	JPS	checker		approver	

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FARO MINE REMEDIATION PROJECT
DOWN VALLEY INTERIM HYDRAULIC UPGRADES
GOVERNMENT OF YUKON
DESIGN

CH2MHILL®

CIVIL

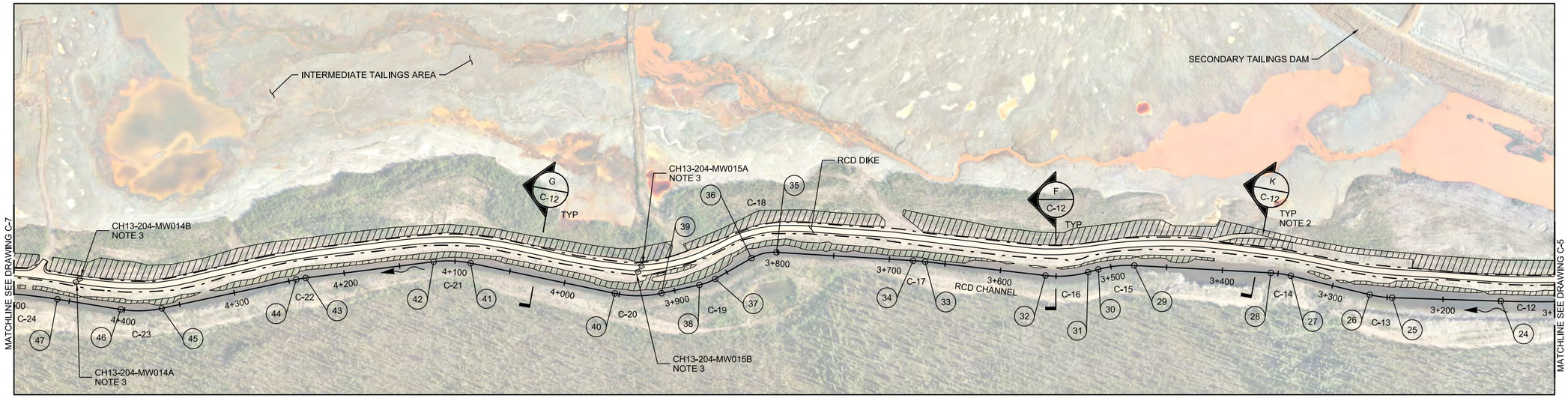
ROSE CREEK DIVERSION CHANNEL
IMPROVEMENT PLAN
STA 1+500 TO 3+100

60% DESIGN - NOT FOR CONSTRUCTION

AS SHOWN
VERIFY SCALE
BAR IS 25mm ON ORIGINAL DRAWING.
0 25mm

DATE	FEBRUARY 2014
PROJ	427716
DWG	C-5
SHEET	7 of 15

FILENAME: 200-016-C-205_427716.dgn PLOT DATE: 2014\02\14 PLOT TIME: 1:51:35 PM



PLAN

SCALE: 1:2000 (FULL SIZE)
1:4000 (HALF SIZE)

N

"RCD" ALIGNMENT POINT CONTROL

POINT NO.	DESCRIPTION	STATION	NORTHING	EASTING
24	PT	3+148.104	6913026.932	582004.243
25	PC	3+245.444	6913068.697	581916.318
26	PT	3+265.797	6913079.235	581898.946
27	PC	3+338.414	6913123.007	581841.005
28	PT	3+356.519	6913132.557	581825.652
29	PC	3+479.019	6913187.590	581716.211
30	PT	3+511.417	6913197.244	581685.433
31	PC	3+521.051	6913198.607	581675.895
32	PT	3+559.495	6913211.139	581639.801
33	PC	3+667.913	6913265.610	581546.061
34	PT	3+678.707	6913270.770	581536.586
35	PC	3+801.311	6913326.570	581427.411
36	PT	3+824.458	6913330.726	581404.967
37	PC	3+861.984	6913326.746	581367.653
38	PT	3+877.170	6913327.436	581352.541
39	PC	3+911.939	6913334.258	581318.448
40	PT	3+954.025	6913350.830	581280.099
41	PC	4+085.926	6913427.290	581172.620
42	PT	4+119.191	6913441.752	581142.834
43	PC	4+234.728	6913474.313	581031.980
44	PT	4+243.208	6913476.355	581023.752
45	PC	4+366.400	6913500.937	580903.038
46	PT	4+403.448	6913514.810	580868.913
47	PC	4+460.862	6913545.858	580820.619

"RCD" ALIGNMENT CURVE DATA

CURVE NO.	RADIUS	DELTA	LENGTH	TANGENT
C13	100.000	11°39'42"	20.353	10.212
C14	100.000	10°22'25"	18.105	9.078
C15	100.000	18°33'46"	32.398	16.342
C16	100.000	22°01'37"	38.444	19.462
C17	200.000	3°05'32"	10.794	5.398
C18	40.000	33°09'18"	23.147	11.907
C19	50.000	17°24'06"	15.186	7.652
C20	100.000	24°06'49"	42.086	21.359
C21	100.000	19°03'33"	33.265	16.787
C22	100.000	4°51'32"	8.48	4.243
C23	100.000	21°13'36"	37.046	18.739
C24	500.000	6°37'56"	57.876	28.97

NOTES:

1. ALL TREES OR WOODY VEGETATION GREATER THAN 50 mm CALIPER DIAMETER OR HIGHER THAN 2 m SHALL BE REMOVED. ROOTS ARE GENERALLY TO REMAIN IN PLACE, BUT SOME ROOTS CONSIDERED DETRIMENTAL TO THE STABILITY OF THE DIKE SHALL BE REMOVED AT THE DIRECTION OF THE ENGINEER.
2. FREQUENT PREVIOUSLY REPAIRED, DISTRESSED OR INADEQUATELY ARMORED DIKE SLOPES IN THIS REACH. REPAIR SLOPES AND AUGMENT RIPRAP IN ACCORDANCE WITH SECTION K ON C-12.
3. RAISE EXISTING MONITORING WELL CASING TO GRADE.

LEGEND:

- WOODY VEGETATION REMOVAL, NOTE 1
- TOE OF NEW FILL
- EDGE OF RCD DIKE CREST RAISE
- (1) CURVE PC/PT NUMBER

NO.	DATE	DSGN	DR	CHK	APVD	BY	REVISION
		LAA	JPS	checker	approver	APVD	

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ROSE CREEK DIVERSION CHANNEL
IMPROVEMENT PLAN
STA 3+100 TO 4+500

FARO MINE REMEDIATION PROJECT
DOWN VALLEY INTERIM HYDRAULIC UPGRADES
GOVERNMENT OF YUKON
DESIGN

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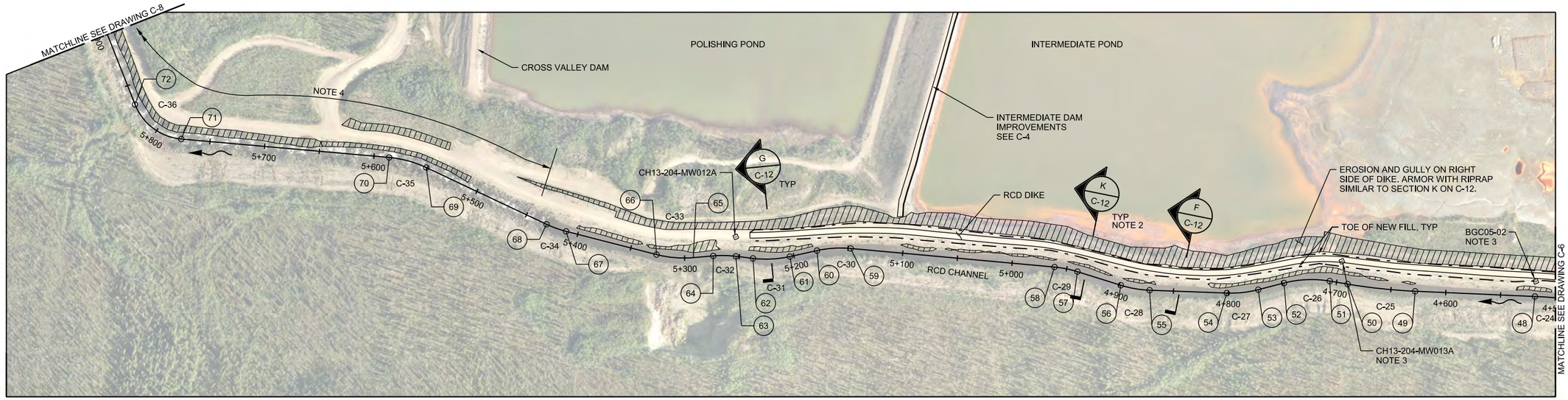
VERIFY SCALE
BAR IS 25mm ON ORIGINAL DRAWING.
0 25mm

DATE	FEBRUARY 2014
PROJ	427716
DWG	C-6
SHEET	8 of 15

FILENAME: 200-016-C-206_427716.dgn PLOT DATE: 2014\02\14 PLOT TIME: 1:33:19 PM



PLAN

SCALE: 1:2000 (FULL SIZE)
1:4000 (HALF SIZE)

N

LEGEND:

- WOODY VEGETATION REMOVAL, NOTE 1
- TOE OF NEW FILL
- EDGE OF RCD DIKE CREST RAISE
- (1) CURVE PC/PT NUMBER

NOTES:

1. ALL TREES OR WOODY VEGETATION GREATER THAN 50 mm CALIPER DIAMETER OR HIGHER THAN 2 m SHALL BE REMOVED. ROOTS ARE GENERALLY TO REMAIN IN PLACE, BUT SOME ROOTS CONSIDERED DETRIMENTAL TO THE STABILITY OF THE DIKE SHALL BE REMOVED AT THE DIRECTION OF THE ENGINEER.
2. FREQUENT PREVIOUSLY REPAIRED, DISTRESSED OR INADEQUATELY ARMORED DIKE SLOPES IN THIS REACH. REPAIR SLOPES AND AUGMENT RIPRAP IN ACCORDANCE WITH SECTION K ON C-12.
3. RAISE EXISTING MONITORING WELL CASING TO GRADE.
4. DO NOT REMOVE ROOTS FROM HIGH GRADIENT SECTIONS OF RCD WHICH ARE ARMORED WITH LARGE DIAMETER RIPRAP.

"RCD" ALIGNMENT POINT CONTROL

POINT NO.	DESCRIPTION	STATION	NORTHING	EASTING
48	PT	4+518.738	6913574.272	580770.235
49	PC	4+627.92	6913622.315	580672.190
50	PT	4+689.730	6913652.869	580618.506
51	PC	4+706.301	6913661.940	580604.639
52	PT	4+748.292	6913676.985	580565.765
53	PC	4+772.501	6913680.826	580541.863
54	PT	4+801.444	6913689.461	580514.343
55	PC	4+871.754	6913719.964	580450.995
56	PT	4+898.467	6913734.612	580428.751
57	PC	4+939.870	6913761.785	580397.512
58	PT	4+961.181	6913773.958	580380.070
59	PC	5+147.644	6913863.809	580216.683
60	PT	5+178.457	6913874.296	580187.839
61	PC	5+203.747	6913879.188	580163.027
62	PT	5+237.532	6913891.146	580131.600
63	PC	5+253.212	6913899.106	580118.091
64	PT	5+273.883	6913907.692	580099.328
65	PC	5+292.112	6913913.527	580082.058
66	PT	5+325.853	6913929.465	580052.499
67	PC	5+410.921	6913961.837	579985.465
68	PT	5+429.872	6913994.845	579971.723
69	PC	5+550.920	6914086.004	579892.080
70	PT	5+586.147	6914107.947	579864.755
71	PC	5+776.242	6914199.159	579697.973
72	PT	5+831.538	6914244.605	579671.995

"RCD" ALIGNMENT CURVE DATA

CURVE NO.	RADIUS	DELTA	LENGTH	TANGENT
C25	500.000	7°04'58"	61.81	30.944
C26	100.000	24°03'33"	41.991	21.31
C27	100.000	16°34'59"	28.943	14.573
C28	100.000	15°18'21"	26.714	13.437
C29	100.000	12°12'37"	21.311	10.696
C30	100.000	17°39'17"	30.813	15.53
C31	100.000	19°21'28"	33.786	17.055
C32	100.000	11°50'37"	20.671	10.372
C33	100.000	19°19'56"	33.741	17.032
C34	100.000	10°51'29"	18.951	9.504
C35	100.000	20°11'01"	35.227	17.798
C36	50.000	63°21'51"	55.296	30.859

NO.	DATE	DR	CHK	APVD	BY	REVISION
DSGN		LAA	JPS	checker	APVD	approver

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FARO MINE REMEDIATION PROJECT
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GOVERNMENT OF YUKON
DESIGN

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ROSE CREEK DIVERSION CHANNEL
IMPROVEMENT PLAN
STA 4+500 TO 5+900

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VERIFY SCALE
BAR IS 25mm ON ORIGINAL DRAWING.
0 25mm

DATE	FEBRUARY 2014
PROJ	427716
DWG	C-7
SHEET	9 of 15

FILENAME: 200-016-C-207_427716.dgn PLOT DATE: 2014\02\14 PLOT TIME: 1:35:45 PM



"RCD" ALIGNMENT POINT CONTROL				
POINT NO.	DESCRIPTION	STATION	NORTHING	EASTING
73	PC	5+906.803	6914320.022	579674.672
74	PT	5+968.177	6914378.228	579658.481
75	PC	6+282.113	6914641.137	579486.916
76	PT	6+457.436	6914803.971	579425.807
77	PC	6+460.212	6914806.719	579425.420
78	PT	6+481.595	6914825.128	579415.452
79	PC	6+498.231	6914836.074	579402.926
80	PT	6+539.279	6914869.773	579408.834

"RCD" ALIGNMENT CURVE DATA				
CURVE NO.	RADIUS	DELTA	LENGTH	TANGENT
C37	100.000	35°09'55"	61.375	31.688
C38	400.000	25°06'47"	175.323	89.092
C39	30.000	40°50'24"	21.384	11.169
C40	20.000	117°35'44"	41.049	33.021

PLAN

SCALE: 1:2000 (FULL SIZE)
1:4000 (HALF SIZE)

N

NOTES:

1. ALL TREES OR WOODY VEGETATION GREATER THAN 50 mm CALIPER DIAMETER OR HIGHER THAN 2 m SHALL BE REMOVED. ROOTS ARE GENERALLY TO REMAIN IN PLACE, BUT SOME ROOTS CONSIDERED DETRIMENTAL TO THE STABILITY OF THE DIKE SHALL BE REMOVED AT THE DIRECTION OF THE ENGINEER.
2. DO NOT REMOVE ROOTS FROM HIGH GRADIENT SECTIONS OF RCD WHICH ARE ARMORED WITH LARGE DIAMETER RIPRAP.

LEGEND:

- WOODY VEGETATION REMOVAL, NOTE 1
- TOE OF NEW FILL
- EDGE OF RCD DIKE CREST RAISE
- (1) CURVE PC/PT NUMBER

NO.	DATE	REVISION	DR	CHK	BY
DSGN	LAA		JPS	checker	APVD
				approver	APVD

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FARO MINE REMEDIATION PROJECT
DOWN VALLEY INTERIM HYDRAULIC UPGRADES
GOVERNMENT OF YUKON
DESIGN

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ROSE CREEK DIVERSION CHANNEL
IMPROVEMENT PLAN
STA 5+900 TO 6+573

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VERIFY SCALE
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0 25mm

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SHEET	10 of 15

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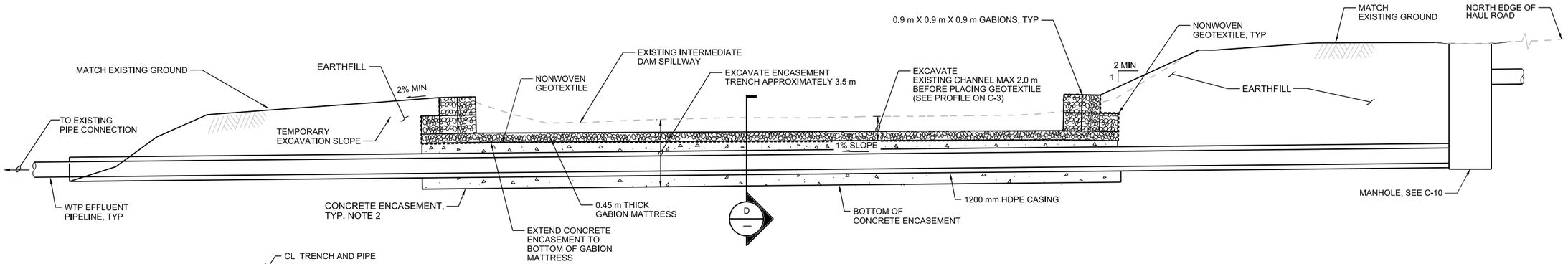
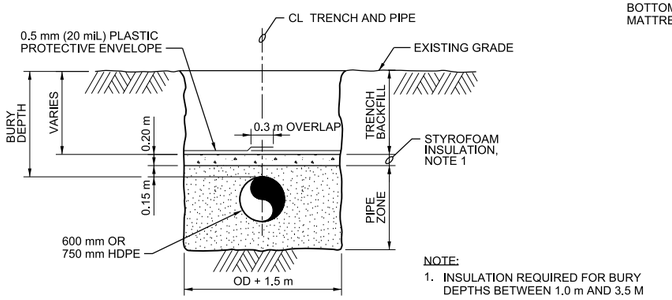


INTERMEDIATE DAM SPILLWAY UNDERCROSSING

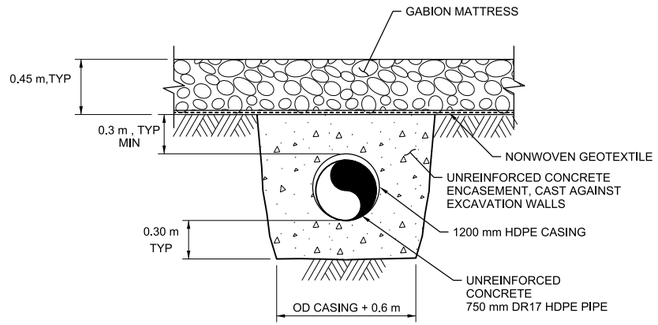
A SECTION
NTS
C-2



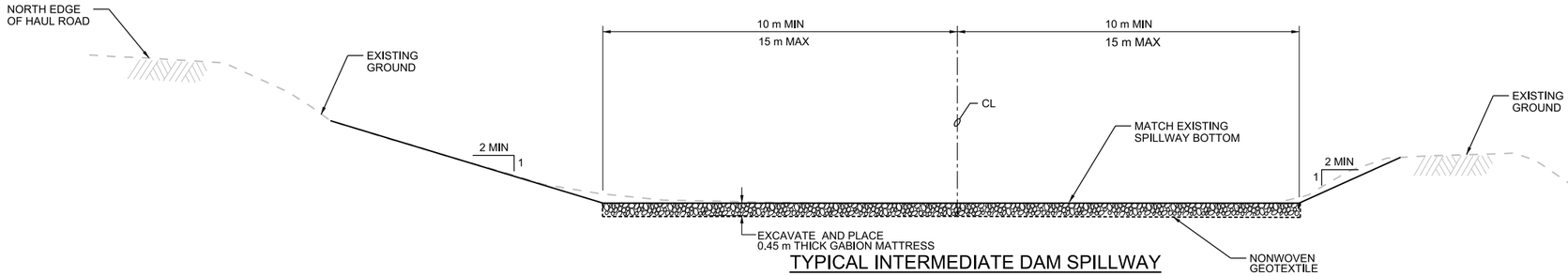
NOTE:
1. INSULATION REQUIRED FOR BURY DEPTHS BETWEEN 1.0 m AND 3.5 M

TYPICAL INSULATED TRENCH

5 DETAIL
NTS
C-2

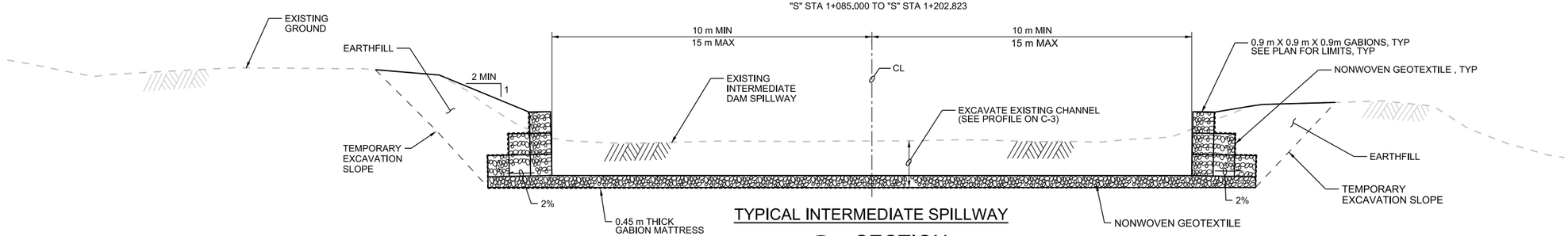


D SECTION
NTS



TYPICAL INTERMEDIATE DAM SPILLWAY

B SECTION
NTS
C-3
"S" STA 1+085.000 TO "S" STA 1+202.823



TYPICAL INTERMEDIATE SPILLWAY

C SECTION
NTS
C-3
"S" STA 1+202.823 TO "S" STA 1+430.238

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FARO MINE REMEDIATION PROJECT
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GOVERNMENT OF YUKON
DESIGN

CIVIL
SECTIONS AND DETAILS
SPILLWAY IMPROVEMENTS

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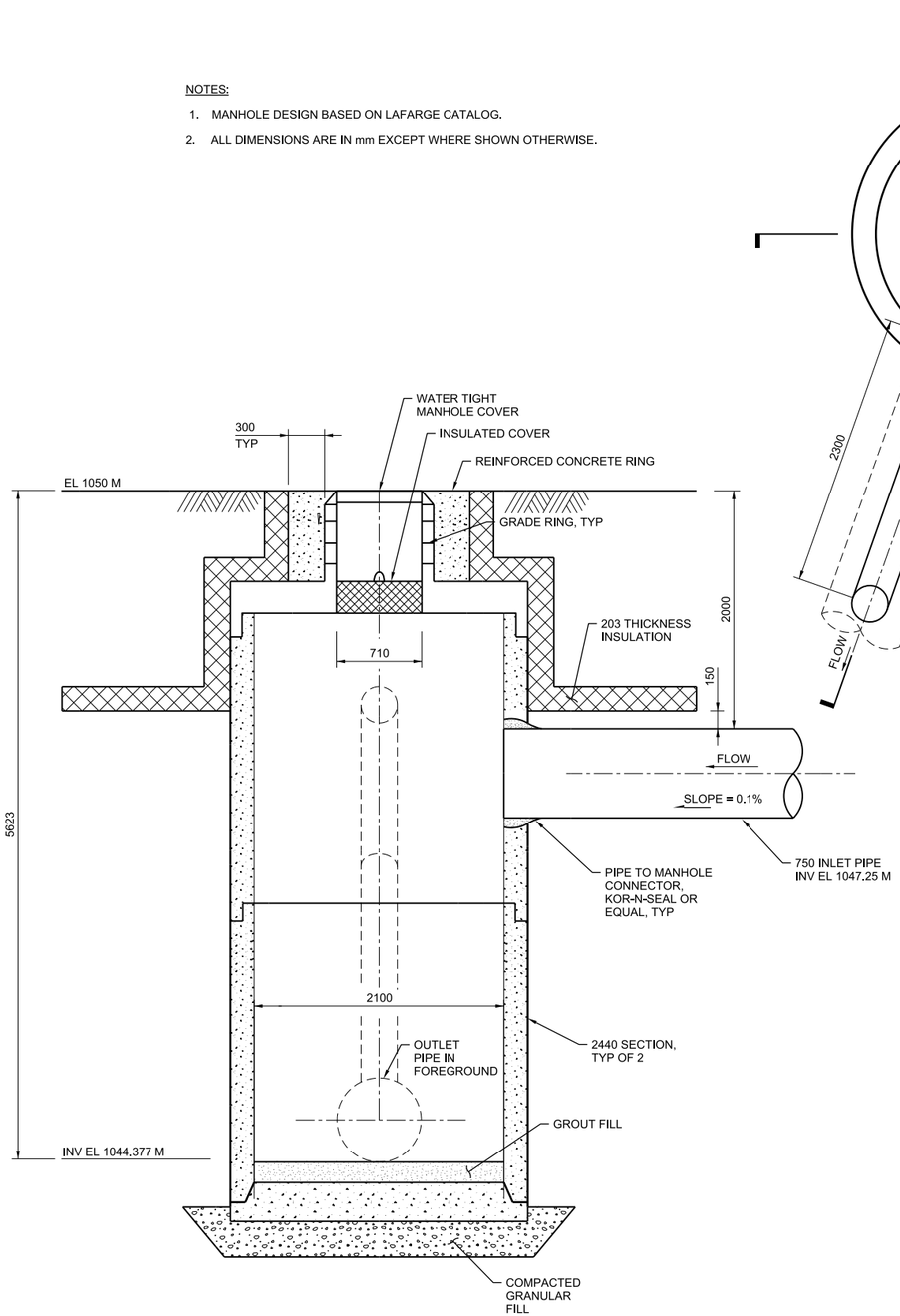
NOTES:

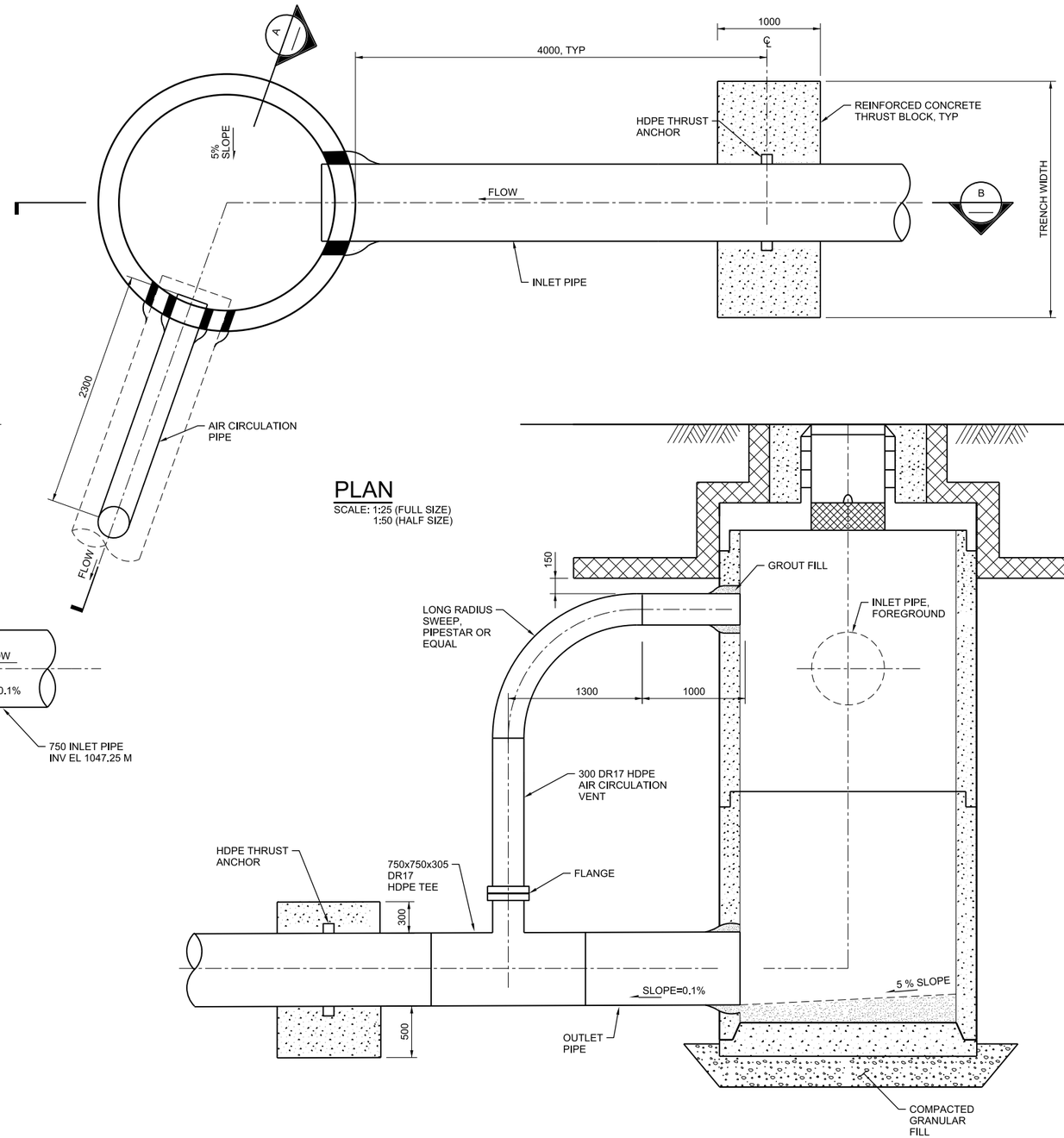
1. MANHOLE DESIGN BASED ON LAFARGE CATALOG.
2. ALL DIMENSIONS ARE IN mm EXCEPT WHERE SHOWN OTHERWISE.



MANHOLE

A SECTION

1:25 (FULL SIZE)
1:50 (HALF SIZE)



PLAN

SCALE: 1:25 (FULL SIZE)
1:50 (HALF SIZE)

MANHOLE

B SECTION

1:25 (FULL SIZE)
1:50 (HALF SIZE)

6 MANHOLE DETAIL

AS SHOWN

C-2

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DROP MANHOLE
PLAN AND SECTIONS
SPILLWAY IMPROVEMENTS

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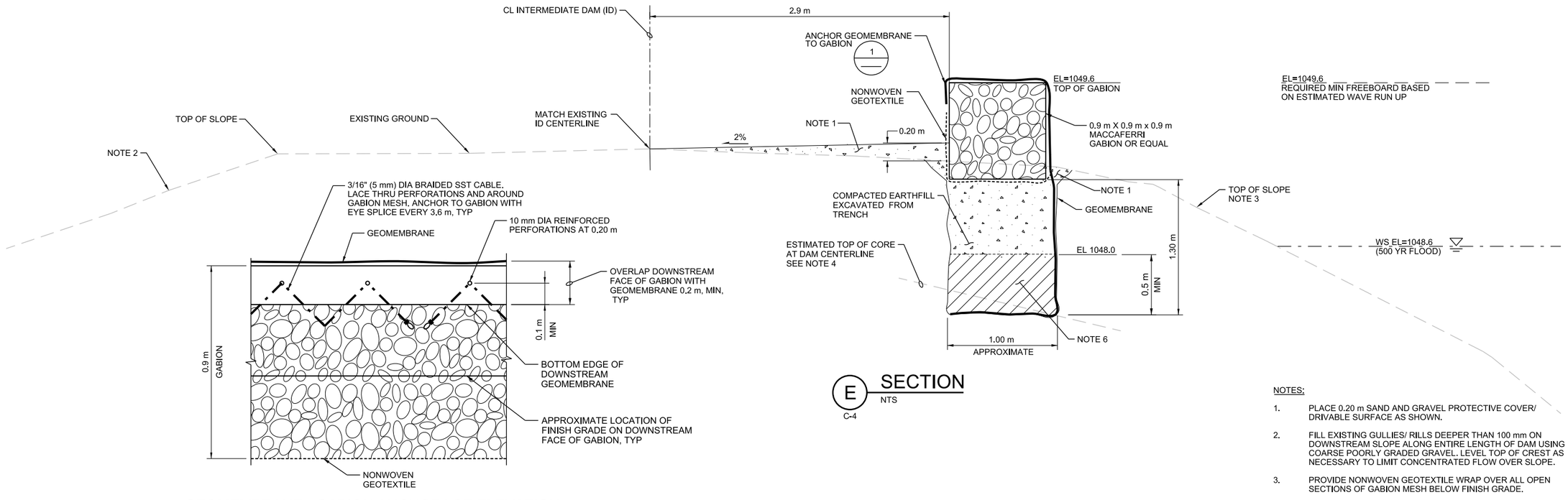


E SECTION
NTS
C-4

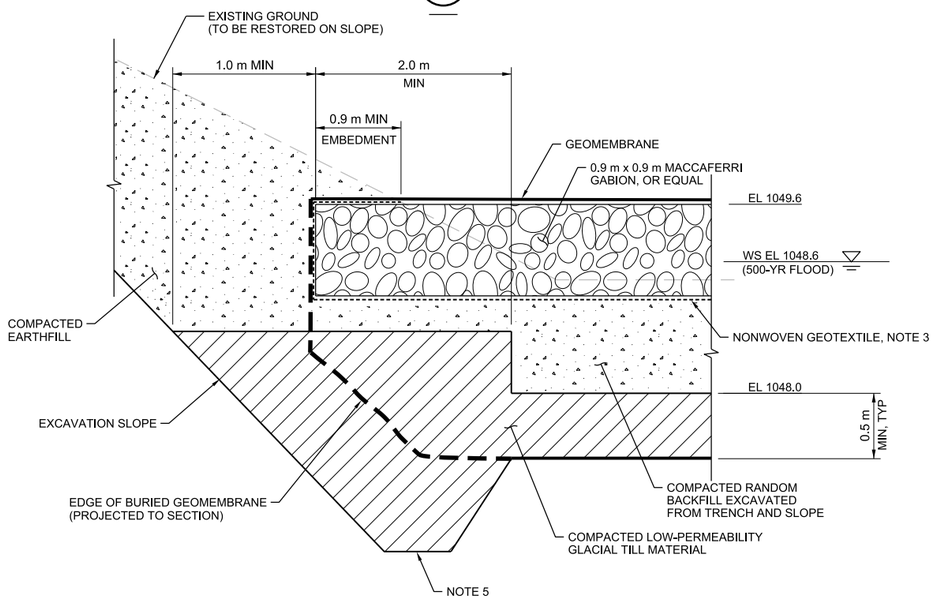
NOTES:

1. PLACE 0.20 m SAND AND GRAVEL PROTECTIVE COVER/ DRIVABLE SURFACE AS SHOWN.
2. FILL EXISTING GULLIES/ RILLS DEEPER THAN 100 mm ON DOWNSTREAM SLOPE ALONG ENTIRE LENGTH OF DAM USING COARSE POORLY GRADED GRAVEL. LEVEL TOP OF CREST AS NECESSARY TO LIMIT CONCENTRATED FLOW OVER SLOPE.
3. PROVIDE NONWOVEN GEOTEXTILE WRAP OVER ALL OPEN SECTIONS OF GABION MESH BELOW FINISH GRADE.
4. NEAR THE CENTERLINE, THE DAM CORE WAS FOUND TO BE W/IN 0.3 TO 0.6 m OF THE GROUND SURFACE AS OBSERVED DURING THE 2013 TEST PIT INVESTIGATION BY CH2M HILL.
5. EXCAVATE AND EXTEND COMPACTED LOW PERMEABILITY GLACIAL TILL IN THE BOTTOM AS DETERMINED NECESSARY IN THE FIELD AND APPROVED BY ENGINEER.
6. EXCAVATE TRENCH TO INSTALL GEOMEMBRANE, REPLACE AND COMPACT WITH LOW PERMEABILITY MATERIAL WHERE EXCAVATION PENETRATES EMBANKMENT CORE AS VERIFIED BY ENGINEER IN THE FIELD.

GEOMEMBRANE - GABION ANCHORAGE ELEVATION

(LOOKING UPSTREAM)

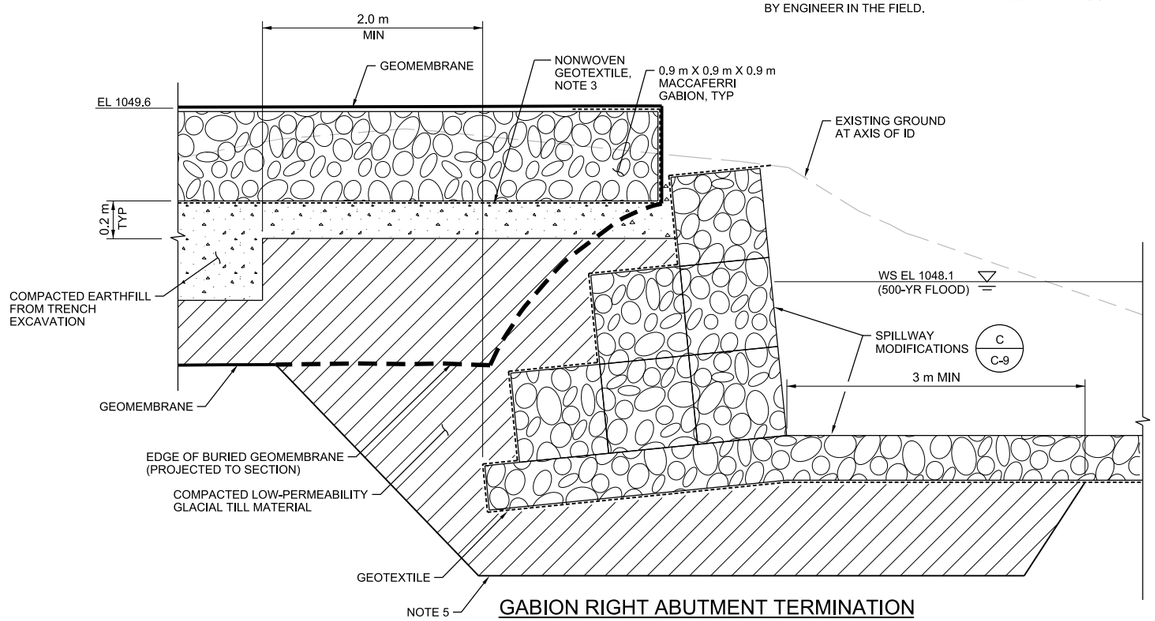
1 DETAIL
NTS



GABION LEFT ABUTMENT TERMINATION

NOTE: SECTION THROUGH ℄ OF GABION WALL

2 DETAIL
NTS
C-4



GABION RIGHT ABUTMENT TERMINATION

NOTE: SECTION THROUGH ℄ OF GABION WALL

3 DETAIL
NTS
C-4

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INTERMEDIATE DAM
IMPROVEMENTS

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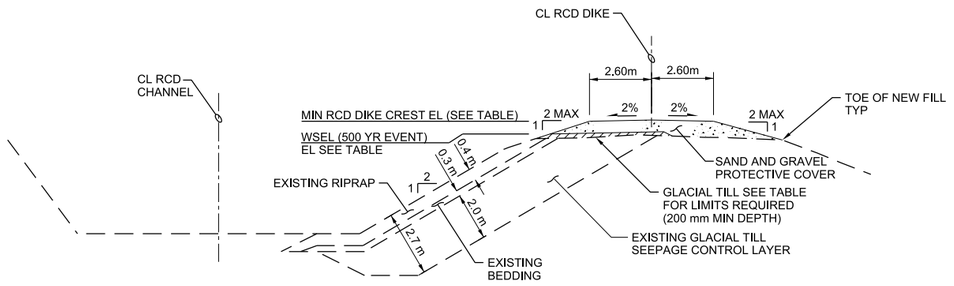


CREST RAISE

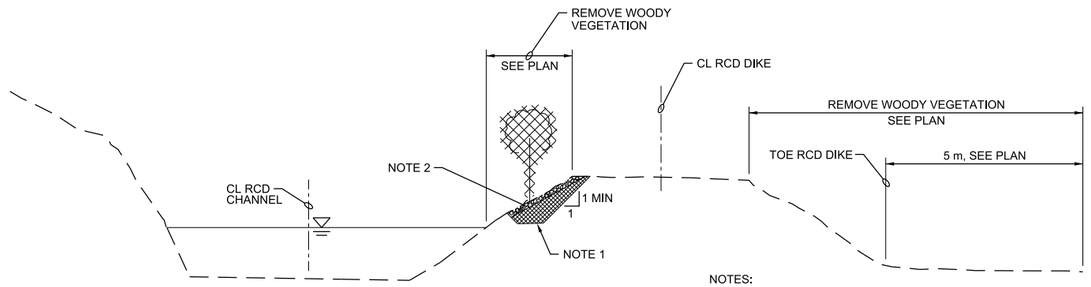
F SECTION
NTS

C-5
C-6
C-7

TABLE 1: RCD DIKE CREST RAISE DATA

RCD DIKE					
"RCD" STA	"RCD" OFFSET LEFT (m)	WSEL (500-YR EVENT) (m)	MIN. RCD DIKE CREST EL (m)	MIN GLACIAL TILL THICKNESS	MIN SAND/GRAVEL THICKNESS
3+950.00	22.17	1055.68	1056.18		0.42
4+000.00	19.48	1055.51	1056.01	0.20	0.42
4+050.00	19.57	1055.43	1055.93	0.20	0.40
4+100.00	16.43	1055.34	1055.84	0.20	0.37
4+150.00	17.77	1055.27	1055.77	0.20	0.49
4+200.00	18.12	1055.18	1055.68	0.22	0.50
4+250.00	18.19	1055.03	1055.53	0.20	0.39
4+300.00	18.03	1054.86	1055.36	0.20	0.36
4+350.00	17.38	1054.73	1055.23		0.45
4+400.00	19.25	1054.59	1055.09		0.41
4+450.00	16.51	1054.53	1055.03		0.35
4+500.00	16.21	1054.42	1054.92		0.48
4+550.00	16.84	1054.33	1054.83		0.48
4+600.00	18.20	1054.27	1054.77	0.20	0.33
4+650.00	19.11	1054.24	1054.74	0.20	0.47
4+700.00	18.44	1054.19	1054.69	0.46	0.50
4+750.00	15.02	1054.10	1054.60	0.41	0.50
4+800.00	16.35	1053.88	1054.38	0.21	0.50
4+850.00	15.49	1053.66	1054.16	0.20	0.36
4+900.00	18.05	1053.61	1054.11		0.32
4+950.00	15.29	1053.45	1053.95		0.41
5+000.00	17.02	1053.34	1053.84		0.44
5+050.00	17.04	1053.20	1053.70		0.38
5+100.00	17.25	1053.01	1053.51		0.01
5+150.00	13.74	1052.89	1053.39		0.14
5+200.00	17.68	1052.75	1053.25		0.24
5+242.45	18.30	1052.59	1053.09		0.00

RCD DIKE					
"RCD" STA	"RCD" OFFSET LEFT (m)	WSEL (500-YR EVENT) (m)	MIN. RCD DIKE CREST EL (m)	MIN GLACIAL TILL THICKNESS	MIN SAND/GRAVEL THICKNESS
2+639.32	53.55	1058.04	1059.42		0.00
2+650.00	28.26	1057.97	1057.97	0.77	0.20
2+700.00	17.08	1058.12	1058.12	0.72	0.20
2+750.00	16.49	1057.78	1058.28		0.29
2+800.00	18.16	1057.62	1058.12		0.28
2+850.00	18.58	1057.37	1057.87		0.34
2+900.00	18.48	1057.28	1057.78		0.42
2+950.00	18.20	1057.17	1057.67		0.40
3+000.00	17.86	1057.06	1057.56		0.25
3+050.00	17.53	1056.96	1057.46		0.12
3+100.00	17.29	1056.87	1057.37		0.05
3+150.00	17.10	1056.84	1057.34		0.23
3+200.00	18.88	1056.82	1057.32		0.00
3+250.00	20.44	1056.80	1057.30		0.00
3+300.00	17.09	1056.76	1057.26		0.22
3+350.00	15.21	1056.70	1057.20	0.20	0.37
3+400.00	18.71	1056.65	1057.15	0.20	0.48
3+450.00	18.99	1056.59	1057.09	0.20	0.50
3+500.00	15.54	1056.46	1056.96	0.20	0.37
3+550.00	19.25	1056.25	1056.75	0.20	0.39
3+600.00	17.60	1056.19	1056.69	0.20	0.47
3+650.00	17.65	1056.13	1056.63	0.22	0.50
3+700.00	19.28	1056.03	1056.53	0.26	0.50
3+750.00	19.75	1055.96	1056.46	0.26	0.50
3+800.00	18.90	1055.97	1056.47	0.28	0.50
3+850.00	21.25	1055.92	1056.42	0.20	0.42
3+900.00	21.11	1055.80	1056.30		0.06



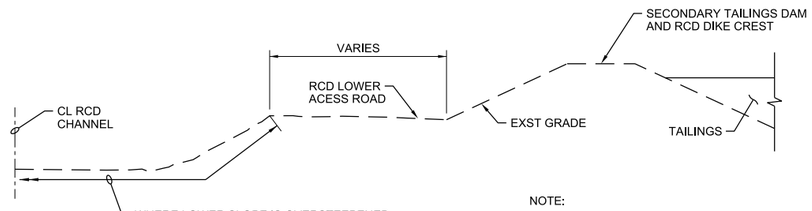
NOTES:

1. BACKFILL EXCAVATION W/ GLACIAL TILL SEEPAGE CONTROL LAYER, FILTER GRAVEL (TRANSITION FILTER), AND RIPRAP TO MATCH DESIGN GEOMETRY.
2. ALL TREES OR WOODY VEGETATION GREATER THAN 50 mm CALIPER DIAMETER OR HIGHER THAN 2 m SHALL BE REMOVED. ROOTS ARE GENERALLY TO REMAIN IN PLACE, BUT SOME ROOTS CONSIDERED DETRIMENTAL TO THE STABILITY OF THE DIKE SHALL BE REMOVED AT THE DIRECTION OF THE ENGINEER.

VEGETATION REMOVAL

G SECTION
NTS

C-5, C-6, C-7, C8



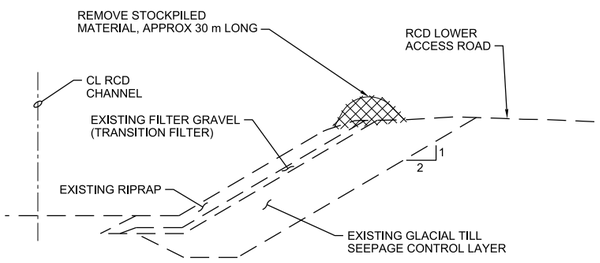
NOTE:

1. PRIOR TO ARMOR AUGMENTATION, REMOVE ALL VEGETATION AND DEBRIS FROM SECONDARY TAILINGS DAM EMBANKMENT AND RIGHT BANK OF RCD CHANNEL. FOR VEGETATION LARGER THAN 50 mm CALIPER DIA, SEE SECTION G.

RCD STA 1+500 TO 2+638

H SECTION
NTS

C-5

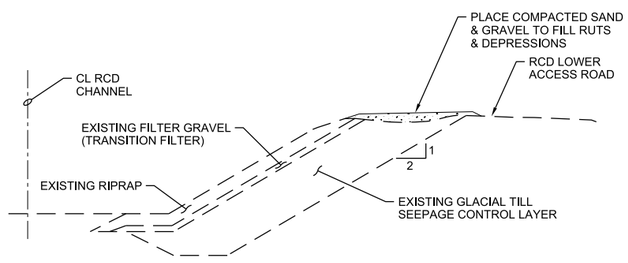


RCD STA 2+220 TO 2+250

STOCKPILE REMOVAL

I SECTION
NTS

C-6



RCD STA 2+127 TO 2+136

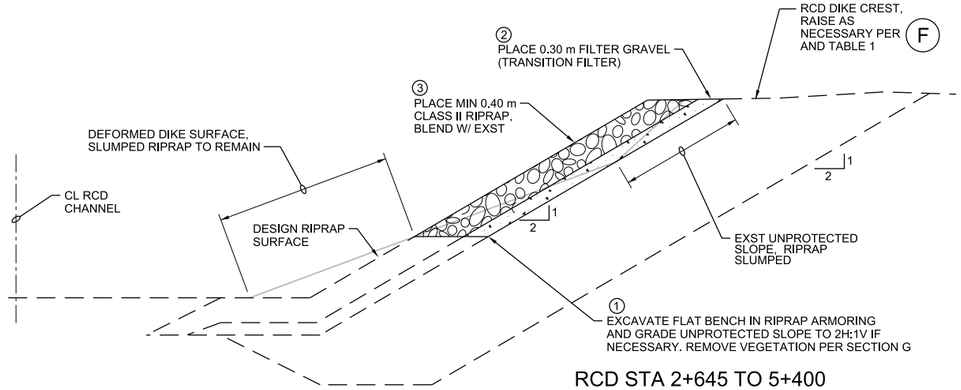
RUT AND DEPRESSION REPAIR

J SECTION
NTS

C-5

NOTE:

1. REMOVE STANDING WATER AND SOFT SATURATED MATERIAL TO EXPOSE FIRM SUBGRADE PRIOR TO PLACEMENT OF LEVELING FILL.



RCD STA 2+645 TO 5+400

RIPRAP REPAIR AND AUGMENTATION

K SECTION
NTS

C-6

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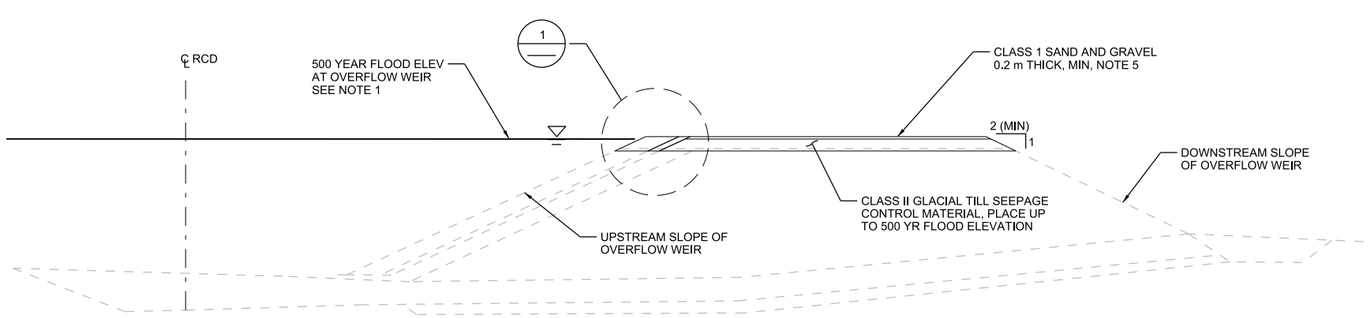
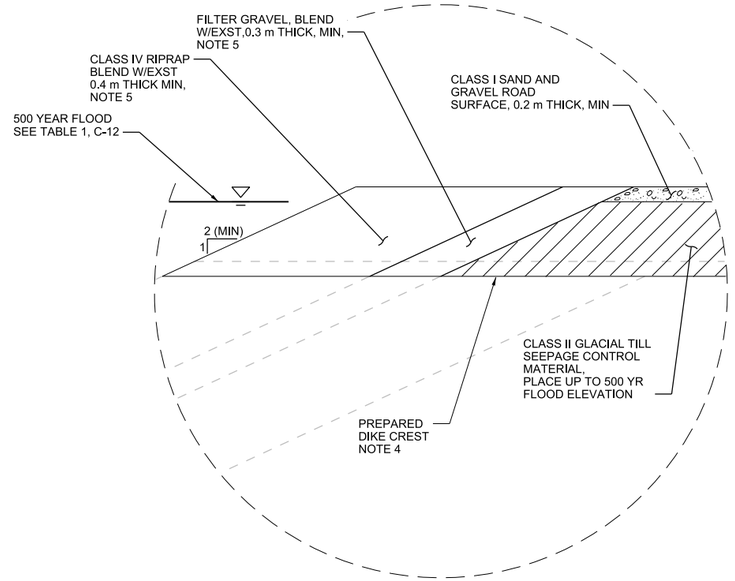


L SECTION
NTS
C-5

NOTES

1. RAISE CLASS III GLACIAL TILL SEEPAGE CONTROL MATERIAL TO 500 YEAR FLOOD ELEVATION AS SHOWN IN SECTION L FROM STATION 2+639.3 TO STATION 2+682.9.
2. PROPERTIES AND GEOMETRY OF MATERIAL SHOWN IN EXISTING DIKE IS APPROXIMATE BASED ON INFORMATION PROVIDED BY OTHERS. ACTUAL MATERIAL PROPERTIES AND GEOMETRIES ENCOUNTERED IN THE FIELD WILL VARY FROM THAT SHOWN.
3. CREST RAISE SHALL OCCUR UNDER THE DIRECTION OF THE ENGINEER.
4. PREPARE EXISTING OVER FLOW WEIR CREST TO RECEIVE FILL BY REMOVING MATERIAL WHICH, IN THE OPINION OF THE ENGINEER, IS NOT SUITABLE. SCARIFY AND RECOMPACT TO SATISFACTION OF ENGINEER PRIOR TO PLACEMENT OF OVER FLOW WEIR CREST RAISE FILL.
5. MINIMUM THICKNESS OF CLASS IV RIPRAP AND FILTER GRAVEL SHOWN TO BE MEASURED PERPENDICULAR TO FINISHED GRADE.



1 DETAIL
NTS

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Appendix B
North Fork Rose Creek Rock Drain Slope Stability Analysis (Available on request)

Appendix C
Original Effluent Pipeline Hydraulics (Available on request)

Appendix D
Preliminary Wall Thickness Calculations (Available on request)

Appendix E
Hydraulic Calculations (Available on request)

Appendix F
Advanced Design Specifications (60 percent)
(Available on request)

Appendix G
Construction Schedule (Available on request)

Appendix H
Intermediate Dam Freeboard Calculations (Available on request)

Appendix I
North Fork Rose Creek Design and Construction Information (Available on request)

Appendix 6A
Geochemical Characterization Report

Draft

Geochemical Characterization Report Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 2014

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309 Strickland Street, Suite 301
Whitehorse, Yukon Y1A 2J9

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Acronyms and Abbreviations

ARD	acid rock drainage
$BaSO_4$	barite
$CaSO_4$	gypsum
CH2M HILL	CH2M HILL Canada Ltd.
$CuFeS_2$	chalcopyrite
CVD	Cross Valley Dam
DES	Denison Environmental Services
ETA	Emergency Tailings Area
FCD	Faro Creek Diversion
FeAsS	arsenopyrite
Fe_3O_4	magnetite
FeS_2	pyrite
FMC	Faro Mine Complex
LaBerge	LaBerge Environmental Services
mg/L	milligram per litre
NFRC	North Fork Rose Creek
NP	neutralization potential
PbS	galena
$PbSO_4$	anglesite
RCAA	Rose Creek Alluvial Aquifer
RCTA	Rose Creek Tailings Area
RGC	Robertson GeoConsultants Inc.
SiO_2	quartz
SIS	seepage interception system
SRK	SRK Consulting Engineering & Scientists
WTP	Water treatment plant
ZnS	sphalerite

SECTION 1

Introduction

This report describes the geochemical conditions and processes affecting water-quality at the Faro Mine Complex (FMC). The FMC consists of three main subareas, presented in Figures 6A-1 through 6A-4: (1) the Faro Mine Area, which includes the Faro Pit and the Faro Waste Rock Dumps, (2) the Vangorda/Grum Area, which includes the Vangorda Pit and Waste Dumps and the Grum Pit and Waste Dumps, and (3) the Rose Creek Tailings Area (RCTA). This report presents mine-related water-contamination information for known impacted areas of the FMC.

Seepage and surface water quality data from each of the main FMC areas were compiled to identify trends over time for selected water-quality parameters. Data from the site-wide database (Environmental Quality Information System) were used in the analyses. The data sources included both historical investigations and recent field monitoring investigations. The evolution of water-quality characteristics through time generally results from the ongoing geochemical processes that occur within mine-influenced areas. At the FMC, there are three main contaminant-load contributors: (1) the waste dumps (including the backfilled Zone II Pit), (2) the three open pits (including discrete inputs into the pits [i.e. pit walls, seeps, and surface runoff]), and (3) tailings (RCTA). These contaminant-load contributors and the geochemical reactions that influence constituent concentrations in seepage and surface water are presented in this section.

Metal attenuation can be a result of adsorption to natural organic matter or to secondary oxyhydroxides, or coprecipitation of secondary mineral phases. This attenuation may act to slow the migration of trace metals away from the waste dumps within the shallow groundwater system. These attenuation processes may be more prevalent in the early stages of seep development when pH is near neutral but zinc and sulphate are elevated. Sulphate is a relatively conservative and abundant constituent that generally is a good indicator for acid rock drainage (ARD). Zinc is used as an indicator metal representing several other trace metals that are released during ARD production because of its more consistently higher concentrations, which make the analytical measurements and trends more reliable. For this report, seep water quality characteristics are described by the relative level of contamination based on concentrations of sulphate and zinc, according to the following criteria (CH2M HILL Canada Ltd. [CH2M HILL], 2012):

- Not impacted or minimally impacted: sulphate ≤ 40 milligrams per litre (mg/L) and zinc ≤ 0.05 mg/L
- Slightly impacted: sulphate > 40 mg/L and ≤ 400 mg/L or zinc > 0.05 mg/L and ≤ 0.5 mg/L
- Moderately impacted: sulphate > 400 mg/L and ≤ 4,000 mg/L or zinc > 0.5 mg/L and ≤ 5 mg/L. This corresponds to sulphate and zinc concentrations one order of magnitude greater than the “slightly impacted” range.
- Highly impacted: sulphate > 4,000 mg/L or zinc >5 mg/L. This corresponds to sulphate and zinc concentrations one order of magnitude greater than the “moderately impacted” range.

Sections 2, 3, and 4 of this report describe the results of the contaminant-loading characterization at each of the main FMC subareas. Time series plots for pH, alkalinity, sulphate, iron, zinc, and magnesium were generated for key locations at the FMC and evaluated for changes in chemistry over time. Locations examined for the Faro Mine Area are presented on Figure 6A-1; locations for the Vangorda/Grum Area are presented on Figure 6A-2, and locations for the Vangorda Area are presented on Figure 6A-3. Monitoring locations for the RCTA are presented on Figure 6A-4 and are described in detail in Appendix 6G.

1.1 Waste Rock Dumps

About 300 million tonnes (about 154 million cubic metres) of waste rock are located in areas adjacent to the three open pits in the Faro Mine Area and the Vangorda/Grum Area. Table 1 provides a list of the Main Dumps and the abbreviations (Code) used throughout this document. Mine waste management at the

Faro Mine Area did not involve rigorous segregation; as a result, water draining from the Faro Mine Area Waste Dumps can be poor quality (SRK, 2010). When the Grum Pit was mined, the highly sulphidic waste dump material was separated and placed in the Grum Sulphide Cell, which has been subsequently capped with a low-permeable cover (SRK, 2011). Despite more rigorous segregation practices when the Vangorda Pit was mined, the waste dumps associated with the Vangorda Pit generally contain greater sulphide content than the Faro Mine Area. As a result, water draining from the Vangorda Waste Dumps can be poor quality (SRK, 2010). Waste rock generated from the Vangorda Pit Area contains some of the highest percentages of sulphide at the FMC (SRK, 2006a).

TABLE 6A-1
List of Waste Dumps and Codes used at the FMC
Faro Mine Remediation Project

General Location	Waste Rock Dump	Code
Faro Pit Area	Zone II East	ZIIE
	Zone II West	ZIIW
	Crusher Stockpile	CHSP
	Faro Valley North	FVN
	Faro Valley South	FVS
	Fuel Tank East	FTE
	Fuel Tank West	FTW
	Intermediate Dump	ID
	Intermediate Dump Sulphide Cell	IDSC
	Low Grade Stockpile A	LGSPA
	Low Grade Stockpile C	LGSPC
	Lower Parking Lot	LPL
	Main Dump East	MDE
	Main Dump Sulphide Cell	MESC
	Main Dump West	MDW
	Medium Grade Stockpile	MGSP
	Mt. Mungly East	MME
	Mt. Mungly West	MMW
	Northeast Lower	NEL
	Northeast Lower Sulphide Cell	NELS
	Northeast Outer	NEO
	Northeast Upper	NEU
	Northwest Lower	NWL
	Northwest Middle	NWM
	Northwest Upper	NWU
	Outer Haul Road East	OHRE

TABLE 6A-1
List of Waste Dumps and Codes used at the FMC
Faro Mine Remediation Project

General Location	Waste Rock Dump	Code
	Outer Haul Road West	OHRW
	Oxide Fines Stockpile	OXSP
	Ramp Zone Dump	RZD
	Ranch Dump	RD
	Southwest Pit Wall Dump	SWPWD
	Stock Piles Base	SPB
	Upper Parking Lot	UPL
Vangorda Pit Area	Vangorda Baritic Fines Dump	V2
	Vangorda Main Dump	V1-B
	Vangorda Main Sulphide Cell	V1-S
	Vangorda Overburden Dump	V3-0
Grum Pit Area	Grum Main Dump	G1-B
	Grum Main Sulphide Cell	G1-S
	Grum Overburden Dump	G3-0
	Grum Southwest Dump	G2
	Ore Transfer Pad	OTP

Geochemical loading from the FMC Waste Dumps is controlled largely by the waste rock material composition, as well as how it was placed, relative to the pre-mining topography. Each of the three ore bodies are in topographic low-lying areas. Before the Faro Pit and the Vangorda Pit were mined, creeks flowed across the planned open pits. Before the Grum Pit was mined, it was a low wetland area with a creek flowing away from the area containing the ore body. At the FMC, these creeks generally flow north to south. Therefore, in general, background conditions prevail north of the FMC, and, where impacted by contaminated seepage, water with degraded quality flows south.

Previous borehole data and historical geological information indicate the FMC Waste Dumps are underlain by discontinuous deposits of glacial till, glaciofluvial sediments, and low-permeability bedrock (RGC, 1996). In general, these deposits are thin (less than 10 metres thick), with some notable exceptions near the Grum and Vangorda Pits, where overburden thickness can range up to 70 metres (RGC, 1996). When the FMC Waste Dumps were established, the relatively coarse waste rock material (which has a fairly high hydraulic conductivity) was placed over the native soil, which is less permeable. As a result, water infiltrating the waste rock pile will either continue to infiltrate the native soil or will travel along the paleosurface at the base of the waste dump until it daylights at the toe of the waste rock. The water infiltrating the native soil impacts local groundwater below the waste dump, and could degrade groundwater in downgradient locations. As mine-influenced water migrates through the aquifer system, some constituents move more quickly than others. Sulphate tends to move at the velocity of groundwater because it does not readily react with or adsorb to aquifer materials. Dissolved metals, however, can react with and adsorb to the subsurface matrix, and this geochemical interaction influences the rate of migration. Elevated sulphate concentrations

and decreasing pH are early signs that upgradient ARD reactions are impacting groundwater quality (CH2M HILL, 2013b).

Seepage water from waste dumps can impact surface water quality directly. Most of the seepage occurs at these locations after freshet or large precipitation events. It takes place over a fairly short timeframe, based on observations during the CH2M HILL 2012 field program (CH2M HILL, 2013b) and based on the historical seep sampling program (SRK, 2010). However, several seeps (generally located in pre-mining drainage channels) flow year-round. The seepage from several perennial seeps is currently collected using seepage interception systems (SIS), located at the S-Wells and the Emergency Tailings Area (ETA). In the future, placing covers to minimize infiltration through the waste dump will reduce the quantity of seepage generated.

The main source of contaminants in the Faro Mine and Vangorda/Grum Areas is sulphide-containing waste rock stored in the waste dumps and tailings located within the Rose Creek Valley. The main sulphide ore minerals in the waste dumps are sphalerite (ZnS), galena (PbS), and pyrite (FeS_2). Minor amounts of chalcopyrite ($CuFeS_2$) and arsenopyrite (FeAsS) are also present in a matrix of gangue minerals that include quartz (SiO_2), magnetite (Fe_3O_4), carbonate minerals, and barite ($BaSO_4$) (SRK, 2004). $FeS_2$is the most abundant sulphide mineral at the FMC. The main source of acidity and metals at the FMC is the oxidation of these sulphide minerals in the waste dumps, denoted in the following chemical reaction:

$$2MeS_2 + 7O_2 + 2H_2O \rightarrow 2Me^{+2} + 4SO_4^{-2} + 4H^+$$

Oxygenated water infiltrates the waste dumps and causes sulphides to oxidize, generating sulphate (the oxidized form of sulphide) and acidity, which contribute to increased metal concentrations. When the hydrolysable metals in solution (such as iron and manganese) are exposed to additional oxygen, they may react, causing oxyhydroxides to precipitate and the solution pH to undergo a net lowering, according to the following reactions:

$$2Fe^{+2} + 0.5O_2 + 2H^+ \rightarrow 2Fe^{+3} + H_2O$$

$$2Fe^{+3} + 6H_2O \rightarrow 2Fe(OH)_3 + 6H^+$$

Trace metals (such as zinc) may co-precipitate with or adsorb to the oxyhydroxide precipitates. The degree of co-precipitation or adsorption is highly pH-dependent, and it varies between the trace metals. In general, sulphide-rich rock at the FMC generates acid almost immediately upon exposure; therefore, the sulphide cells at the FMC are characterized as acid-generating (SRK, 2004). The process of sulphide mineral oxidation is tempered by the presence of alkaline mineral phases (i.e., neutralization potential [NP]) that help buffer the solution at a more neutral pH. Carbonate minerals (such as calcite and dolomite) are the most important of these minerals at the FMC. Acid released during the oxidation process will partially dissolve carbonate minerals, and the released bicarbonate ions will help to maintain the pH at circum-neutral values according to the following reaction:

$$3Me^{+2} + Ca(HCO_3)_2 + O_2 + 2H_2O \rightarrow 3Me(OH)_2 + Ca^{+2} + 2CO_2$$

As oxidation proceeds in the exposed natural rock and in the waste materials, the carbonates buffer the pH (and, in turn, the metal mobility) to maintain a chemical semi-steady condition. For most waste dumps at the FMC, the acid potential of the waste materials is greater than the NP of the carbonates. At some point, the NP will be depleted, the pH will drop, and metal concentrations will rise. The long-term remediation plan must consider this eventual condition to effectively treat current and future seepage from the FMC.

There are several stages of ARD development within the waste dumps. These stages are observed at different areas of the FMC, depending on waste dump age, exposure, and mineralogy (SRK, 2004). The first stage of seepage chemistry evolution is characterized by neutral to alkaline pH, with low sulphate and metal concentrations and possible elevated calcium and magnesium cations from carbonate dissolution. Seepage chemistry evolves further through the following processes:

- As sulphide-bearing materials oxidize, the pH may decrease to neutral or slightly acidic with an associated increase in zinc and sulphate concentrations. Calcium and magnesium carbonates still control water chemistry and secondary gypsum ($CaSO_4$), and trace metal (i.e., zinc, copper) carbonates may form. Trace metal adsorption to oxyhydroxide precipitates may also be an important controlling factor.
- When the advanced oxidation of sulphides begins to overcome the available NP within the waste dump, pH begins to decrease. The pH of the seepage may fall below 4 and exhibit high concentrations of iron, aluminum, zinc, sulphate, and other trace metals. While iron and aluminum oxyhydroxides are still likely forming downgradient of sulphide oxidation, the adsorptive trace metal capacity at more depressed pH significantly decreases. In highly sulphidic areas, the pH may fall well below 4, stabilizing between 2.5 and 3, and may contain the highest metal and sulphate concentrations at the FMC.
- In the waning stages of seep evolution, pH may increase as the sulphide minerals with acid-generating potential are exhausted or armoured by oxide rinds and coatings. Metal and sulphate concentrations (except for lead) begin to decrease as pH increases. Lead may increase because of the increased anglesite ($PbSO_4$) solubility resulting from lower sulphate concentrations.

Although seepage chemistry develops within the waste dumps and evolves over time, processes within the receiving environment may still impact the fate of metals, sulphate, and acidity. As the seepage infiltrates the alluvial and till material underlying the waste dumps, some acid neutralization may occur and the trace metal load may attenuate. Metal attenuation can result from adsorption to natural organic matter, precipitation of secondary oxyhydroxides, or co-precipitation with secondary mineral phases. This attenuation may retard the trace metals' migration from the waste dumps within the shallow groundwater system, especially during the early stages of seep development, when pH is near-neutral but zinc and sulphate are elevated. However, the underlying alluvial/till material has a finite adsorptive capacity, and the adsorption process is susceptible to reversal at low pH. As the seep chemistry evolves, becoming more acidic, the underlying alluvial/till material's attenuation capacity is expected to decrease, and the material may ultimately release metals captured during the earlier stages of seep development.

1.2 Open Pits

The three open pits at the FMC (Faro, Grum, and Vangorda) have unique geochemical properties that contribute to the water quality of the lakes therein. Constituents primarily load to the pit lakes through seepage from pit walls and waste dumps. Predicting future water quality conditions in each of the pits is an ongoing process. The following additional factors influence the pit lakes' geochemical compositions:

- The Faro and Vangorda Pits provide storage for water pumped by various water interception systems year-round, so it is possible to operate the water treatment plant (WTP) seasonally. Therefore, groundwater inputs from surrounding waste dumps (e.g., associated with S-wells SIS, Zone II Pit, and the Vangorda seepage collection ditch) are contributing to the load within the pits. Additional remedial system waters may be pumped to the pits in the future; this would further impact the pit lakes water quality (SRK, 2010).
- The Faro Pit received tailings from milling operations from 1992 to 1998. The presence of net acidic, yet alkaline-bearing, tailings complicates the geochemistry of the pit lake. In the short term, these tailings are contributing alkalinity to the water column. The tailings at the bottom of the Pit are not expected to become acid-generating or a significant source of metals, because the subaqueous disposal limits contact with oxygen. Disposing oxidized, alkaline WTP sludge to the Pit would further mitigate potential metal loading from the tailings to the pit water.
- Adding WTP sludge to the bottom of the Grum or Vangorda pits is an ongoing consideration. If the pH at the bottom of the pits drops significantly, the WTP sludge could release trace metals. However, given the alkaline content of the WTP sludge, the sludge may act to raise and buffer the bottom water pH to minimize or prevent trace metal release. The Grum Pit was operated as an in situ biological treatment

system (algal-based bioreactor) by adding nutrients over approximately 10 years. The treatment process was discontinued in 2012. Therefore, the sulphidic pit wall oxidation and the composition of the influent seep chemistry are the main controlling factors for the Grum Pit's future chemistry.

1.3 Rose Creek Tailings Area

Approximately 55 million tonnes of tailings generated from ore processing at the mill operations were deposited in the RCTA over an area approximately 0.7 kilometre wide by 3.7 kilometres long within the former Rose Creek Valley. The mill process that generated the RCTA tailings took place at a pH of greater than 11. Therefore, the tailings material contains some NP even though it is net acidic (i.e., has greater acid-generating capacity than available NP). This NP neutralized some of the acidity while it was generated within the tailings, thereby slowing the acid-generation process. The fine-grained nature of the tailings limits oxygen transfer into the tailings, further slowing the oxidation and consequent acid-generating processes. The rate of oxidation within the tailings was evaluated using samples from the RCTA, and showed an oxidation front moving through the tailings pile over time (RGC, 2012). As this oxidation front migrates through the largely sulphidic tailings material, acidity and high concentrations of metals are released to the pore water. Over time, the pore water is displaced by precipitation infiltration, driving impacted water into the underlying Rose Creek Alluvial Aquifer (RCAA).

Models of the release of contaminants from the RCTA have been based on pore water displacement estimates, combined with pore water quality estimates, to provide time-based estimates of contaminant loadings from the base of the tailings deposit to the RCAA (Gomm Environmental Engineering Consulting, 2010). Once the tailings-impacted water reaches the RCAA, it reacts with the alluvial aquifer sediments and attenuation occurs. The effect of attenuation by the alluvial material is a delayed, sequential release of contaminants over time. Sulphate, which is largely unattenuated, is the first contaminant to migrate from the RCTA source area. Zinc, iron, and other metals are retained through changes in pH that cause precipitation, coprecipitation, and adsorption. As the aquifer material's attenuation capacity declines, either by metals occupying adsorption sites or through decreased pH (which can result in metal desorption), metals (i.e., zinc) are transported downstream of the RCTA, arriving later than the sulphate front. As the alluvial aquifer material's attenuation capacity continues to decline, iron-bearing, highly acidic water will be released downgradient of the RCTA. This process will continue until the RCTA source material is exhausted and the oxidation front moves completely through the tailings pile. Recently, elevated sulphate has been observed in groundwater at the downstream end of the RCTA, at the toe of Cross Valley Dam (CVD). However, trace metals such as zinc, lead, and cadmium are being actively attenuated by existing and newly precipitated oxyhydroxides and by organic material, maintaining concentrations well below levels of concern in the downgradient half of the RCTA.

SECTION 2

Faro Mine Area

The Faro Pit is used as a reservoir to store contaminated for water treatment. Because the pit is pumped to lower the water level, the Faro Mine Area is characterized by a regional groundwater sink (the Faro Pit). waste dumps in the Faro Mine Area are unsaturated and of variable composition. When precipitation infiltrates through the waste dumps, it collects at their bases, near pre-mining topographic lows (Appendix 6G). Depending on the subcatchment area a waste dump is located in, seepage from the waste dumps near the Faro Pit may flow to the Faro Pit, Zone II Pit, North Fork Rose Creek (NFRC), old Faro Creek, Guardhouse Creek, or Rose Creek Valley (Figure 6A-1) (RGC, 1996). Data compiled from samples collected at seepage, surface water monitoring stations, and monitoring wells provide the foundation for the characterization of water-quality conditions in the Faro Mine Area (Figure 6A-1).

2.1 Faro Background Water Quality

Except for seepage collected at the ETA, the S-Wells, or behind the Intermediate Dam, water from the Faro Waste Dumps ultimately flows into Rose Creek, which contributes to Anvil Creek, before flowing into the Pelly River. Faro Creek flows from the north and is diverted around the Faro Pit via the Faro Creek Diversion (FCD) (Figure 6A-1). Water in the FCD flows into the NFRC, northeast of the Faro Northeast Waste Dump. Upstream from the FCD and the NFRC above the confluence of FCD and the NFRC, Faro Creek and NFRC are generally considered unimpacted, and are sampled for background conditions. Two main surface water locations have historically been sampled for background conditions in the Faro Mine Area: (1) Faro Creek, upstream from the FCD (Station FCO), and (2) NFRC, upstream from the confluence with the FCD (Station R7). In 2012, background samples were collected from a new location in Faro Creek, Station FDU, which is upstream from the historical Station FCO sampling location (Figure 6A-1).

2.2 Constituent Loading to the Faro Pit

The Faro Pit lake water quality is monitored at X22B (located on the lake surface at the southwest end of Faro Pit lake, near the pumping barge) and can be described as buffered ARD (Figure 6A-1). It has a neutral pH and is highly impacted based on concentrations of zinc. The dissolved sulphate concentrations have been consistent in recent years, and the zinc concentration has been increasing over time (CH2M HILL, 2013b). As the alkalinity is consumed, the acidity will rise, resulting in an increase in acid mine drainage products. The following sources contribute influent waters that affect water quality in the Faro Pit:

- Seepage from the North Faro Waste Dumps (FVN and FVS)
- The Northeast Faro Waste Dumps (NEU, NEL, NELS, and NEO)
- Pumping from the Zone II Pit (X26)
- Pumping from the S-wells (Figure 6A-1)

Figure 6A-5 shows a summary of the water quality and level of impact at seepage monitoring stations in the Faro Pit area. Water that is not captured by the FCD (including potential leakage from the FCD) flows through the Faro Valley Dumps (FVN and FVS) and seeps into the Faro Pit along the north pit wall (Figure 6A-1). Location A30 is on the north pit wall of Faro Pit and is on the flow path of the historical Faro Creek (Figure 6A-1). The flow in this area is high, and the high flux of oxygenated water through the Faro Valley Dumps (FVN and FVS) may be causing relatively acidic conditions in this area, relative to other seepage areas. The water is highly impacted with a low pH and moderate concentrations of sulphate (545 mg/L) and high concentrations of zinc (47.3 mg/L), based on the criteria outlined in Section 1 (Figure 6A-6). Characteristics of acid mine drainage (i.e., increased sulphate and zinc) have been present and have shown variability since 2002, with concentrations of iron (2.1 mg/L) generally increasing over time (Figure 6A-5). The observed general decrease in alkalinity over time and increased sulphate concentrations

indicate much of the available NP in this area has been consumed, and there is a net acid generation effect on seepage from A30 reporting to the Faro Pit lake (Figure 6A-5).

Seepage from the Northeast Waste Dumps flows either to the Faro Pit or to the NFRC along a pre-mine surface drainage divide (Figure 6A-1). A geochemical characterization of the Northeast Waste Dumps' waste rock materials indicates substantial potential for long-term acid generation (CH2M HILL, 2013c). Water quality results from samples collected from the Northeast Waste Dumps indicate widely variable composition and highly impacted waters. The most highly impacted waters are generally downgradient from the East Sulphide Cell. The two main flows from the Northeast Waste Dumps report to the Faro Pit lake: (1) SRK -FD24 and (2) SRK-FD26 (Figure 6A-1). SRK-FD24, which is west of and topographically lower than the Northeast Sulphide Cell, is characterized as highly impacted water with high concentrations of iron (10.8 mg/L), zinc (40 mg/L), and sulphate (1,060 mg/L) (Figure 6A-7). A review of the data at SRK-FD24 highlights the transition from neutral to acidic conditions over time, marking a distinct stage in the evolution of the Northeast Waste Dump seepage chemistry (Figure 6A-7). SRK-FD26 is a moderately impacted, high-flow monitoring location that follows a pre-mine drainage just north of the former Zone II Pit (Figure 6A-1). Concentrations of sulphate and zinc were 806 mg/L and 5.7 mg/L, respectively, and iron was less than the detection level in samples collected at SRK-FD26 (Figure 6A-7).

In general, very little seepage flows from the south and west pit walls into the Faro Pit. The only other important inputs into the Faro Pit are from the X26 well and the S-wells SIS area (Figure 6A-1). The X26 well maintains groundwater levels through pumping in the former Zone II Pit and contributes water and constituent loading to the Faro Pit lake. Based on the criteria presented in Section 1, groundwater pumped from the Zone II Pit is considered highly impacted, with high sulphate content (3,320 mg/L) and concentrations of zinc that are greater than 20 mg/L (Figure 6A-8). Through time, X26 has maintained one of the highest average zinc (79 mg/L), iron (53 mg/L) and sulphate (2657 mg/L) concentrations of all the inputs into Faro Pit (Figure 6A-8) (DES, 2012,).

The S-wells SIS area is another source of water and constituent loading to the Faro Pit lake (Figure 6A-1). The numerous contaminant sources that contribute to the S-wells area are attributed to the pre-mine topography. The current conceptual site model indicates pre-mining drainage patterns are focusing seepage water from the Intermediate and Main Dumps, towards the S-wells SIS area and ETA, respectively. Monitoring wells (MW-007 and MW-003) have recently been installed through the waste dump into the underlying alluvium upstream of these seepage areas, to evaluate the evolution of seepage chemistry along the flow path of these historical drainages (CH2M HILL, 2012).

Seepage water collected by the S-wells SIS, represented by the water quality observed in SRK08-SPW3, is considered highly impacted. The S-wells area is expected to be a large contributor to increased contaminant loads through time, with sulphate and zinc concentrations greater than 5,000 mg/L and 300 mg/L, respectively, in SRK08-SPW3 (Figures 6A-1 and 6A-8). Alkalinity in SRK08-SPW3 has decreased over time, from 587 mg/L to 401 mg/L, but has remained present to neutralize acidic drainage (Figure 6A-8). Although groundwater quality in the S-wells area was expected to improve with the installation of the SIS, no notable change in water quality (better or worse) was observed. Contaminant concentrations were neither shown to increase, nor to decrease, in groundwater downgradient of the S-wells SIS. Increased concentrations of sulphate and zinc in groundwater monitored by wells southeast of the S-wells SIS (i.e., SRK05-SP3A/B, SRK05-SP1A/B, and SRK05-SP2) indicate the SIS may not be capturing at least a portion of the waste dump seepage.

2.3 Constituent Loading to the North Fork Rose Creek

Seepage water that flows west from the Northeast Waste Dumps and from the former Zone II Pit area (i.e. water that is not captured by the X26 well) contributes to the NFRC, upstream of the North Fork Rock Drain and is represented by the water quality measured at monitoring stations SRK- FD21, SRK-FD05, SRK-FD06, NE1, NE2, and NE3 (Figure 6A-1). Although SRK-FD21 is within the catchment boundary for NFRC, seepage

likely also flows to the Faro Pit (Figure 6A-1). Seepage from SRK-FD21 is highly impacted, with concentrations of sulphate and zinc at 3,200 mg/L and 36.7, respectively (Figure 6A-9). Highly impacted seepage water (based on the criteria outlined in Section 1) has been observed emanating from the west side of the Northeast Waste Dump at SRK-FD05 (Figure 6A-9). SRK-FD05 and SRK-FD06 represent a widespread perennial seep located near the base of the west face of the Northeast Waste Dump (Figure 6A-1). Observed water quality at SRK-FD05 indicates seasonal fluctuations in concentrations of sulphate (692 mg/L [September 2012] to 904 mg/L [June 2013]) and zinc (5.9 mg/L [September 2012] to 8.3 mg/L [June 2013]), with greater concentrations observed in the spring than in the fall, and an overall trend of increasing concentrations through time (Figure 6A-9) (SRK, 2010). The highly impacted seepage waters emanating from the Northeast Waste Dumps support the need for continued monitoring at these locations. Monitoring stations BH 14, A/B, located to the south of SRK-FD05 (Figure 6G-17), indicate groundwater is highly impacted with sulphate (about 2,500 mg/L) and zinc (about 10 mg/L) (Figure 6G-1-3).

Seepage water in the waste dumps adjacent to the Zone II Pit that is not captured by the X26 well continues along a flowpath toward the Zone II Outwash and is further influenced by waste dump seepage (RGC, 2012). Wells near the base of the waste dump (i.e., BH8) (Figure 6G-17) indicate groundwater is highly impacted with sulphate (about 3,000 mg/L) and zinc (greater than 100 mg/L), flowing toward the NFRC (Figure 6G-1-1). Increased concentrations of zinc (greater than 5 mg/L) have also been observed in wells closer to the NFRC (i.e., BH6) (Figure 6G-1-2). SRK-FD08 is the only seepage water monitoring station located within the Zone II Outwash area, and it has been dry during the 2012 and 2013 sampling events (Figure 6A-1). Well P96-6, located downstream of the Zone II Outwash area and upstream of the North Fork Rock Drain, indicates groundwater moderately impacted with sulphate (518 mg/L) and zinc (0.73 mg/L) and seasonal fluctuations where water quality improves (through dilution) during freshet conditions (RGC, 2013).

Downstream from the Zone II Outwash, the NFRC flows southwest at the base of the Intermediate Dump, underneath the Haul Road through the North Fork Rock Drain, and past the S-wells area. As Section 2.2 described, the S-wells area is characterized by highly impacted water that is collected and pumped to the Faro Pit. However, water that is not captured by the S-wells SIS continues down the flowpath toward NFRC and its confluence with the South Fork Rose Creek (Figure 6G-9)

2.4 Constituent Loading to between S-Wells and X23

While the S-wells area and the X23 seepage area are considered “hot spot” seepage areas south of the Main Dump and Intermediate Dump, reduced monitoring takes place between the two locations because significant surface seepage locations have not been identified in this area. However, one well (SRK08-P9) makes it possible to assess the groundwater conditions flowing from the Faro Waste Dumps towards the RCAA in this region (Figure 6G-24). Samples collected in 2012 suggest this area is moderately impacted with sulphate (1,160 mg/L), but not impacted with zinc (0.01 mg/L). Additional monitoring is required to determine whether this area reflects localized impacts from specific waste dumps or represents regional constituent loading because of premining topography and contributions from the waste dumps.

2.5 Constituent Loading to Faro Creek Canyon

Water quality at X23, which is the surface expression of groundwater flow along the pre-mine Faro Creek Channel, is characterized as highly impacted. The most recent (September 2013) concentrations of sulphate (8,750 mg/L) and zinc (1,380 mg/L) were some of the highest concentrations measured at the FMC (Figure 6A-10). Concentrations of iron at X23 were also indicative of highly impacted water, at 613 mg/L. The highly impacted water quality at X23 is not unexpected, as this site of the pre-mine Faro Creek south of Faro Pit includes waste dumps with some of the highest metal and sulfide content in the Faro Mine area, such as the Low-grade Stockpiles “A” and “C” (LGSPA, LGSPC), the Oxide Fines Stockpile (OXSP), Medium-grade Stockpile (MGSP), Stockpiles Base (SPB), Chrusher Stockpile (CHSP), and the Main Dump (MDE, MESC, MDW) (Figure 6A-1). Seepage water from X23 flows across the eastern edge of the ETA and into old Faro Creek Canyon, just south of the mine Access Road. Drainage from the Mill Area also contributes to flow

across the ETA. Along these flowpaths, water interacts with the ETA tailings material before discharging into Faro Creek Canyon. Flow that bypasses the collection system flows through Faro Creek Canyon and continues down an unlined earthen ditch along the northern side of the Intermediate Tailings Impoundment, before flowing out over the western end of the Intermediate Tailings Impoundment and into the Intermediate Dam Pond. A sump interception system at the head of Faro Creek Canyon, just below mine Access Road, is designed to capture the bulk of X23 and Mill Area flows, as well as subsurface flows from the ETA, before they reach Faro Creek Canyon and the flow to the Intermediate Dam Pond. The ETA sump operates seasonally and does not capture all of these inputs year-round. Even when the ETA sump is operating, the sump does not capture all of the flow. Flow that is not captured by the ETA sump (approximately 20 percent of the flow when operating) flows through Faro Creek Canyon at FCS-4 (RGC, 2010). In general, the contaminant concentrations at FCS-4 are slightly less than those in the ETA sump, but follow the general trends observed at the ETA sump (DES, 2012). One exception to the observed trend is the observed decreased constituent concentrations at FCS-4 during freshet conditions, when an influx of “clean” surface runoff dilutes the seepage chemistry.

During the September 2012 field investigations, it was determined that the WTP clarifier, located within the former Mill Building, was leaking at a rate of approximately 2 litres per second. While some of the leakage water is captured in sumps and pumped back to the WTP, the majority flows from the Mill Area into the former Mill Canyon drainage before flowing out over the ETA toward Faro Creek Canyon. Based on samples collected in 2012, the majority of this water appears to be relatively clean (i.e., alkaline pH [greater than 7] and low conductivity) based on field results from September 2012 sampling. However, a fraction of this water is considered highly impacted immediately adjacent to the former Mill Building (CH2M HILL, 2013b). Water that leaks from the Mill Building and is not captured in sumps flows across the ETA to the settling basin north of mine Access Road, which discharges toward Faro Creek Canyon.

FCS-3 monitors seepage from the south side of the mine Access Road near the ETA sump and combines flow from several seeps. The seeps represented by FCS-3 account for approximately half of the total flow to the ETA sump and are considered highly impacted, with sulphate concentrations of 10,700 mg/L (June 2013) and zinc concentrations of 724 mg/L (June 2013).

2.6 Constituent Loading to Guardhouse Creek

There are two main contributors of flow in the Guardhouse Creek area: (1) Upper Guardhouse Creek and (2) Lower Guardhouse Creek. Upper Guardhouse Creek flows adjacent to the Faro Northwest Waste Dump (along the westernmost edge) and may partially flow under the Northwest Waste Dump (Figure 6A-1). Upper Guardhouse Creek ultimately flows to the CVD area, bypassing collection systems, and into Rose Creek (upstream of X14). Although Upper Guardhouse Creek flows through largely unimpacted terrain, there are several seeps (FD16, FD17, FD18) along the westernmost edge of the Faro Northwest Waste Dump that flow into Upper Guardhouse Creek (Figure 6A-1). These seeps, represented by the water quality measured at SRK-FD18, have maintained a slightly impacted status over the past 10 years, with sulphate concentrations generally less than 50 mg/L and zinc concentrations of about 0.1 mg/L (Figure 6A-11). Increasing constituent concentrations to Upper Guardhouse Creek from these seeps indicate the possibility of future water quality impacts, and support the need for continued monitoring of the Northwest Waste Dumps. However, these seeps contribute relatively little flow compared with the large volume of flow in Upper Guardhouse Creek. A downstream surface monitoring station (CH12_102_SG001) established in May 2012 (CH2M HILL, 2013b) yielded low sulphate (10 mg/L) and minor zinc (18 micrograms per litre) concentrations.

In contrast with the relatively unimpacted Upper Guardhouse Creek, Lower Guardhouse Creek originates from waste dump seeps with mine-influenced water quality (SRK-FD01) that flow into a ditch across from the Warehouse Building (Figures 6A-1 and 6A-11). In addition to the waste dump seepage creating Lower Guardhouse Creek, at least some seepage from the Mill Area appears to discharge to the creek (CH2M HILL, 2013b). According to pre-mining maps, this ditch is located in an area that was once a small pond (RGC,

1996). Lower Guardhouse Creek flows from this ditch to the Intermediate Dam Pond, where the water is captured for treatment. Concentrations of sulphate (3,020 mg/L) and zinc (87.7 mg/L) in SRK-FD01 are increasing and reflect highly impacted water (Figure 6A-11). Seepage water discharging from the south toe of the Northwest Lower (NWL) Waste Dump, at location SRK-FD19, contributes to X23 (50 percent of flow) and to Lower Guardhouse Creek (50 percent of flow) (Figure 6A-1) (Gomm Environmental Engineering Consulting, 2010). Water quality at SRK-FD19 is highly impacted, with trends of decreasing alkalinity (from 386 mg/L [September 2002] to 151 mg/L [September 2013]) and increasing sulphate (from 3,810 mg/L [September 2002] to 6,300 mg/L [September 2013]) and zinc (from 51 mg/L [September 2002] to 257 mg/L [September 2013]) (Figure 6A-11).

SECTION 3

Vangorda/Grum Area

The Vangorda/Grum Area is characterized by two localized groundwater sinks (the Grum and Vangorda Pits) and regional groundwater flow toward Vangorda Creek, which drains the area and flows south toward the Pelly River (Figure 6G-10). Similar to the Faro Mine Area, precipitation that infiltrates through the waste dumps collects at their bases, near pre-mining topographic lows (Appendix 6G). Depending on the subcatchment that a particular waste dump is located in, seepage from the waste dumps may flow to the Grum Pit, the Vangorda Pit, or Vangorda Creek (Figures 6A-2 and 6A-3). Data have been compiled from samples collected at seepage locations, surface water monitoring stations, and monitoring wells; these provide the foundation for characterizing water quality conditions in the Vangorda/Grum Area.

3.1 Background Water Quality

Before mining at the Vangorda Pit began, a diversion channel was constructed to divert Vangorda Creek around the Vangorda Pit, minimizing its exposure to mine waste. Background surface water sampling takes place in the main fork of Vangorda Creek at Station V1, immediately upstream of the Vangorda/Grum Area (Figure 6A-3). The water quality of Vangorda Creek at Station V1 is characterized by neutral pH (7.34) and low concentrations of sulphate (11.4 mg/L) and zinc (0.003 mg/L), and is representative of water that has not been influenced by mine materials.

3.2 Grum and Vangorda Pits

Figure 6A-12 shows a summary of the water quality and level of impact at seepage monitoring stations in the Grum Pit area. The Grum Pit receives water from surface runoff within the Grum Pit catchment, as well as groundwater inflow from the surrounding Thalweg aquifer (Appendix 6G). Seepage water samples are collected regularly at GP02 and GP09 (Figure 6A-2). The observed water quality at GP02 is characterized by alkaline pH (8.04) water, slightly impacted with sulphate concentrations of 439 mg/L, and no detectable zinc (Figure 6A-13). Similarly, seepage water quality observed at GP09 is characterized by alkaline pH (7.98) and water slightly impacted with sulphate and zinc (703 mg/L and 0.04 mg/L, respectively) (Figure 6A-13).The water quality of the Grum Pit lake (V23) is characterized by alkaline pH (7.84) and moderately impacted mine water, based on sulphate (435 mg/L) and zinc (3.14 mg/L) concentrations from samples taken in June 2013 (Figure 6A-2). An in situ biological treatment process was initiated within the Grum Pit in 2004 and used until it was discontinued in 2011. The Grum Pit lake is conveyed to the Vangorda Pit and treated at the Grum water treatment plant.

Similar to the Grum Pit, the Vangorda Pit lake is largely the result of surface runoff within the pit catchment area and groundwater flow (Appendix 6G). The Vangorda Pit also receives constituent loading from water pumped from the Grum Pit and water collected in the Grum Creek Collection System, V15 sump, and Little Creek Pond (Figure 6A-3). The Vangorda Pit lake water quality is monitored at location V22 (Figure 6A-3). The current water quality is characterized as slightly acidic pH (6.24) and is highly impacted, based on concentrations of sulphate (857 mg/L) and zinc (52.5 mg/L) measured in June 2013. Concentrations of sulphate and zinc in the Vangorda Pit lake have been increasing steadily during the period of record (CH2M HILL, 2013b). Seasonal fluctuations were observed in the water quality of the Vangorda Pit lake, with decreased sulphate and zinc concentrations during freshet and increased concentrations during low flow conditions (DES, 2012; CH2M HILL, 2013b).

3.3 Grum Waste Dump

The easternmost flank of the Grum Waste Dump was built over the former Grum Creek, where drainage flows toward two contiguous perennial seep locations (SRK-GD01 and SRK-GD02) (Figure 6A-2). These two

seeps indicate moderately impacted water quality, based on sulphate (1,578 mg/L) and zinc (2.3 mg/L) concentrations (Figure 6A-13).

The south-central portion of the Grum Waste Dump is identified by the sulphide-dominant waste rock found in the Grum Sulphide Cell (Figure 6A-2), and has some of the greatest potential (at the FMC) for generating acid and leaching metals. Because of this, to minimize downgradient impacts, it was segregated during mining and capped with a low-permeability cover in 2010 (SRK, 2011).

Seepage collects in a small sump (V15) and along the former Grum Creek downstream of the Grum Waste Dump before flowing to Moose Pond. Water quality at V15 showed moderately impacted water, based on zinc concentrations (4.1 mg/L) measured before the low-permeability cover was installed; concentrations have somewhat stabilized (to observed 2010 concentrations) since the cover has been placed (DES, 2012). The increased contaminant loading at V15 resulted in increased zinc concentrations downstream in Grum Creek (V2); to mitigate this, the V15 seepage path was rerouted to Moose Pond in 2011 (CH2M HILL, 2013b). Sampling of Moose Seep and Moose Well No. 2 confirm that losses from Moose Pond (via infiltration to the surrounding formation) flow towards Vangorda Creek. Facilities are now in place for seasonal water collection from Upper Grum Creek and V15 and pumping to Vangorda Pit. Collection began in 2013.

Time-series plots for the Grum seeps were generated for locations SRK-GD05 and SRK-GD13. SRK-GD05 is located at the southern toe of the Grum Waste Dump, downgradient from the Grum Sulphide Cell (Figure 6A-2). Water at this location is different from other seepage water at the FMC because of its abundant algal growth and hard, white, crusty deposits where the seep emerges from the base of the waste dump. SRK-GD05 is characterized by neutral to alkaline pH (7.32) and water moderately impacted with sulphate (2,330 mg/L) and zinc (2.95 mg/L) (Figure 6A-13). Seep SRK-GD13 is located at the western toe of the southwest Grum Waste Dump with westward flow that ultimately connects with the West Vangorda Creek drainage (Figure 6G-10). Water quality at SRK-GD13 indicates neutral to alkaline pH (7.57) and moderately impacted drainage, based on concentrations of sulphate (1,140 mg/L) and zinc (0.23 mg/L) (Figure 6A-13).

Seepage from the Ore Transfer Pad, located to the northwest of the Grum Pit, is monitored at location SRK-GD23 (Figure 6A-2). Flow from SRK-GD23 travels to Vangorda Creek downstream of the routine monitoring station V27. Water quality at SRK-GD23 is characterized by neutral pH and minimally to moderately impacted drainage, based on concentrations of sulphate (552 mg/L) and zinc (0.45 mg/L) (CH2M HILL, 2013b).

3.4 Vangorda Waste Dump

The Vangorda Waste Dump was constructed on a topographic high point south of the Vangorda Pit (Figure 6A-3). This waste dump is composed of sulphide-rich waste rock with little NP available to buffer acid generation processes. It is surrounded to the south, west, and north by a drainage ditch that collects seepage from the toe of the waste dump. Several transverse drains were constructed beneath the till berm surrounding the waste dump; these direct the seepage toward a perimeter collection ditch and Little Creek Pond, where it is stored before being pumped seasonally to Vangorda Pit. Samples collected from the transverse drains are acidic, with elevated concentrations of iron, zinc, and sulphate. Figure 6A-14 presents a summary of the water quality and level of impact at seepage monitoring stations in the Vangorda area. The greatest impacts were observed in the drains adjacent to the Little Creek Pond, SRK-VD04, and SRK-VD05 (CH2M HILL, 2013b). Station LCD monitors water quality in the Little Creek Pond, which fluctuates seasonally, with decreased concentrations observed during freshet (DES, 2012; SRK, 2010). Although decreased concentrations are observed during freshet, water quality observed at LCD is highly impacted, based on sulphate (6,330 mg/L) and zinc concentrations (1.78 mg/L, but as high as 960 mg/L historically) (Figure 6A-15) (CH2M HILL, 2013b).

Time-series plots were generated for five transverse drains: SRK-VD01, SRK-VD02, SRK-VD03 (V30), SRK-VD04 (V32) and SRK-VD05 (V33) (Figures 6A-3 and 6A-15). The water at all of these locations is classified

as highly impacted, with low pH and elevated concentrations of sulphate and zinc. Values of pH in the transverse drain monitoring locations range from 2.71 (SRK-VD05) to 5.84 (SRK-VD03) (Figure 6A-15). Concentrations of sulphate and zinc range from 1,740 mg/L (SRK-VD01) to 87,400 mg/L (SRK-VD05) and 0.73 mg/L (SRK-VD03) to 87.3 mg/L (SRK-VD01), respectively. These concentrations identify this as one of the most mine-affected areas of the FMC (Figure 6A-15). Continued monitoring of the Vangorda transverse drains is recommended to support future water collection and treatment options.

Monitoring wells V34 through V37 and P2001-1-3 monitor seepage beneath the Vangorda Waste Dump drainage ditch (Figure 6G-31). Current water quality at these locations is characterized by high pH with slightly-to-moderately elevated dissolved sulphate and zinc concentrations (Figure 6G-31). Zinc concentrations are stable at wells V34, V35, and V37, and are increasing at well V36. The observed increases in sulphate concentrations in all four wells suggests that some groundwater from the Vangorda Waste Dump is bypassing the seepage collection system (Appendix 6G and CH2M HILL, 2013b).

Currently, V1, V4, V5, V6A, V17A, V19, V20, V27, and VG Main monitor the surface water along Vangorda Creek and its tributaries (Figure 6A-3). Water quality is characterized by pH ranging from neutral to alkaline, with minimal impacts to water quality. These characteristics suggest Vangorda Creek has experienced minimal impacts from the mining activities to date. However, increasing concentrations of mine-related contamination and evidence of affected waters bypassing the seepage collection system indicate future impacts are possible (Appendix 6H and CH2M HILL, 2013b).

SECTION 4

Rose Creek Tailings Area, Rose Creek Alluvial Aquifer, and Cross Valley Dam

The RCTA generally receives clean groundwater from the south and southeast and receives impacted waters from the FMC, located to the north (Appendix 6G and Figure 6A-4). Locally, tailings contribute to groundwater contamination in the RCTA. Vertical hydraulic gradients measured in multi-level wells within the RCTA indicate the presence of downward gradients between the tailings and the underlying alluvial deposits. This suggests either (1) contaminants mobilized because precipitation infiltrated through the tailings or (2) contaminants that are discharged from the ETA and then enter the tailings could be transported vertically downward and discharged into the underlying RCAA (Appendix 6G). The unlined ditch conveying ETA water from FCS-4 to the Intermediate Dam Pond may also be a substantial source of contamination to the northern portion of the RCAA underlying the RCTA (Figure 6A-4). This assumption is supported by increasing trends in sulphate (from about 1,000 mg/L [January 2006] to about 3,500 mg/L [June 2012]) and zinc (from about 0.1 mg/L [January 2006] to about 11 mg/L [June 2012]). These concentrations were observed in the RCAA underlying the Secondary Tailings in monitoring well P03-06, downgradient of the Faro Creek Canyon (Figures 6G-28 and 6G-1-8) (RGC, 2012). The greatest concentrations of sulphate and metals of interest were observed in tailings porewater in the southeastern (P03-01 and P03-03) and northwestern (P03-06) sections of the Secondary Tailings. Conversely, the lowest concentrations of contaminants occur in groundwater in the southwestern section of the Second Impoundment at P03-05 (Figure 6G-28) (RGC, 2012). In the RCAA area, downgradient from the Faro Creek Canyon and towards the Intermediate Dam Pond, observations over the past 10 to 12 years have noted a gradual increase in sulphate, followed by a lagging increase in zinc (RGC, 2012).

While inputs from the Faro Waste Dumps appear to be impacting the northern portion of the RCAA, the southern portion of the RCAA is generally less impacted, possibly because of “clean” water leaking from the Rose Creek Diversion. This appears evident at the Intermediate Impoundment, where the Rose Creek Diversion is topographically higher than the Intermediate Impoundment (RGC, 2012).

The exception is in the southeastern corner of the RCTA, where oxidation appears to be more rapid in the Second Impoundment and seepage from the tailings appears to be impacting the RCAA. Significant increases in sulphate and zinc concentrations were observed in wells P03-03 (sulphate from about 1,000 mg/L to about 5,000 mg/L and zinc stable at about 0.01 mg/L in P03-03-06) and P03-05 (sulphate from about 400 mg/L to about 800 mg/L and zinc from about 0.01 mg/L to about 10 mg/L in P03-05-02) (RGC, 2012). Care and Maintenance personnel have observed iron stains in the ice covering the Rose Creek Diversion during the low-flow winter months when groundwater input contributes the most flow. This suggests metal-rich groundwater from the RCTA is reaching the Rose Creek Diversion during this time (Cherian, 2010, personal communication)

In addition to the impacts to the RCAA, groundwater in the underlying weathered bedrock downgradient of the CVD shows signs of impact, especially on the northern side of the valley (RCG, 2012). However, while a trend of deteriorating groundwater quality in alluvium and weathered bedrock downgradient of the CVD is evident, the contamination remains limited to major ions (i.e., magnesium and sulphate). The metal plumes (i.e., zinc and iron) currently remain upgradient of the CVD (RGC, 2012). Zinc concentrations in alluvial groundwater remain below 0.5 mg/L downgradient of the Second Impoundment, while concentrations are below 0.1 mg/L beneath the Intermediate Dam and CVD. This has been attributed to metal attenuation by adsorption to iron oxyhydroxides and carbonates (CH2M HILL, 2013a) and also to adsorption to organic matter near CVD (SRK, 2006b).

SECTION 5

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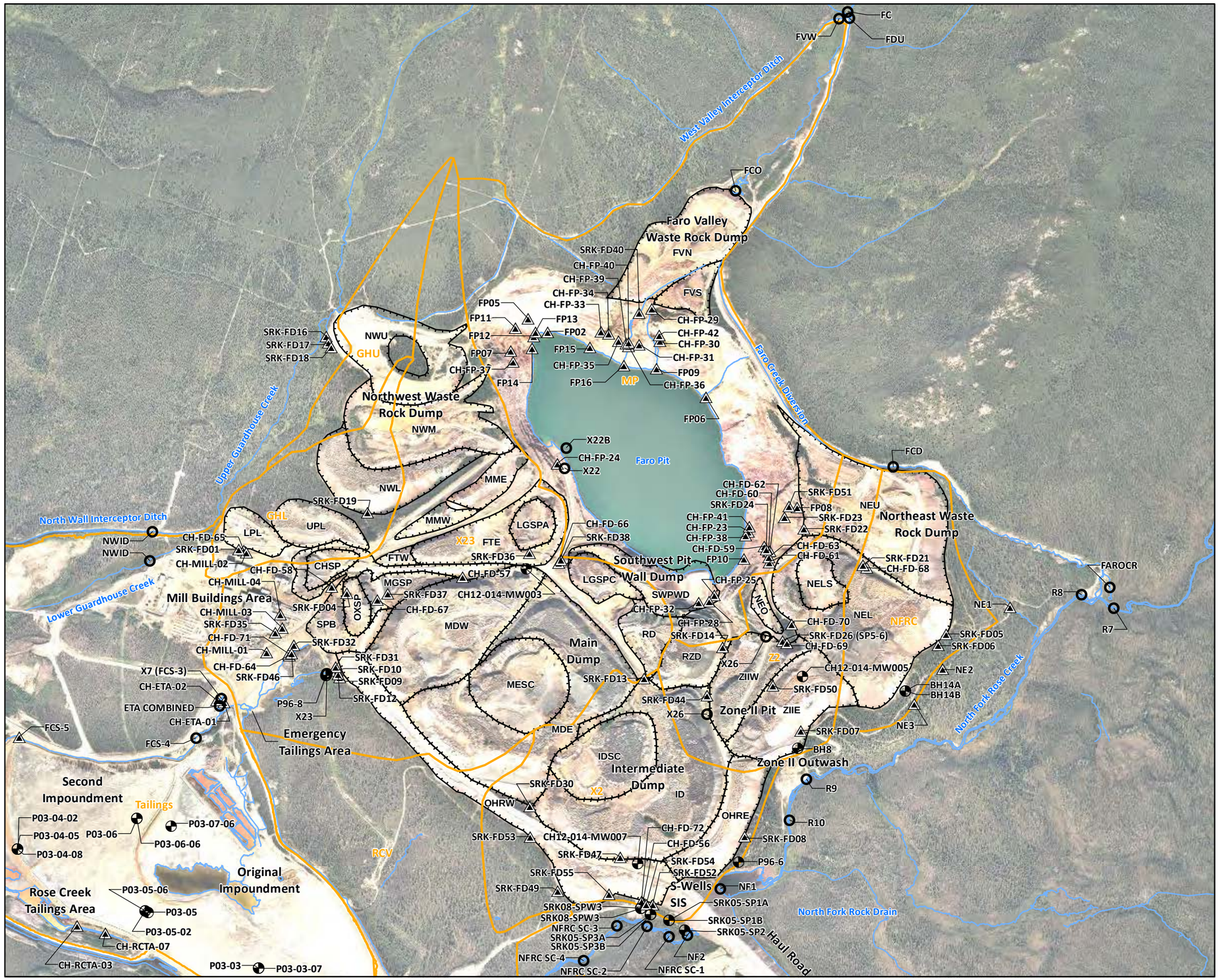
Figures



VICINITY MAP



LEGEND

- Monitoring Well Location
- Surface Water Location
- Seep Location
- Catchment Area
- Waste Dump

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Rose Creek Tailings Area is also called Down Valley Tailings Area, and is where the Rose Creek Alluvial Aquifer is located.
4. Waste Dump Definitions:

CHSP - Crusher Stockpile
FTE - Fuel Tank East
FTW - Fuel Tank West
FVN - Faro Valley North
FVS - Faro Valley South
ID - Intermediate Dump
IDSC - Intermediate Dump Sulphide Cell
LGSPA - Low Grade Stockpile A
LGSPC - Low Grade Stockpile C
LPL - Lower Parking Lot
MDE - Main Dump East
MDW - Main Dump West
MESC - Main Dump Sulphide Cell
MGSP - Medium Grade Stockpile
MME - Mt. Mungly East
MMW - Mt. Mungly West
NEL - Northeast Lower
NELS - Northeast Lower Sulphide Cell
NEO - Northeast Outer
NEU - Northeast Upper
NWL - Northwest Lower
NWM - Northwest Middle
NWU - Northwest Upper
OHRE - Outer Haul Road East
OHRW - Outer Haul Road West
OXSP - Oxide Fines Stockpile
RD - Ranch Dump
RZD - Ramp Zone Dump
SPB - Stock Piles Base
SWPWD - Southwest Pit Wall Dump
UPL - Upper Parking Lot

N

0 200 400 600 800

Metres

Created by:
CRITIGEN

FIGURE 6A-1
Seep and Surface Water Monitoring Stations, Waste Dump Boundaries, and Catchment Boundaries in the Faro Pit Area
Faro Mine Interim Works

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VICINITY MAP



LEGEND

Catchment Area

Waste Dump

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Waste Dump Definitions:
   G1-B - Grum Main Dump
   G1-S - Grum Main Sulphide Cell
   G2 - Grum Southwest Dump
   G3-0 - Grum Overburden Dump
   OTP - Ore Transfer Pad

N

0 100 200 300 400

Metres

Created by: CRITIGEN

FIGURE 6A-2

Seep and Surface Water Monitoring Stations, Waste Dump Boundaries, and Catchment Boundaries in the Grum Pit Area

Faro Mine Interim Works

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CH2MHILL



VICINITY MAP



LEGEND

- Monitoring Well Location
- Surface Water Location
- Seep Location
- Catchment Area
- Waste Dump

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Waste Dump Definitions:
   - V1-B - Vangorda Main Dump
   - V1-S - Vangorda Main Sulphide Cell
   - V2 - Vangorda Baritic Fines Dump
   - V3-0 - Vangorda Overburden Dump
   - VPL1 - Dump Southeast of Ramp
   - VPL2 - Dump inside Hairpin
   - VPL3 - Oxide Fines Dump

N

0 100 200 300 400

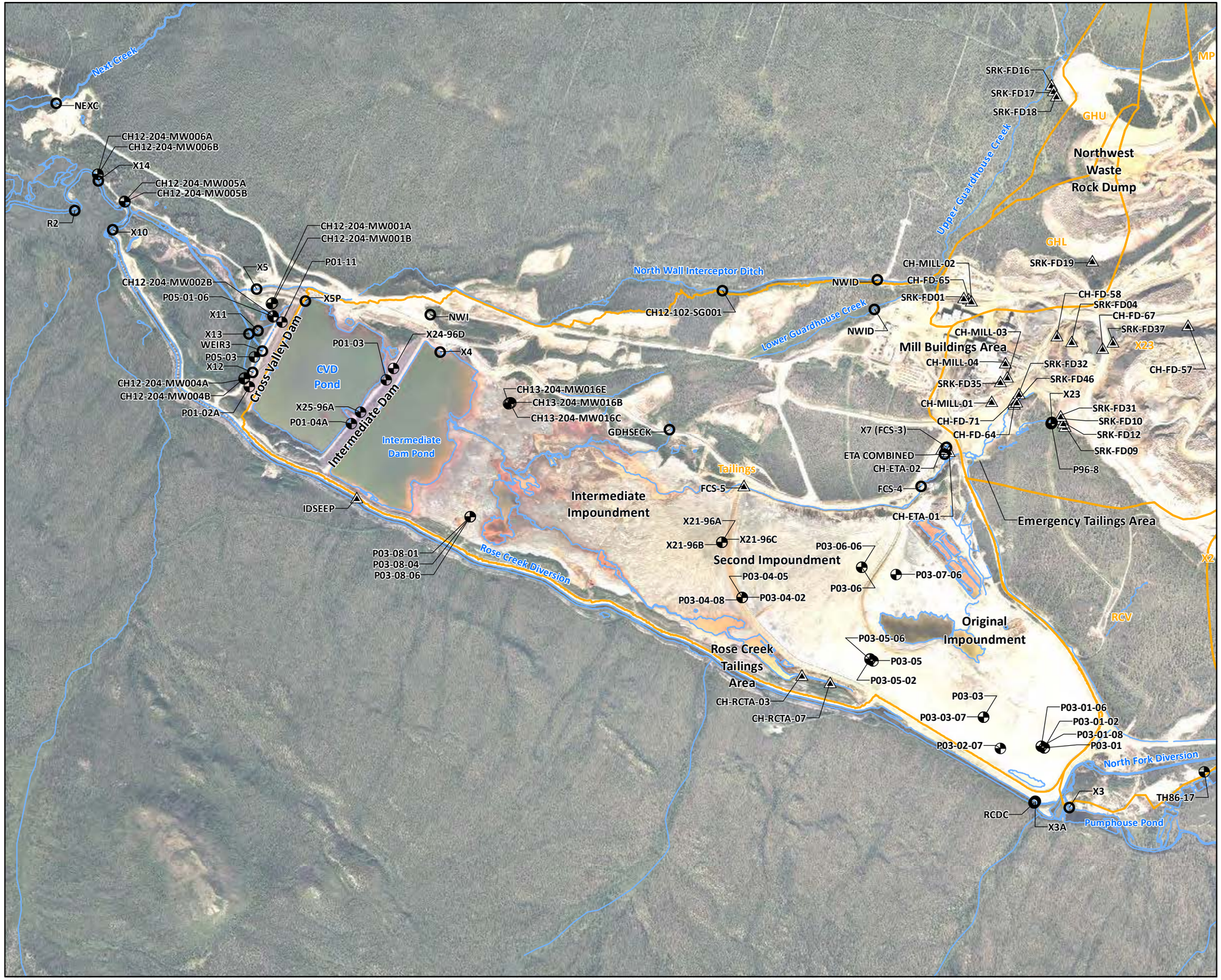
Metres

Created by: CRITIGEN

FIGURE 6A-3

Seep and Surface Water Monitoring Stations, Waste Dump Boundaries, and Catchment Boundaries in the Vangorda Pit Area

Faro Mine Interim Works



VICINITY MAP



LEGEND

- Monitoring Well Location
- Surface Water Location
- Seep Location
- Catchment Area

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Rose Creek Tailings Area is also called Down Valley Tailings Area.

LEGEND

N

0 200 400 600 800

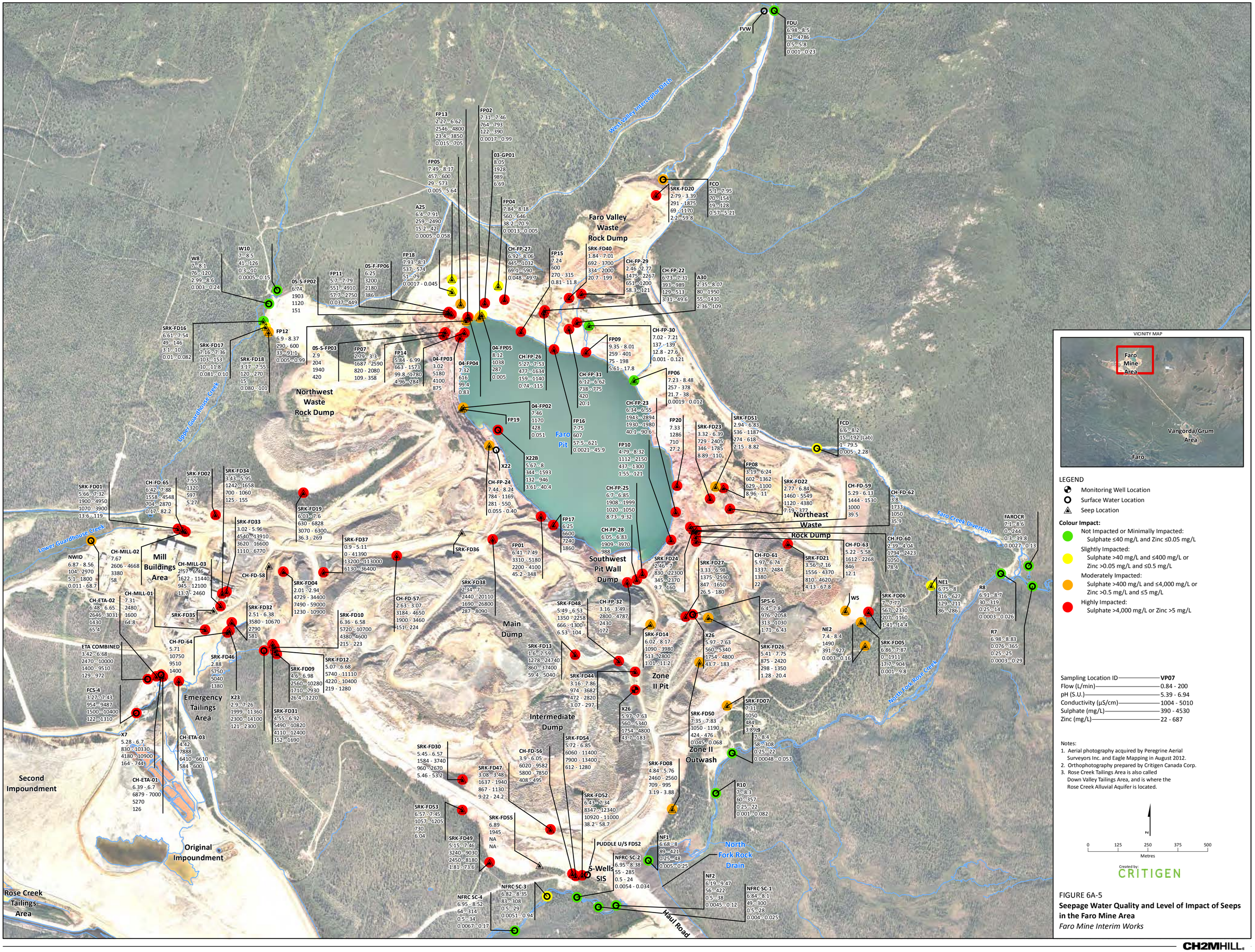
Metres

Created by: CRITIGEN

FIGURE 6A-4

Seep and Surface Water Monitoring Stations in the Rose Creek Tailings Area

Faro Mine Interim Works



VICINITY MAP

LEGEND

- Monitoring Well Location
- Surface Water Location
- Seep Location

Colour Impact:

- Not Impacted or Minimally Impacted: Sulphate ≤40 mg/L and Zinc ≤0.05 mg/L
- Slightly Impacted: Sulphate >40 mg/L and ≤400 mg/L or Zinc >0.05 mg/L and ≤0.5 mg/L
- Moderately Impacted: Sulphate >400 mg/L and ≤4,000 mg/L or Zinc >0.5 mg/L and ≤5 mg/L
- Highly Impacted: Sulphate >4,000 mg/L or Zinc >5 mg/L

Sampling Location ID	VP07
Flow (L/min)	0.84 - 200
pH (S.U.)	5.39 - 6.94
Conductivity (µS/cm)	1004 - 5010
Sulphate (mg/L)	390 - 4530
Zinc (mg/L)	22 - 687

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Rose Creek Tailings Area is also called Down Valley Tailings Area, and is where the Rose Creek Alluvial Aquifer is located.

N

0 125 250 375 500

Metres

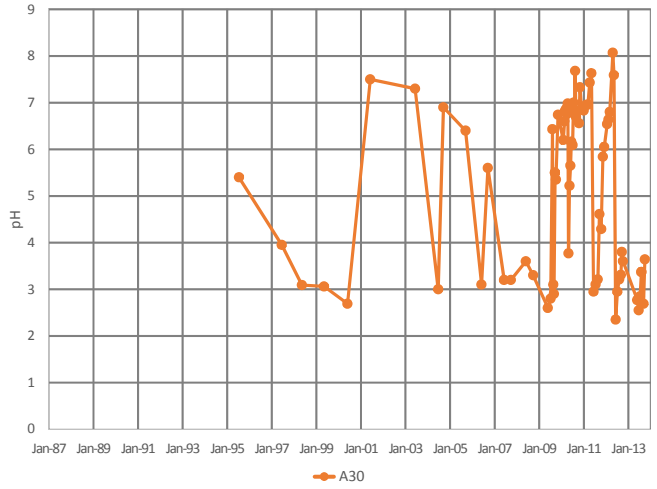
Created by: CRITIGEN

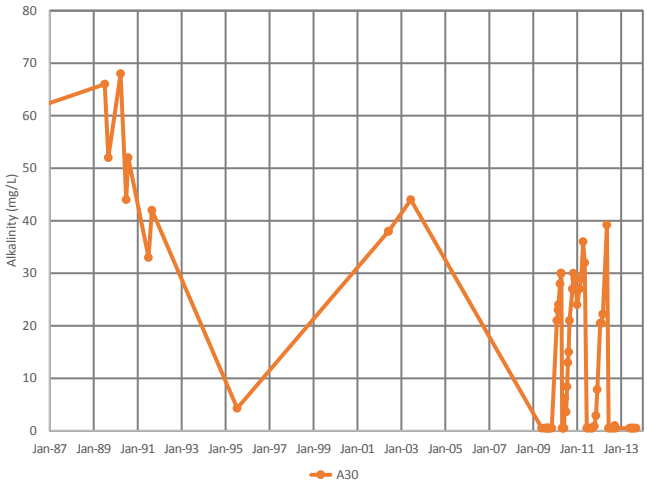
FIGURE 6A-5

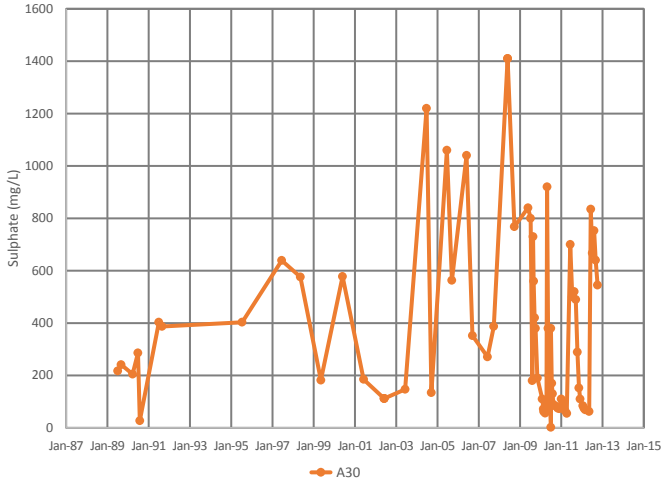
Seepage Water Quality and Level of Impact of Seeps in the Faro Mine Area

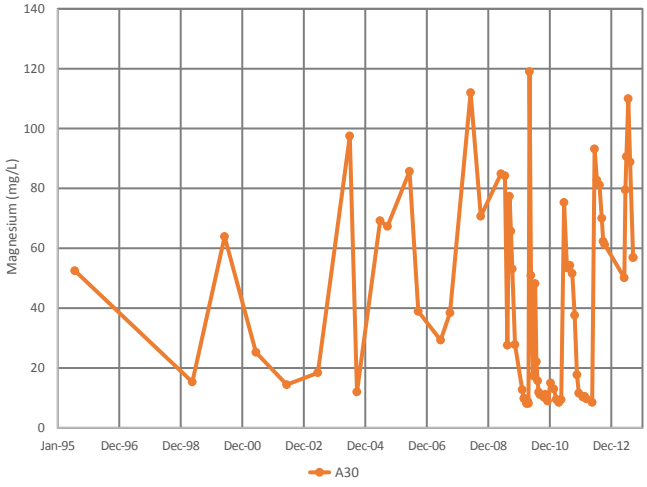
Faro Mine Interim Works

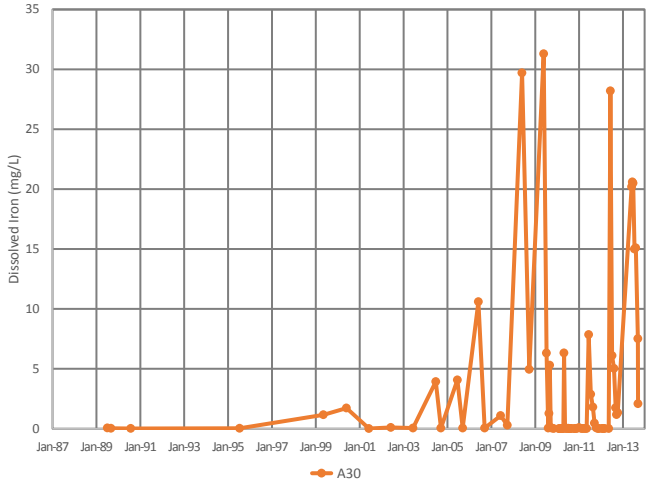
CH2MHILL











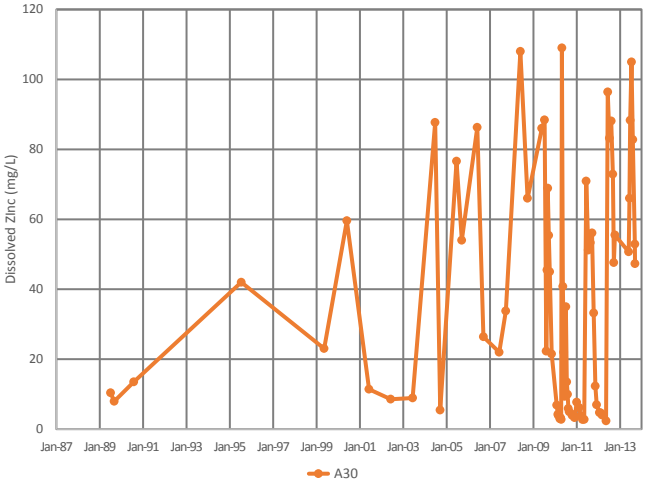
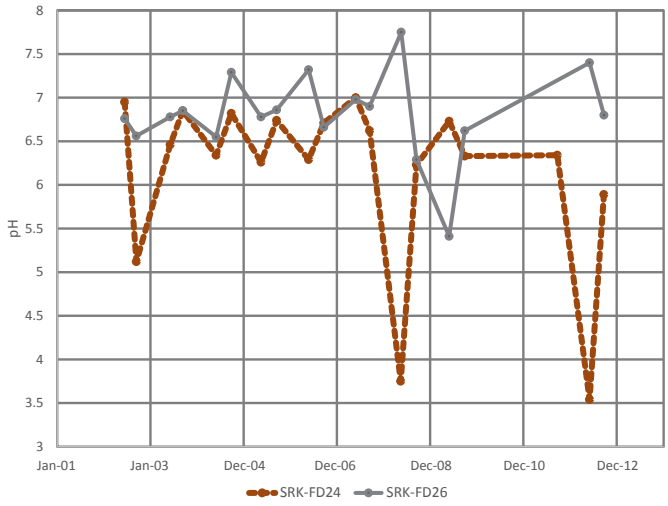
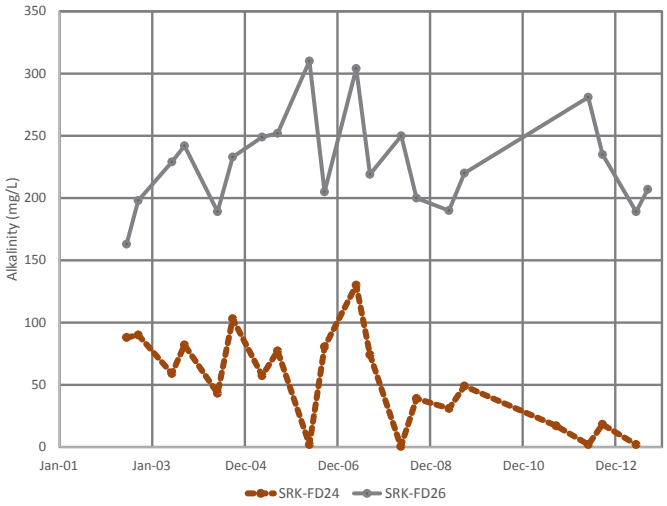
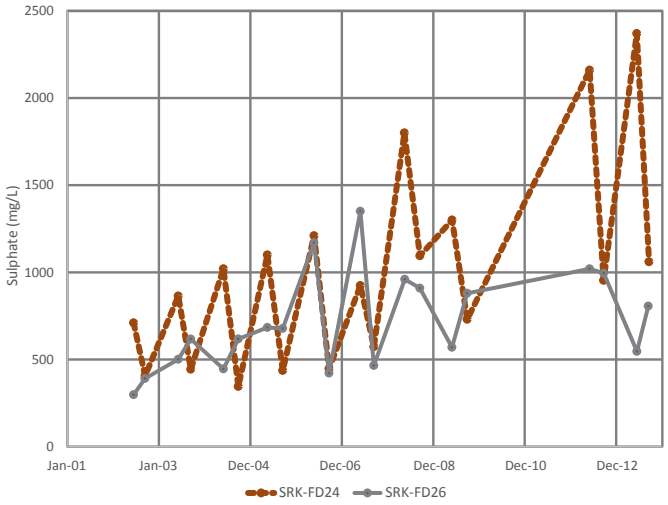
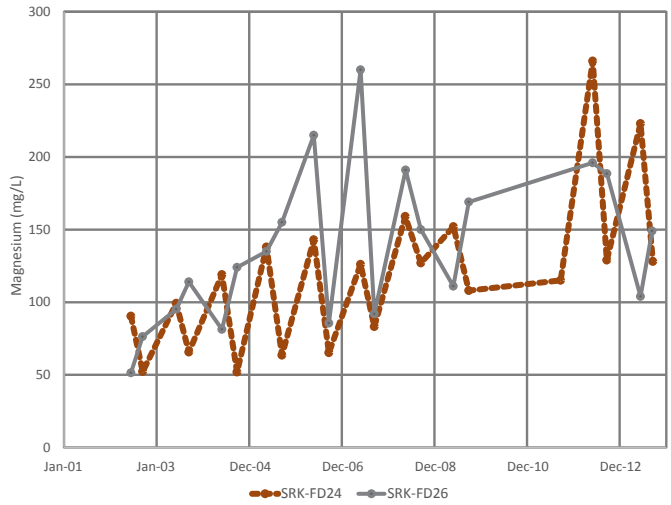


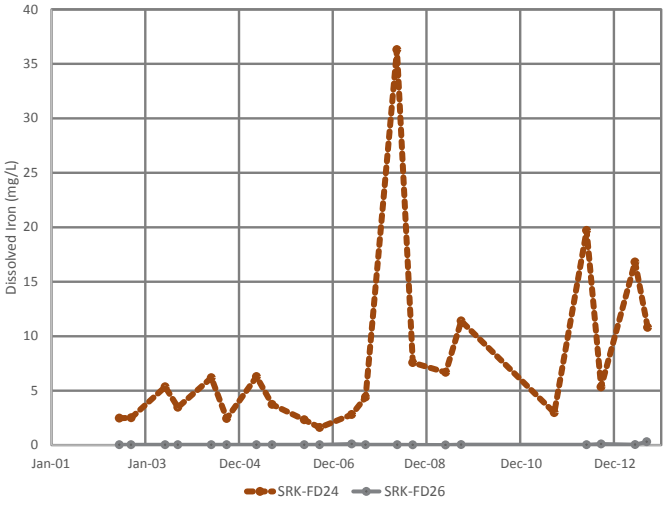
FIGURE 6A-6
Trends in Selected Water Quality Parameters of Seepage from the North Faro Pit Area
Faro Mine Interim Works











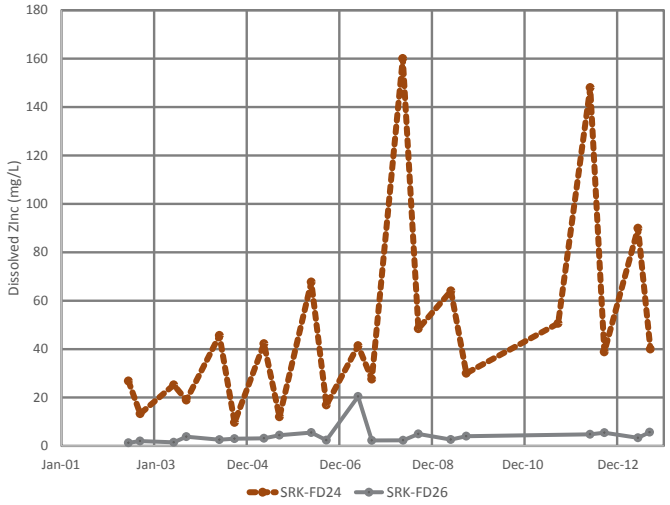


FIGURE 6A-7
Trends in Selected Water Quality Parameters of Seepage from the Northeast Faro Pit Area
Faro Mine Interim Works

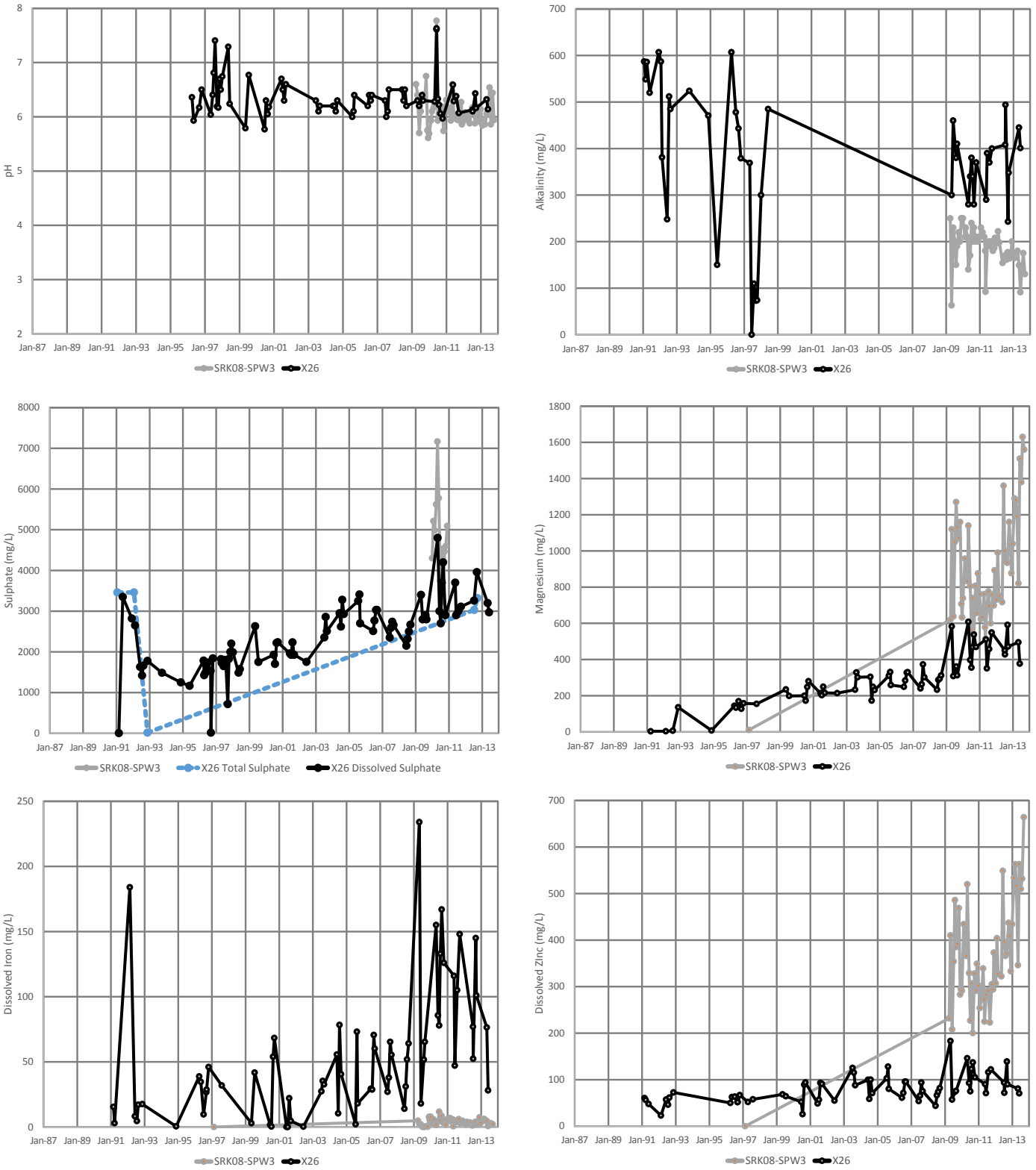


FIGURE 6A-8
Trends in Selected Water Quality Parameters of Intercepted Water from the Zone II and S-wells Area
Faro Mine Interim Works

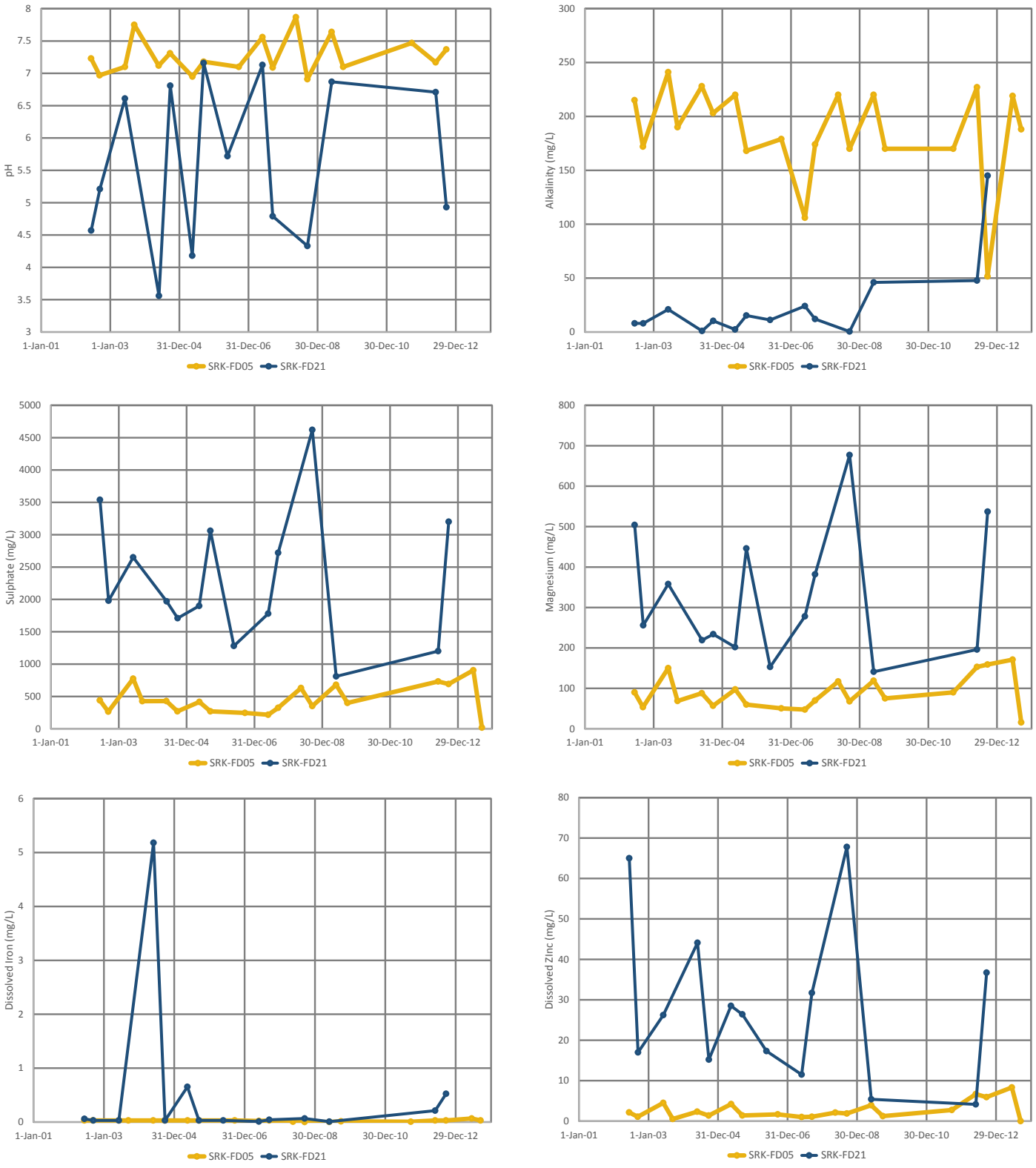


FIGURE 6A-9
Trends in Selected Water Quality Parameters of Seepage Draining toward North Fork Rose Creek
Faro Mine Interim Works

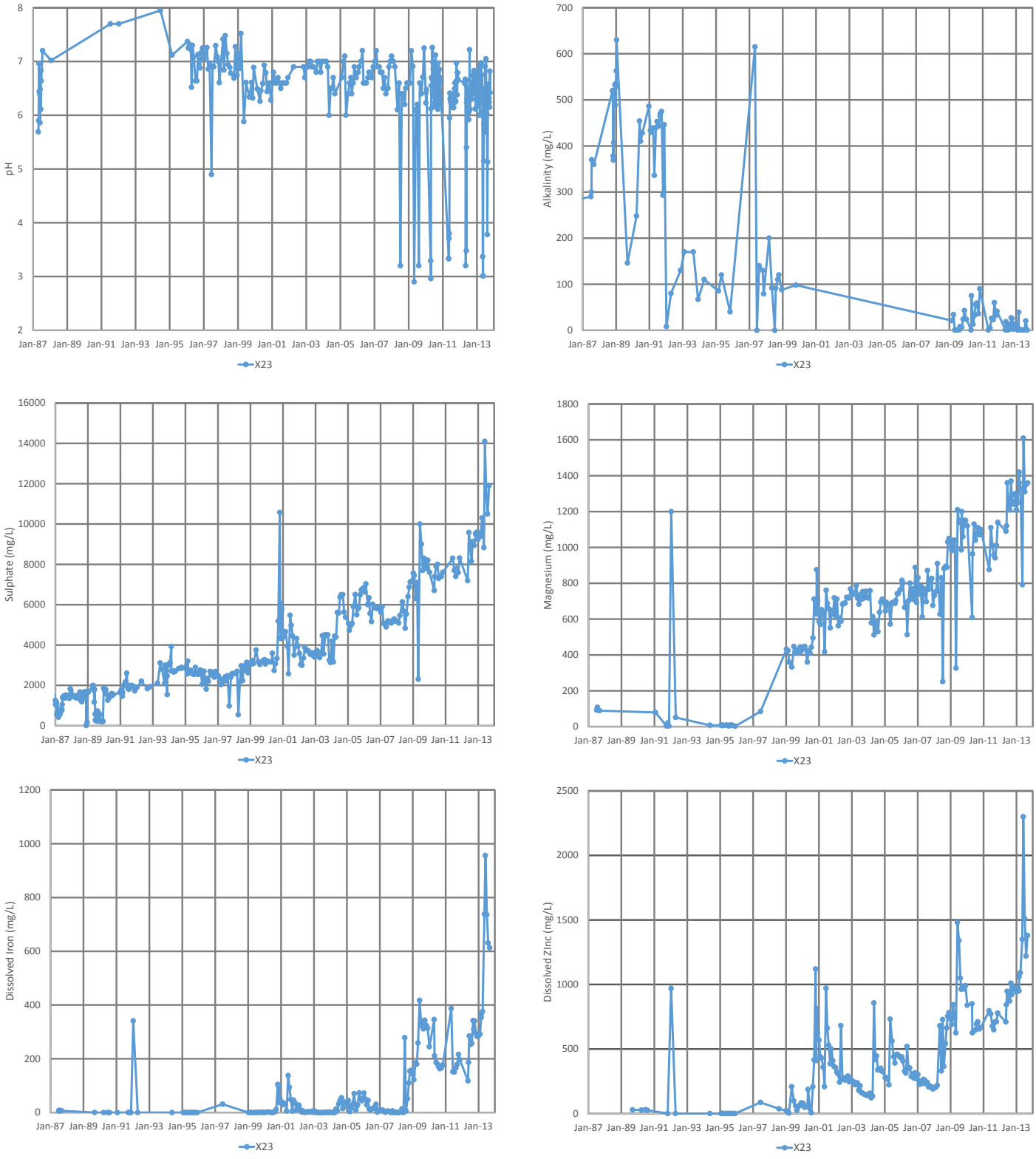


FIGURE 6A-10
Trends in Selected Water Quality Parameters at X23
Faro Mine Interim Works

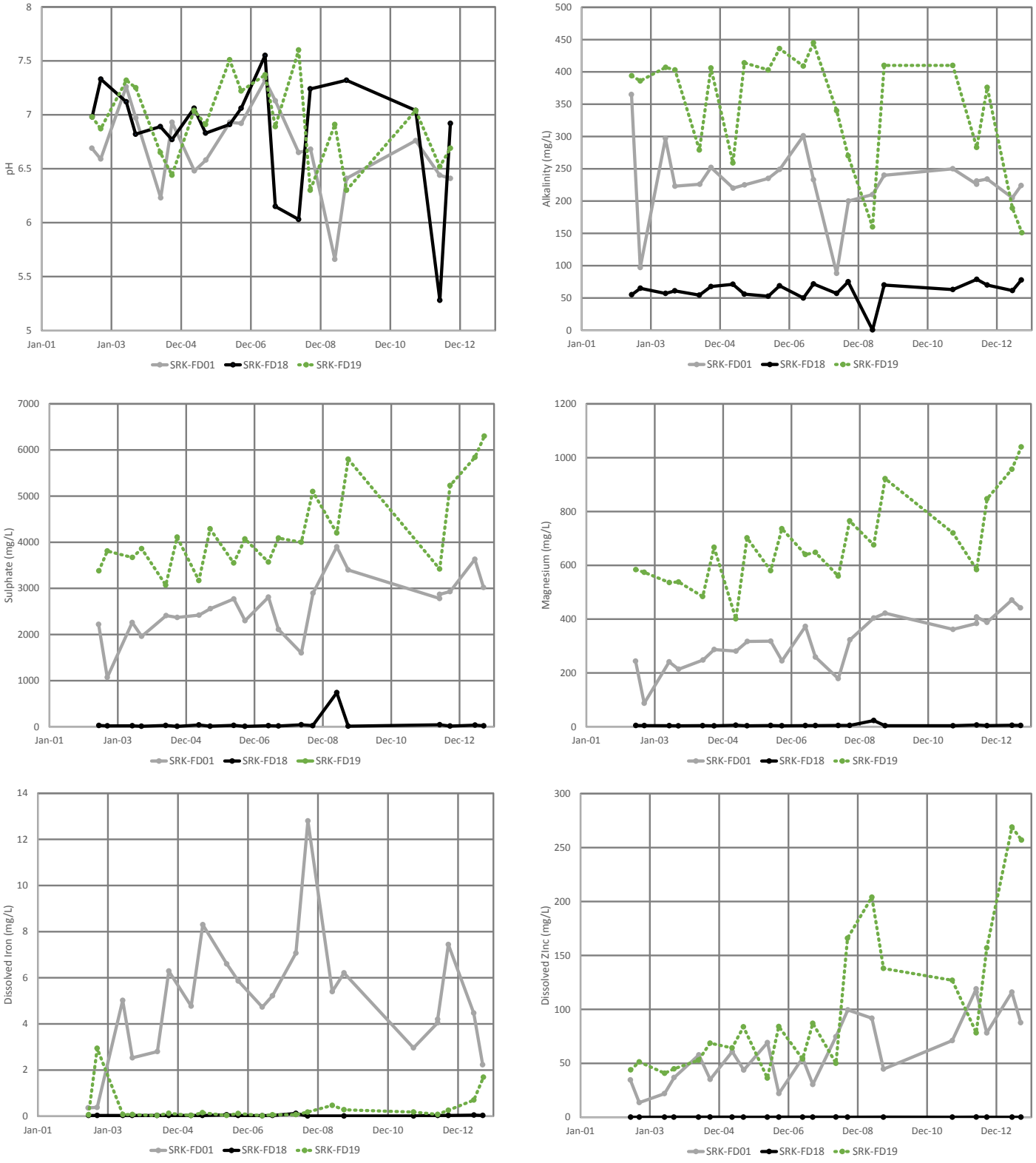


FIGURE 6A-11
Trends in Selected Water Quality Parameters of Seepage Draining toward Lower Guardhouse Creek
Faro Mine Interim Works

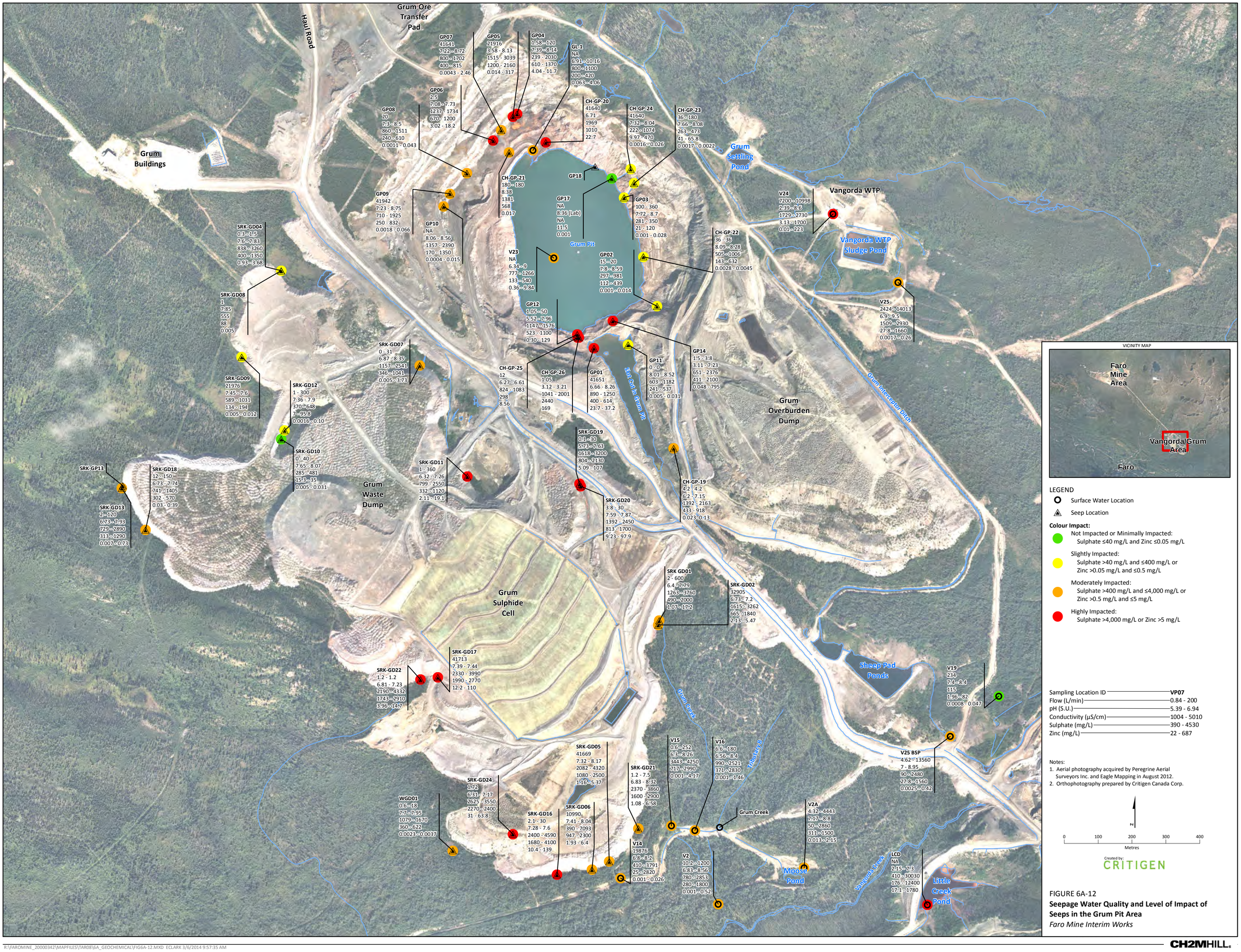


FIGURE 6A-12
Seepage Water Quality and Level of Impact of Seeps in the Grum Pit Area
Faro Mine Interim Works

CH2MHILL

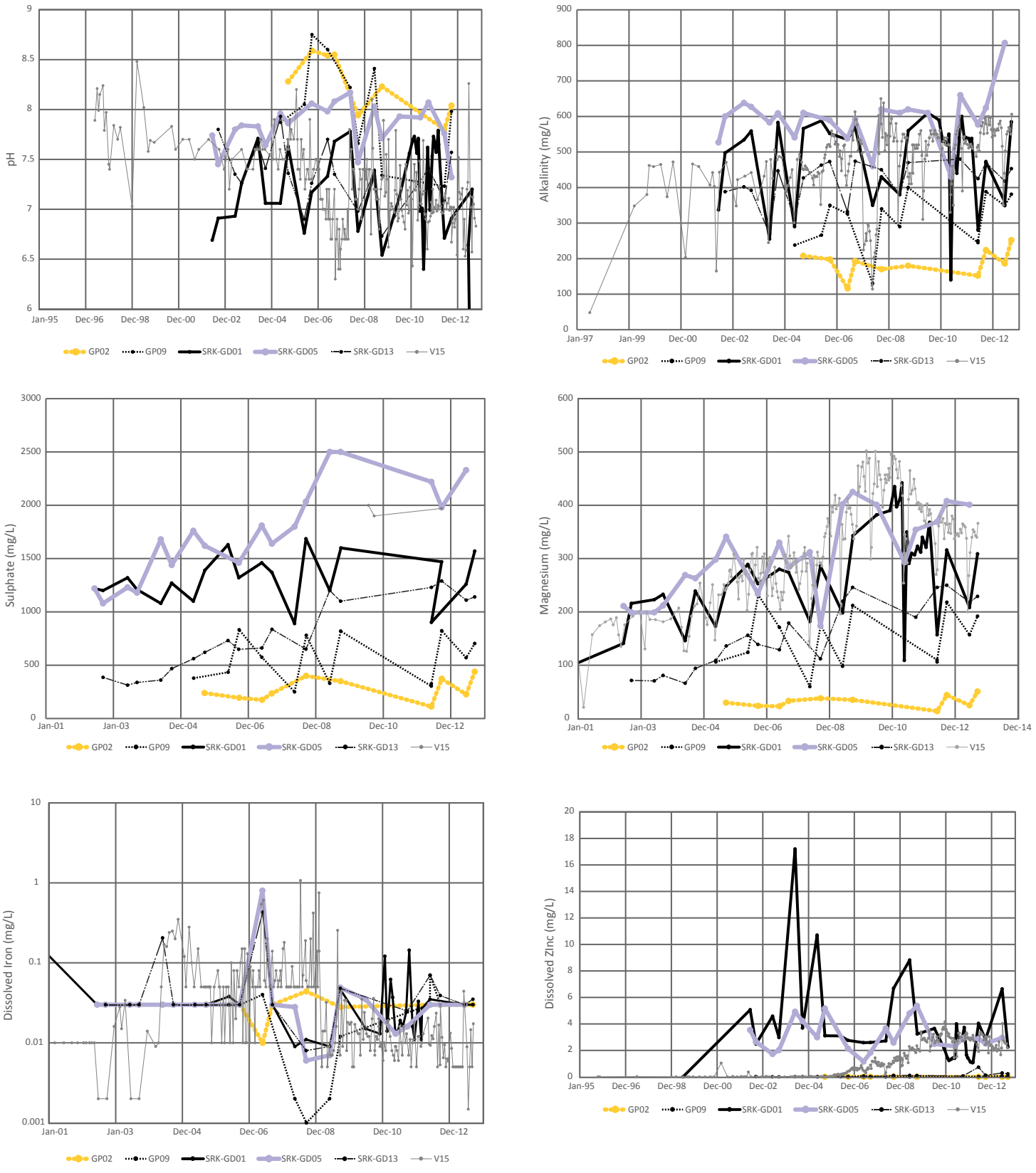
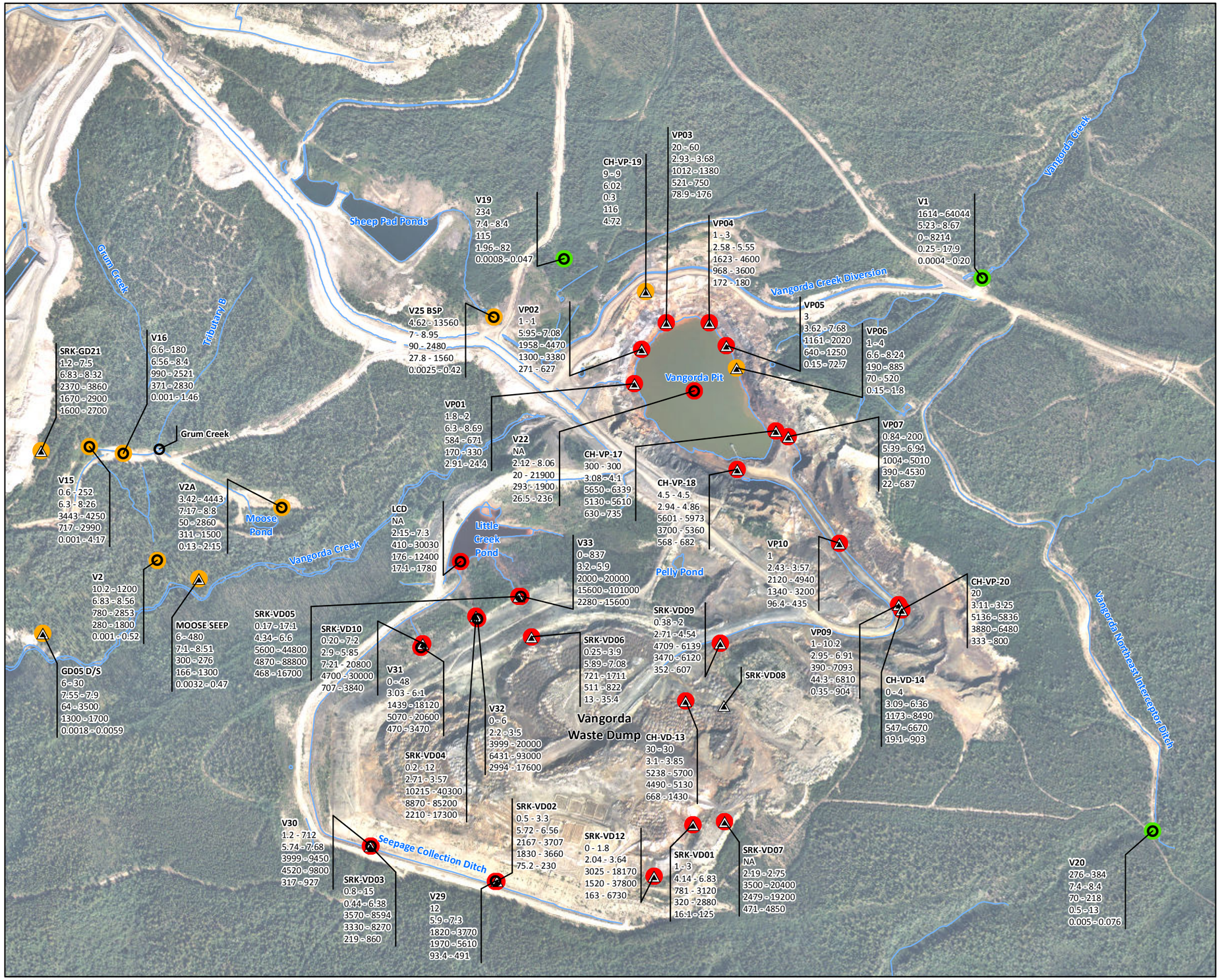


FIGURE 6A-13
Trends in Selected Water Quality Parameters of Seepage from the Grum Area
Faro Mine Interim Works



VICINITY MAP



LEGEND

- Surface Water Location
- Seep Location

Colour Impact:

- Not Impacted or Minimally Impacted: Sulphate ≤40 mg/L and Zinc ≤0.05 mg/L
- Slightly Impacted: Sulphate >40 mg/L and ≤400 mg/L or Zinc >0.05 mg/L and ≤0.5 mg/L
- Moderately Impacted: Sulphate >400 mg/L and ≤4,000 mg/L or Zinc >0.5 mg/L and ≤5 mg/L
- Highly Impacted: Sulphate >4,000 mg/L or Zinc >5 mg/L

Sampling Location ID	**VP07**
Flow (L/min)	0.84 - 200
pH (S.U.)	5.39 - 6.94
Conductivity (µS/cm)	1004 - 5010
Sulphate (mg/L)	390 - 4530
Zinc (mg/L)	22 - 687

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 100 200 300 400

Metres

Created by: CRITIGEN

FIGURE 6A-14

Seepage Water Quality and Level of Impact of Seeps in the Vangorda Pit Area

Faro Mine Interim Works

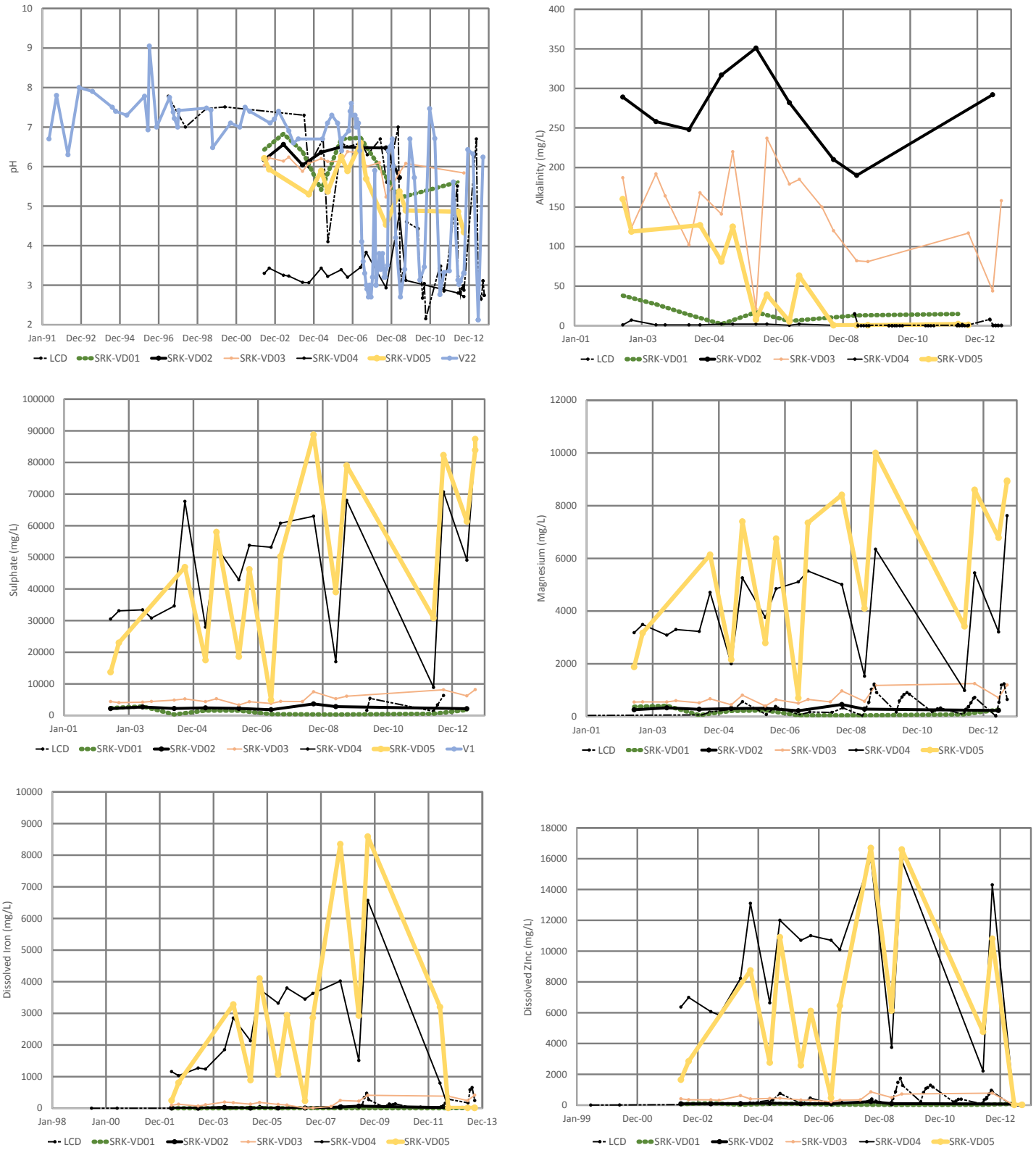


FIGURE 6A-15
Trends in Selected Water Quality Parameters of Seepage from the Vangorda Area
Faro Mine Interim Works

Appendix 6B
Hydraulics Characterization of Existing Facilities

Draft

Hydraulics Characterization of Existing Facilities, Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 6, 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon Y1A 2J9

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6B-3 Faro Mine Area Current Water Collection and Treatment

6B-4 Vangorda/Grum Current Water Collection and Treatment

Acronyms and Abbreviations

AECOM	AECOM Technology Corporation
AMP	Adaptive Management Plan
BGC	BGC Engineering
CDA	Canadian Dam Association
CH2M HILL	CH2M HILL Canada Limited
CSP	corrugated steel pipe
CVD	Cross Valley Dam
DES	Denison Environmental Services
DVIHU	Down Valley Interim Hydraulic Upgrades
ETA	Emergency Tailings Area
FCD	Faro Creek Diversion
FMC	Faro Mine Complex
FVID	Faro Valley Interceptor Ditch
FVIT	Faro Valley Interceptor Trench
GID	Grum Interceptor Ditch
GLL	Gartner Lee Limited
HDPE	high-density polyethylene
ID	Intermediate Dam
IW	Interim Works
IWPP	Interim Works Project Proposal
km	kilometre
km^2	square kilometre
LCD	Little Creek Dam
LCP	Little Creek Pond
m^3	cubic metre
m^3/sec	cubic metre per second
mm	millimetre
NFRC	North Fork of Rose Creek
NFRD	North Fork Rock Drain
NHC	Northwest Hydraulic Consultants
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCD	Rose Creek Diversion

RCTA	Rose Creek Tailings Area
SD	Secondary Dam
SFRC	South Fork Rose Creek
SPP	Sheep Pad Ponds
SRK	SRK Consulting Engineers and Scientists
WRD	Waste Rock Dump
VCD	Vangorda Creek Diversion
WTP	Water Treatment Plant

SECTION 1

Introduction

The intent of this characterization report is to describe the current status of hydraulic facilities at the Faro Mine Complex (FMC), including their existing capacity and condition. It summarizes how these features are maintained and monitored, and their hydraulic functions in relation to the Faro Mine Interim Works (IW). This report is based on external, stand-alone documents, as well as ongoing hydraulic studies. This hydraulics characterization report assesses the available information and data used to characterize the hydraulic functioning of engineered conveyance and impoundment features at the FMC and, where appropriate, references additional, more detailed hydraulic and hydrologic information available from other appendixes in the Interim Works Project Proposal (IWPP). During and after mining operations, considerable effort was expended to monitor the integrity and effectiveness of hydraulic features (i.e., streams, diversions, and impoundments) and related conveyance infrastructure. This document describes these sources of hydraulic data for the FMC and discusses the analysis methods used to characterize the site hydraulics.

Figure 6B-1 shows the FMC area. This report discusses the hydraulic features based on the two main watersheds illustrated in Figure 6B-2: (1) the Rose Creek watershed, which contains the Faro Mine Area, and (2) the Vangorda Creek watershed, which contains the Vangorda/Grum Area.

SECTION 2
Methods

Historically, a number of streams and creeks conveyed runoff through the FMC. To prevent potential surface water contamination associated with mining activities, many of these systems were rerouted via diversions, flumes, and ditches. The resulting hydraulic structures have been studied by various investigators to document site conditions, and, in some cases, original design information is available. Monitoring studies have also documented hydraulic information such as surface water flows and water levels. Relevant site information and data were collected from numerous sources to characterize site hydraulic conditions. CH2M HILL collected and reviewed historical data collection reports, design study reports for FMC activities, and site characterization reports and assessments. Most of these data sets included local, FMC-related data that were collected through post-mining monitoring programs.

2.1 Sources of Data and Information

Supporting data for hydraulic characterization consist of stream flow and water level data collected over various time periods and, where available, design data related to conveyance capacities. Hydraulic characterization also includes information from detailed inspection and analysis reports about the stability, operations, and maintenance of hydraulic features.

2.1.1 Flow Data

Flow data and estimates support the determination of how the FMC hydraulic structures are performing, and could perform in the future.

2.1.1.1 Continuous and Spot Flow Measurements

The *Hydrology Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a) provides a detailed summary of available continuous flow measurement data for the FMC. It also discusses quality assurance /quality control processes for this data, to support hydrological characterizations. These characterizations will assist with remediation and closure efforts at the FMC.

2.1.1.2 Regional Analyses

The FMC's flood hydrology is an important consideration for hydraulic assessment, as it represents a condition that occurs very infrequently but presents one of the greatest risks to the integrity and functioning of hydraulic elements (SRK Consulting Engineers and Scientists [SRK], 2010a). Flood estimates have been developed for the FMC using a technique known as Regional Analysis. Regional Analysis consists of fitting the annual series of peak flood rates at a number of flow stations throughout the Yukon and Alaska, for a range of return periods to the FMC flow stations. The analysis identifies trends that could be used to transpose flood estimates from the regional streamflow gauging stations to the FMC (SRK, 2010a).

As the Hydrology Baseline Report (CH2M HILL, 2013a) discusses, AECOM (2009a) documents the most recent regional analysis work, and refines the regional analysis developed for the 1996 *Integrated and Comprehensive Abandonment Plan* report (Robertson GeoConsultants Inc., 1996). AECOM examined available data to develop empirical relationships that can be used to relate a flow statistic (e.g., Mean Annual Runoff) to a catchment characteristic (e.g., drainage area). The regional analysis prepared by AECOM (2009a) was used to develop a site-wide water balance and relationships for mean annual runoff and low flows.

As discussed in the *Stability Analysis Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013b), Northwest Hydraulic Consultants (NHC) and BGC Engineering (BGC) (2004) conducted a regional analysis based on data obtained from seven regional gauges. During the study, the period of record represented by the gauges ranged from 14 years to 40 years. The catchment areas for the gauges ranged from 91 square kilometres (km^2) to 7,250 km^2. Instantaneous peak discharges were estimated for the mean annual event and for the 1-in-50-year, -100-year, -200-year, -500-year, and -1,000-year return period floods.

As discussed in the Hydrology and Stability Analysis baseline reports, another regional study was conducted as detailed in the *Anvil Range Mining Complex 2005 Seepage Investigation at the Emergency Tailings Area* report (SRK, 2006) to determine average daily flows for the 1-in-2-year, -100-year, -200-year, -500-year, and -1,000-year floods. The recurrence interval floods were determined for flow durations ranging from 1 to 365 days. Using plots of peak discharge versus catchment area, a relatively constant discharge per km^2 was observed for flow records representing catchment areas ranging from 13.7 km^2 to 7,250 km^2. This observation led to the conclusion that the catchment response to floods could be estimated by using recurrence interval estimates from the single gauge with the most extensive period of record (because catchment unit discharge during recurrence interval events appeared to be independent of total catchment area).

Finally, as discussed in the Hydrology Baseline Report, SRK performed a regional analysis for Vangorda Creek as part of a draft design report for the VCD (SRK, 2010a), to estimate instantaneous peak discharge for 1-in-2-year, -100-year, -500-year, and -1,000-year floods.

2.1.1.3 Probable Maximum Precipitation and Probable Maximum Flood

Water Management Consultants and a committee of the Faro Mine Closure Planning Office conducted a 2006 study that examined the Probable Maximum Flood (PMF) event for the Rose Creek catchment in detail (Water Management Consultants, 2006). The development of the PMF and Probable Maximum Precipitation (PMP) was peer-reviewed to confirm that valid assumptions were used and realistic outcomes were developed (CH2M HILL, 2012b).

2.1.2 Annual Reports

Environmental monitoring programs required under the previous water licenses and the current Care and Maintenance contract provide information about the operation and maintenance of hydraulic infrastructure at the FMC (Denison Environmental Services [DES], 2010).

CH2M HILL reviewed the following reports, which summarized the last 6 years of operations and maintenance activity at the FMC, to establish the baseline hydraulic condition:

- Anvil Range Mine Complex – 2006 Annual Environmental Report - License QZ03-059 (Gartner Lee Limited [GLL], 2007)
- Anvil Range Mine Complex – 2007 Annual Environmental Report – License QZ03-059 (GLL, 2008)
- Anvil Range Mine Complex – 2008 Annual Environmental Report – Water License QZ03-059. (AECOM, 2009b)
- Faro Mine Complex Annual Environmental Monitoring and Activity Report 2009 (DES, 2010)
- 2010 Annual Environmental Monitoring and Activity Report – Faro Mine Complex - Faro, Yukon (DES, 2011)
- 2011 Annual Environmental Monitoring and Activity Report – Faro Mine Complex - Faro, Yukon (DES, 2012)
- 2012 Annual Activities Report (Tlicho Engineering and Environmental Services, 2013)

Annual reports are particularly useful for identifying hydraulic issues with conveyance elements that are not included in the annual geotechnical inspections. They provide information about operations and maintenance issues with specific features, and summarize site-wide observations about hydraulic functioning.

2.1.3 Geotechnical Reports

CH2M HILL reviewed the following geotechnical reports, related to the functioning and integrity of hydraulic features (including dams, impoundments, and diversion structures):

- Anvil Range Property 2007 Dam Safety Review – Cross Valley Dam, Intermediate Dam, and Little Creek Dam (Klohn Crippen Berger, 2008)
- 2009 Annual Geotechnical Evaluation and Instrument Review – Various Facilities at Faro Mine, Yukon (BGC, 2010)

- 2010 Annual Inspection – Waste and Water Management Facilities - Vangorda/Grum, Faro Mine Complex, Yukon (SRK, 2011a)
- 2011 Geotechnical Inspection – Waste and Water Management Facilities - Vangorda/Grum, Faro Mine Complex, Yukon (SRK, 2011b)
- Faro Mine Complex - 2011 Annual Geotechnical Review (Klohn Crippen Berger, 2012)

Annual inspection and review reports (Klohn Crippen Berger, 2012; 2008; BGC, 2010), comment on the geotechnical performance of the following structures in the Faro Mine Area:

- Cross Valley Dam (CVD) and emergency spillway
- Intermediate Dam (ID) and emergency spillway
- Rose Creek Diversion (RCD): dike crest, top of backslope, and toe of slope
- North Wall Interceptor Ditch
- North Fork Rock Drain (NFRD)
- Selected portions of the Faro waste rock dumps (WRDs)
- Intermediate Impoundment
- Faro Creek Diversion (FCD), upstream of the Faro Pit

The annual inspection and review reports (SRK, 2011a), (SRK, 2011b), comment on the geotechnical performance and stability of the following structures at the Vangorda/Grum Area:

- Vangorda Waste Dump and seepage collection system
- Little Creek Dam (LCD)
- Vangorda Creek Diversion (VCD)
- Embankments of the Vangorda Water Treatment Plant (WTP) Clarification Pond
- WTP Freshwater Supply Pond
- Grum Interceptor Ditch (GID)
- Sheep Pad Ponds (SPP)
- Lower slopes of the Grum Waste Dump

Appendix 6C describes major facilities in detail and discusses their conditions.

2.1.3.1 Down Valley Interim Hydraulic Upgrades Phase 2 Basis of Design Report

The existing ID spillway does not have the capacity to safely pass a moderate or major flood event without potentially failing the dam. The Down Valley Interim Hydraulic Upgrades (DVIHU) work package, (CH2M HILL, 2014a) and *Down Valley Interim Hydraulic Upgrades Design, Faro Mine Interim Works* (CH2M HILL, 2014b), provide an upgrade of the hydraulic capacity of the ID spillway so that it can safely pass approximately 115 cubic metres per second (m^3/sec), which is the peak flow at the ID spillway for a 1-in-500-year flood event, while maintaining a freeboard of 1.0 metres (m). This estimate of the flood event takes into account attenuation by the Rock Drain and storage by the Intermediate Impoundment. The increase in hydraulic capacity of the ID spillway will be accomplished by raising the effective height of the dam and by increasing the cross-sectional area of the spillway. The 1-in-500-year flood event was selected as the design flood event for the interim improvements. The proposed work includes RCD improvements to safely pass the 1-in-500-year flood event without overtopping the RCD dike.

The intent of the DVIHU project is to address these issues in the interim period, before the permanent solution of increasing the ID spillway capacity by constructing a PMF spillway is implemented as part of the FMRP.

2.1.4 Culvert Survey

The 2012 Field Survey of Existing Features included a survey of all existing (known) culverts within the mine site area (Challenger Geomatics, 2012). The invert elevations at both ends of the culvert were measured using standard survey methods. Other data collected for each culvert included the diameters and material types. Each side of the culvert was photographed, looking upstream and downstream (Challenger Geomatics Limited, 2012).

Attachment 6B-1 includes site plans, culvert photographs, and related data collected during the 2012 field investigation.

SECTION 3
Results

3.1 Hydraulic Component Inventory

The following sections describe the hydraulic components that control surface flows within the Faro Mine Area and the Vangorda/Grum Area.

3.1.1 Faro Mine Area Hydraulic Components

Figure 6B-3 shows the Faro Mine Area hydraulic components.

3.1.1.1 West Valley Interceptor Ditch

The West Valley Interceptor Ditch (WVID) intercepts runoff from the hillsides northwest of the Faro Valley Waste Dump, and redirects it northward to the FCD. The WVID is a simple excavation into the native surficial soil and rock (GLL, 2007), which was built in conjunction with the FCD to direct surface water flow away from the Faro pit as it was being developed.

3.1.1.2 Faro Creek Diversion

The FCD collects uncontaminated surface water from the original Faro Creek Channel upstream of the Faro Pit. It diverts the water around the northeast side of the Pit, into the North Fork Rose Creek (NFRC). The FCD does not collect all of the flow in the old Faro Creek drainage area; some surface flow and groundwater seepage water continues to flow directly into the Faro Pit (GLL, 2007).

3.1.1.3 North Fork Rose Creek

The NFRC is a natural channel that conveys runoff from the upper, undisturbed portion of the FMC catchment, south towards the intersection point with the South Fork Rose Creek (SFRC). The FCD discharges into the NFRC, prior to the creek flowing adjacent to the Northeast WRD. The NFRC passes through the NFRD, adjacent to the Intermediate WRD.

3.1.1.4 North Fork Rock Drain

The Haul Road crossing for the NFRC was constructed as a dumped rockfill structure, called a “rock drain” (BGC, 2006). The NFRD comprises clean waste rock at the base of the road structure, with enough capacity to pass water through the void space.

Although the NFRD is not designed to retain water, it has the ability to temporarily retain a significant volume of water during very large flood events. A breach analysis of the NFRD was performed (CH2M HILL, 2014a), to evaluate the consequences of failure under the 1-in-500-year flood event used for the DVIHU evaluations. The consequences of NFRD breach vary depending on the volume of water retained at the time of breach, which depends on the assumed flow rates through the NFRD. High flow-through rates result in a lower volume of water impounded behind the NFRD, whereas low flow-through rates result in higher volumes of impounded water. The breach analyses were performed for three flow-through rates:

- Best estimate flow-through scenario,
- Low flow-through scenario, and
- Low flow-through with 25-percent reduction in capacity scenario.

For the best estimate flow case, it was found that the NFRD would not be overtopped. For the low-flow case, short duration overtopping is predicted. For the low flow case with 25 percent reduction, longer duration overtopping is predicted. The potential breach mechanism assumed in the breach analysis was piping. Other potential failure mechanisms include progressive ravelling and sloughing of the downstream slope under high flow-through velocities.

Given the severe consequence of breaching the NFRD when assuming a conservative set of flow conditions for a 1-in-500-year flood event, it is reasonable to assume that the likelihood of increased ponding, breaching, and the severity of incremental downstream damage will increase for floods larger than a 1-in-500-year flood. A detailed discussion of the analysis is provided in *Down Valley Interim Hydraulic Upgrades Design, Faro Mine Interim Works* (CH2M HILL, 2014b).

3.1.1.5 South Fork Rose Creek and Fresh Water Supply System

The decommissioned freshwater dam and reservoir in the SFRC represented a large component of the fresh water supply system to the FMC Mill during mine operations. The dam was breached to original ground level in 2004. Some components of the freshwater supply system are no longer in use but remain in place; these include the Pumphouse Pond and the associated building and freshwater pipeline (GLL, 2007).

The Pumphouse Pond is located at the confluence of the NFRC and SFRC, and passes all of the flow from SFRC and most of the flow diverted from NFRC. High flows in the NFRC partially spill into the lower portion of the North Fork Rose Creek Diversion before it discharges to the RCD (GLL, 2007).

3.1.1.6 Rose Creek Tailings Area

The Rose Creek Tailings Area (RCTA) encompasses the tailings impoundment at the base of Rose Creek Valley, about 2.5 kilometres (km) southwest of the Faro Pit (Figure 6B-3). Approximately 28.6 million cubic metres (m^3) of flotation-derived process tailings were deposited in the RCTA between 1969 and 1998. The tailings are contained by a series of three dams (Original Dam, Secondary Dam [SD], and ID) constructed across the Rose Creek Valley (Figure 6B-3). The Original Dam no longer functions as a dam structure, because it is completely enclosed by tailings.

The CVD was constructed as part of the Down Valley Project in the early 1980s. The CVD Pond, downstream from the tailings impoundment dams, serves as a polishing pond for treated effluent for water treatment processes in the Faro mine area. The CVD has the same hazard classification as the ID. The main hazard from a CVD breach is not only the uncontrolled release of water from the CVD Pond, but sudden release of the pond could also cause significant danger to the ID. The ID does not have filter and drainage systems in the lower part of the embankment below the downstream bench, and it depends on the polishing pond to provide a counterbalancing hydrostatic head to reduce seepage and the need for filtering. A sudden drawdown of the pond is likely to result in significant seepage from the saturated ID downstream slope, which in turn could lead to progressive sloughing, even more seepage, possibly backward erosion, and eventually could result in piping or loss of the crest from larger slope stability failures. Based on this potential impact on the ID, the CVD is considered to have the same potential hazard classification as the ID.

A breach of the SD could also lead to a loss of tailings into the environment, but the magnitude of such a tailings loss would be much smaller and more contained than the tailings loss associated with an ID breach. Whereas the ID and CVD need to accommodate hydraulic (flood) loading as well as seismic (earthquake) loading, the SD only needs to be designed for seismic loading. Seismic loading could cause liquefaction of the dam foundation, and specifically at the locations where Rose Creek sediments are present in the foundation of the dam. At the West Limb, which is the curved portion of the SD that crosses the valley roughly north to south, there are intermediate tailings on the downstream toe of the SD. These intermediate tailings would prevent failure of the dam during seismic loading even if the foundation soils liquefy. Even if some tailings loss would occur along this portion, the tailings are likely to be contained within the Intermediate Impoundment.

A breach of the East Limb of the SD, which is the portion of the SD that is parallel to the RCD and where there are no tailings at the toe, could result in tailings flowing into the RCD. It is noted that the likelihood of tailings loss is low even when losing a portion of the East Limb crest; given that the upper layers of the secondary tailings are not saturated and given the relatively small height of about 4.6 metres (m).

The ID is the major Intermediate Tailings Area structure that also contains runoff and flood waters entering the Intermediate Tailings Area from a small residual catchment area. Any potential floodwater routed through the ID spillway would flow into the CVD Pond, and once the CVD Pond's storage capacity was exceeded, water would flow through the CVD spillway down into the Rose Creek Valley, and then into Rose Creek. This routing would

represent a noncompliant release of contaminated water to the environment and would only occur in extreme flood situations to protect the ID. Upstream flows are currently routed around the tailings facility in the RCD, and site water-management activities convey water from the intermediate pond to the water treatment circuit.

3.1.1.7 Rose Creek Diversion

The RCD passes Rose Creek water around the RCTA. The existing RCD is approximately 4,700 m long with a 0.23 to 5.0 percent slope, interrupted by numerous drop weirs. The diversion was originally designed to carry a 1-in-50-year flood event (approximately 79 m^3/sec), with 1 m of freeboard. It was subsequently modified to bypass stream flows of 140 m^3/sec, which is slightly more than the 1-in-500-year flood event (BGC, 2006; NHC, 2006), when neglecting any flood attenuation by the NFRD.

Water from the SFRC and the NFRC enters the upper section of the RCD, which was constructed in 1974 in conjunction with the construction of the secondary dam. The upper section of the RCD is predominantly a straight channel approximately 700 m long that includes riprap for erosion protection (GLL, 2007).

The section of the crest of the dike known as the fuse plug was constructed approximately 1 m lower than the crest of the adjacent dike structure and was armoured with riprap. The fuse plug was constructed to direct flow from the upper section of the RCD into the lower section of the RCD and to ensure that flows in excess of the RCD design flow would be diverted into the Intermediate Impoundment.

The lower section of the RCD below the fuse plug is approximately 4,000 m long and was constructed in 1980 and 1981, in conjunction with the ID development. It passes water along the south side of the Intermediate Impoundment and returns flow into the natural Rose Creek Channel, downstream of the CVD. The Lower Diversion includes a series of boulder-lined drop structures and a sharp bend at the downstream end. The Lower Diversion is constrained by natural slopes on the south side and by a till dike on the north side. In 2004, the dike along portions of the lower RCD was rebuilt to restore the freeboard, which was necessary to safely pass the design flood (1 in 500 year) (GLL, 2007).

Slumping in the containment dike in the upper section of the RCD has limited the success of this rebuild, however, and the RCD's capacity in this section remains below the intended design flood capacity. Addressing this capacity issue is a component of the DVIHU.

3.1.1.8 Upper Guardhouse Creek

Upper Guardhouse Creek collects uncontaminated surface water from the catchment area north of the FMC and directs it to the North Wall Interceptor Ditch.

3.1.1.9 Lower Guardhouse Creek

Lower Guardhouse Creek collects potentially contaminated mill area surface water and discharges it to the intermediate impoundment where it is eventually pumped for treatment.

3.1.1.10 Old Faro Creek Channel

The Faro Pit and Main Dump were constructed through the original alignment of Faro Creek. Old Faro Creek is the part of the original creek alignment that exists downgradient of Faro Pit and the Main Dump. It has become a focal point for surface seepage. It is assumed that a large portion of the seepage originates at the Faro Main Dump and Intermediate WRD, and is subsequently conveyed through the Old Faro Creek Channel (GLL, 2007). The ETA is located in the Old Faro Creek Channel, and this seepage is contained in the ETA.

3.1.1.11 North Wall Interceptor Ditch

The North Wall Interceptor Ditch intercepts runoff and shallow groundwater from the north side of the Rose Creek Valley and diverts it around the north abutment of the CVD (GLL, 2007). It is approximately 3 km long and comprises constructed and natural stream channel reaches. The North Wall Interceptor Ditch has relatively flat channel gradients along the constructed reaches and steep gradients along the natural stream reaches (Kohn Crippen Berger, 2012).

3.1.1.12 K-8 Rock Drain

The K-8 Rock Drain is a mine haul road stream crossing, constructed of coarse waste rock fill. It is located approximately 2.5 km east of the NFRD. It functions as a conduit for water flowing along the northern reach of the K8 Creek to cross the Haul Road. At the creek crossing, the haul road is approximately 55 m high, with a 25-m-wide crest.

3.1.1.13 Faro Mine Area Water Storage Facilities and Pit Water Management

A review of the water elevations for each onsite storage reservoir or pit (e.g., CVD Pond, ID Pond, Faro Pit, and Zone II Pit) in the Faro Mine Area was compiled in two technical memoranda and attached to the *Hydrology Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a) as Attachments 6F-4a and 6F-4b. The two technical memoranda summarize the analysis of water management strategies.

Cross Valley Pond

The CVD Pond is part of the active water management program at the FMC. Although the Faro WTP did not discharge treated water to the CVD Pond in 2013, the CVD Pond still requires active management to remove water from inputs such as rainfall and seepage. Operational experience at the FMC indicates the water elevation in the CVD Pond should not be lowered below about 1,027.5 m. If it is, sludge beds could be exposed and sludge particulate suspended, which may impact water quality and the ability to discharge from the CVD Pond.

Intermediate Pond

Water and tailings are retained behind the Intermediate Dam, which is approximately 650 m long, 7 m wide, and 32 m high, with a crest elevation at 1,049.2 m (Klohn Crippen Berger, 2012) and has a spillway elevation of 1,047.7 m (DES, 2012). The water level in the ID Pond has historically ranged between 1,043.0 and 1,047.6 m (DES, 2012; Tlicho Engineering and Environmental Services Ltd. [TEES], 2013a). In 2013, ID Pond water was pumped to the Faro Pit. There are two constraints on the drawdown of water in the ID Pond: (1) a maximum drawdown per day of 40 millimetres (mm) and (2) the operations regime prescribed by KCB (2012) because of concerns about the ID's geotechnical stability (CH2M HILL, 2013a). No changes are recommended for the ID Pond target water levels.

Emergency Tailings Area

In previous years, water from the ETA was collected at a cut-off trench and dual sump and then pumped to the Faro WTP. In 2013, water was not initially collected at the ETA; however, as the season progressed, water was collected and pumped from the ETA to the Faro Pit via the old tailings box and a booster pump located east of the former Mill Building. There is no target elevation for the ETA, but the objective is to collect as much water as practical based on the system capacity. This will limit water of deteriorated quality from seeping downgradient to the ID Pond and the underlying Rose Creek Aquifer, and will reduce the volume of water in the ID Pond.

S-Wells and S-Wells Bypass

The S-Wells are located between the Intermediate WRD and the NFRC and consist of two parts: the S-Wells and the S-Wells Bypass (or Shallow Interception Trench). There were no changes to water management for the S-Wells in 2013. CH2M HILL (2012a) provides additional details about this system.

Zone II Pit

The Zone II Pit is located directly southeast of the Faro Pit and northwest of the NFRC. The pit was mined in the late 1970s and early 1980s and subsequently filled with about 40 million tonnes of unclassified waste rock from mining operations at other areas at the FMC (RGC, 1996). The Zone II Pit base is at an elevation of about 1,094.5 m (RGC, 1996) and the current surface topography is at an elevation of about 1,166 m. If water rose above 1,128 m, it would spill over the buried rim and seep toward the NFRC. Between the base of the Zone II Pit and an elevation of 1,128 m, the backfilled pit has about 480,000 m^3 of storage capacity, assuming 30 percent porosity of the backfilled waste rock (SRK, 2007). In 1991, a pumping well was installed to manage the water level and limit water from migrating towards the NRFC. In 2012, a replacement pumping well (CH12-Z2-PW01) was added.

The water-level elevation at Zone II Pit has been managed at approximately 1,107 m and has ranged between about 1,103 and 1,111 m since October 2010 (DES, 2012). However, this elevation leaves a hydraulic gradient

between the groundwater elevation in the Pit and the stage elevation of the NFRC (about 1,096 m). The expired water licence (QZ03-059) required the groundwater elevation in Zone II Pit to be maintained lower than 50 m below ground (mbg), or 1,116 m.

X26 (Zone II – Old Well)

X26 was not used to dewater the Zone II Pit in 2013. The well is still used to monitor the water elevation in the Zone II Pit. CH2M HILL (2012a) provides additional details about this pumping well. There is no target elevation for this location.

CH12-Z2-PW01 (Zone II – New Well)

During the summer of 2012, CH2M HILL oversaw the drilling and installation of CH12-Z2-PW01. This well extends to a total depth of 77.4 mbg, with a screened interval between 1,091.7 and 1,114.0 m and a sump extending below 1,091.7 m to the end of the hole at 1,088.6 m (CH2M HILL, 2013a). The lithology consisted of waste rock to a depth of approximately 69.45 mbg (1,096.5 m) (i.e., within 2 m of the reported base of the pit). The purpose of this well was to replace X26 and allow the groundwater levels within the pit to be managed so they are lower than those previously achievable. The objective of this deeper well was to lower the groundwater elevation below the stage elevation of the NFRC, to reverse the hydraulic gradient. CH2M HILL understands the water conveyance system installed at this location consists of an insulated high-density polyethylene (HDPE) pipeline, heat-traced for year-round operation. According to the 2011 WMP (Brodie, 2011), the pipeline is positioned to discharge water at 30 m below the surface of the Faro Pit lake. The recommended target elevation for the water level in the Zone II Pit is at or below 1,096 m. Groundwater collection should continue from Zone II Pit year round.

Faro Pit

The Faro Pit receives groundwater seepage, direct precipitation, runoff, FCD seepage, and water from managed sources such as the ID Pond, the ETA, S-Wells, and Zone II Pit. From 2004 until 2012, the water level elevation in the Faro Pit was maintained between approximately 1,140 m and 1,143 m (DES, 2012; TEES, 2013a). During the 2013 treatment season, source areas that used to go to the Faro WTP (which did not operate in 2013) went to the Faro Pit, which raised its water elevation above this range. On September 9, 2013, the Faro Pit water elevation was 1,146.1 m. The end-of-season target elevation (between 1,140 and 1,141 m) and the maximum recommended elevation (1,144.3 m) (DES, 2012) have been exceeded. Dewatering activities are planned to begin at Faro Pit as early as possible in 2014, at a high enough rate to control and reduce the Faro Pit water level and the potential for seepage increases towards Zone II Pit or towards the ETA.

3.1.1.14 Culvert Crossings

Specific hydrology information related to culvert flows and water elevations is limited to monitored locations. This data is discussed in the *Hydrology Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a).

3.1.2 Vangorda/Grum Hydraulic Components

The Vangorda/Grum Area consists of a number of significant hydraulic components, including the Vangorda Pit and the Grum Pit. There are also a number of natural creek sections and surface water diversions and impoundments that direct flow eventually to the lower sections of Vangorda Creek and on to the Pelly River. The Vangorda WTP is also in this section of the mine area.

Figure 6B-4 shows the Vangorda/Grum Area hydraulic components.

3.1.2.1 Vangorda Creek Diversion

The Vangorda Pit was constructed in the early 1990s. This required diverting Vangorda Creek around the pit to limit the amount of runoff that entered the pit. The approximately 1,200-m-long VCD was constructed in 1991 around the northern perimeter of the pit (SRK, 2010a). The VCD was realigned between 1991 and 1992 because of the changing footprint of the Vangorda Pit. Since that time, the VCD has been maintained to convey flows but its alignment has not changed (SRK, 2010b). The existing VCD, was designed with a capacity to convey the 100-year return period flow of approximately 10 m^3/sec.

The VCD currently consists of the following components (SRK, 2010a):

- Headworks comprising an 8-m-high earth dam and a 1.5-m-diameter culvert within the dam that directs the water into an 800-m-long, 2,400- mm-diameter, half-round corrugated steel pipe (CSP) culvert section
- A plunge pool or stilling basin located at the end of the culvert sections
- A 3,000-mm-diameter drop-box structure, a 2,000-mm CSP culvert, and a 600-mm outfall culvert conveying the discharge from the plunge pool beneath the Haul Road back into Vangorda Creek
- Two 1,000-mm-diameter culverts at the headworks to provide an emergency spillway (installed 2005) to the Vangorda Pit for events that exceed the 1-in-100-year event

3.1.2.2 Old Vangorda Creek Channel

Natural runoff water collects in the old Vangorda Creek channel downstream of the headworks and northeast of the Vangorda Pit. There is a small catchment area referred to as the Vangorda Watering Hole that is adjacent to the VCD flume. This surface water naturally flows into the Vangorda Pit. Since 2002, this water has been pumped from a natural depression in the old Vangorda Creek channel into the VCD flume during the summer season (Figure 6B-4).

3.1.2.3 Vangorda Northeast Interceptor Ditch

The Vangorda Northeast Interceptor Ditch passes uncontaminated surface runoff water that would originally have flowed directly to Vangorda Creek, around the east and south sides of the Vangorda pit and rock dump area. This diverted water then enters Dixon Creek (DES, 2011).

3.1.2.4 Dixon Creek

Dixon Creek captures unimpacted runoff from the catchment northeast of the Vangorda/Grum Area (DES, 2011).

3.1.2.5 Vangorda Northwest Interceptor Ditch

The Vangorda Northwest Interceptor Ditch is an open ditch excavated into the native soils and surficial bedrock upslope of the VCD flume at the top of the northwest wall of the Vangorda Pit. This ditch passes uncontaminated surface water around the northwest area of the pit to Vangorda Creek, via the VCD plunge pool.

3.1.2.6 Grum Interceptor Ditch

The GID diverts water around the Grum Pit and Grum Overburden Dump. It consists of three reaches: (1) a 900-m-long ditch upslope of the Grum Pit to divert clean water away from the pit, (2) a 900-m-long ditch along the northeast toe of the Grum Overburden Dump, and (3) a 650-m long-ditch to convey flow downhill to Vangorda Creek (Klohn Crippen Berger, 2012).

3.1.2.7 Vangorda WRD Seepage Collection Ditch

Runoff and seepage water from the Vangorda WRD is contaminated with metals, and requires treatment before it can be released to Vangorda Creek. An open ditch around the toe of the WRD intercepts runoff and seepage that would otherwise enter Vangorda Creek directly. The ditch directs water into Little Creek Pond (LCP) for later treatment in the Grum/Vangorda Water Treatment Plant (GLL, 2007).

3.1.2.8 Vangorda/Grum Area Water Storage Facilities and Pit Water Management

A review of the water elevations for each onsite storage reservoir or pit (e.g., Vangorda Pit, Grum Pit, and LCP) in the Vangorda/Grum Mine Area was compiled in two technical memoranda and attached to *Hydrology Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a) as Attachments 6F-4a and 6F-4b . The two technical memoranda summarize the analysis of water management strategies.

V15 Seepage Collection Ditch and Moose Pond

Seepage and runoff from the Grum Waste Dump surfaces at V15 and Grum Creek, downgradient from the waste dump on the southeastern side. A collection ditch, installed in 2007, conveys seepage from V15 into an existing ditch routing Grum Creek water to Moose Pond, away from lower Grum Creek. In 2011, in response to continued increasing contaminant levels at V15 and to manage peak spring runoff conditions, the V15 and Grum Creek

Pumping System was installed. The pumping system, located east of the Grum Waste Dump, consists of an insulated and heat-traced, 76-mm HDPE pipeline, a power supply, and pump. The system can redirect seepage from the Grum Waste Dump (V15, Grum Creek, or both) to the Vangorda Pit, year-round. When the system is not operated, discharge flows to Moose Pond. The target objective for the V15 and Grum Creek Pumping System is to limit water of deteriorated quality from seeping to the downstream receiving environment. Currently the system is operated during peak freshet and storm event flows only, with Moose Pond receiving normal flows. As part of the IW, operations may be expanded to year-round to ensure achievement of this target objective.

Little Creek Dam and Pond

The LCP collects runoff and seepage from the Vangorda WRD via a seepage collection ditch. The LCD was completed in 1992 to collect water pumped from the Vangorda Pit and from runoff and seepage at the Vangorda WRD. Water from the LCP was pumped directly to the Vangorda WTP. Once mine operations ceased, water management at the FMC changed. Currently, only runoff from the Vangorda WRD collects behind the LCD. During ice-free periods, this water is pumped to the Vangorda Pit. CH2M HILL (2012a) provides additional details about the system.

Grum/Vangorda Freshwater Supply Pond

When the Vangorda WTP operates, it draws a relatively small amount of freshwater from the Grum/Vangorda Freshwater Supply Pond, which stores some surface runoff that flows into the GID, just upgradient from the water treatment plant. Upon demand, water is pumped from the Freshwater Supply Pond to the WTP, to maintain an adequate supply of mix water in a storage tank located in the WTP (GLL, 2007).

Sheep Pad Ponds

The SPP collect localized runoff from the Grum Overburden Dump and water conveyed from the GID. The SPP are located south of the Grum Overburden Pile. They collect runoff from upslope areas, and discharge to the lower portion of the Vangorda Creek Diversion (KCB, 2012). CH2M HILL (2012a) provides additional details about the system.

Vangorda Watering Hole

The Vangorda Watering Hole is understood to be located in the original Vangorda Creek Channel, upstream from the VCD. Since 2002, a sump at this location has collected runoff from the local catchment and pumped it to the Vangorda Creek Diversion (DES, 2011). CH2M HILL (2012a) provides additional details about the system.

Grum Pit

The Grum Pit receives groundwater seepage, direct precipitation, runoff, and GID seepage. The Adaptive Management Plan (AMP) threshold level to trigger a response to rising water levels (1,210.8 m) was surpassed in October 2011. The trigger and maximum water elevation was set under AMP Event 6 (GLL, 2005) to manage water level increases in the Grum Pit, which was a requirement of the expired water licence (QZ03-059). 2013 was the first year water elevations in the Grum Pit were actively managed. The objective is to prevent water of deteriorated quality from reaching downstream receptors and to provide additional storage capacity to retain water received in the Grum Pit. In August 2013, water transfer from Grum Pit to Vangorda Pit began (TEES, 2013b). SRK (2009) indicated the overflow elevation to be 1,232.3 m, which is the lowest elevation of the Pit walls in the Grum Slot, located at the southern end of Grum Pit. The maximum recommended elevation, 1,213.4 m, allows storage capacity for a 1-week PMF before the water reaches the contact elevation of the overburden and bedrock (at 1,216 m) near the Grum Slot (DES, 2011a). The permeability of the overburden above the bedrock contact was estimated to be about $5x10^{-4}$ metres per second (SRK, 2009). The 2011 Annual Review, AMP Report (DES, 2012) suggests a revised maximum pit water elevation between 1,214.3 and 1,216.1 m, considering potential hydraulic containment south of the pit (CH2M HILL, 2012a provides additional discussion). This suggested elevation range is based on the storage capacity between this range of elevations and the elevation of the potential hydraulic containment, as well as the estimated volume of water that could drain to the Grum Pit during an extreme precipitation event or breach of the Grum Northeast Interceptor Ditch.

3.1.2.9 Culvert Crossings

Specific hydrology information related to culvert flows and water elevations is limited to monitored locations. This data is discussed in the *Hydrology Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a).

3.2 Hydraulic Component Baseline Condition

The following sections summarize the hydraulic performance for each of the main hydraulic components within each of the Faro and Vangorda/Grum Areas identified in Section 2, which could impact FMC facilities.

3.2.1 Faro Hydraulic Components

3.2.1.1 West Valley Interceptor Ditch

Maintenance work took place on the WVID from 2002 through 2005. This work substantially restored its effectiveness in passing uncontaminated runoff water to the FCD. The work consisted primarily of bottom-grading and excavating slumped and eroded sections of the WVID (GLL, 2007).

Ongoing site surveillance has indicated the WVID continues to function and, that based on observed performance, it provides adequate capacity. It does not present a substantial hydraulic risk because it conveys limited flows on an intermittent basis, and failures would result in flow being directed to the Faro Pit for containment until implementation of remedial steps.

3.2.1.2 Faro Creek Diversion

In 2002 and 2003, maintenance work took place on sections of the FCD. This work substantially reduced leakage from the FCD to the Faro Pit (GLL, 2007). The work consisted mainly of bottom-grading, excavating a pilot channel for low winter flows, placing a geomembrane liner, and installing riprap erosion protection in select locations. Since 2003, ongoing maintenance has included maintaining roadside ditches, grading a new road surface with an alignment that is further away from weaker areas of the pit wall, repairing/replacing rock covering channel liners, maintaining the Bentomat and Bitumen liners, and removing flow obstructions.

Between January and March 2010, water was observed flowing on top of the ice, along the upper stretch of the FCD (DES, 2011). During the winter, ice is now removed regularly to keep the diversion clear.

The FCD was reported to have performed well throughout 2009 (DES, 2010). It is anticipated that ongoing maintenance will support the function of the FCD for the duration of the IW schedule. FCD failures would result in flow being directed to the Faro Pit for containment until implementation of remedial steps.

3.2.1.3 North Fork Rose Creek

The NFRC is primarily a natural stream system; as such, it is not necessary to manage the creek function through site maintenance. Flow monitors on the NFRC provide subwatershed data that is relevant to understanding the hydraulic function of downstream built stream components, such as the NFRD.

3.2.1.4 North Fork Rock Drain

Appendixes 6C and 5I detail hydrotechnical work related to determining the conveyance capacity and stability of the NFRD. Based on review of the design and construction records of the NFRD and the embankment haul road and given the objective of the interim improvements to prevent overtopping and breach of the ID during the 500-year flood, the Main Haul Road Embankment and NFRD cannot be relied upon to serve as a reliable attenuation barrier and provide protection to the ID and beyond.

A discussion of the NFRD stability is provided in *Down Valley Interim Hydraulic Upgrades Design, Faro Mine Interim Works* (CH2M HILL, 2014b).

3.2.1.5 Rose Creek Diversion

The channel and side slopes of the RCD appear to be stable, with satisfactory rock armour conditions (Klohn Crippen Berger, 2012). Based on observations and regular inspections, maintenance should include clearing ice from the channel (GLL, 2007). It should also consist of repairing the backslope and dike crest and removing woody vegetation from along the banks and from the fuse plug (DES, 2009). *Stability of Major Existing Facilities, Faro*

Mine Interim Works (CH2M HILL, 2013b) and *Down Valley Interim Hydraulic Upgrades Design, Faro Mine Interim Works* (CH2M HILL, 2014b) describe assessments of the RCD's stability and hydraulic functions.

The existing RCD has a design capacity of 140 m^3/sec, without freeboard, which is slightly more than the 1-in-500-year flood event (NHC, 2006). The flow capacity has been reduced by settlement of the dike and growth of vegetation on the side slope of the channel. If storm events result in flows that exceed RCD capacity, the excess water will overtop the RCD dike at the overflow weir/fuse plug. Flow will then discharge into the Intermediate Tailings Area, and flow out through the ID spillway into the CVD Pond.

3.2.1.6 Tailings Facility

Stability of Major Existing Facilities, Faro Mine Interim Works (CH2M HILL, 2013b) and *Down Valley Interim Hydraulic Upgrades Design, Faro Mine Interim Works* (CH2M HILL, 2014b) discuss assessments of stability and hydraulic functioning of the SD, ID, and CVD.

3.2.1.7 North Wall Interceptor Ditch

Klohn Crippen Berger (2012) noted that the North Wall Interceptor Ditch and side slopes appeared to be stable, with sediment deposits upgradient and downgradient from the well-access-road crossing. It also noted moderate to heavy vegetation growth in upper and middle constructed channel reaches (Klohn Crippen Berger, 2012).

GLL (2007) noted the North Wall Interceptor Ditch performed reasonably well through 2005, although erosion and sedimentation caused partial blocking at times. The twin culverts located in the outfall section at Station X5 have also experienced icing problems during the winter months, because of the low flow of water (DES, 2010). Culvert blockages in the North Wall Interceptor Ditch area have been an ongoing issue throughout the FMC's history, and must be cleared periodically (BGC, 2010).

Regular maintenance of the North Wall Interceptor Ditch includes removing ice from the ditch and culverts, as well as clearing deposition and debris to maintain channel and culvert capacity.

3.2.1.8 K-8 Rock Drain

A 2009 geotechnical inspection (BCG, 2010) noted the following observations:

- The upstream face appeared to be in good condition, with no cracking or sloughing.
- Some woody debris and silty material is collected at the base of the upstream face.
- The downstream face appeared to be in good condition.
- The head pond level was normaly during the inspection and the drain appeared to be passing the flows in a satisfactory manner. The upstream pond contained circular "holes" in the surface of the accumulated sediment. Rock was exposed at the base of the holes and flow into the rock drain was concentrated at these locations. It was speculated that sediment accumulated on the upstream surface, raising the water surface, until enough pressure built up to cause a piping event, which washed the sediment through the rock fill structure. Further monitoring was recommended to confirm this assessment.

A subsequent 2011 geotechnical inspection indicated the crest and side slopes of the mine Haul Road at the K-8 Rock Drain appeared to be stable and that the downstream drainage condition was acceptable (Klohn Crippen Berger, 2012).

3.2.1.9 General Faro Mine Complex Care and Maintenance

Annual environmental monitoring programs and related reports provide valuable information about the operation and maintenance activities for hydraulic infrastructure at the FMC. Regular maintenance activities at the FMC take place, in part, to maintain the hydraulic capacity of surface water conveyance components within the drainage system. Hydraulic maintenance includes the following regular activities:

- During winter, steaming road culverts and charging of thaw pipes with glycol for de-icing if required
- Monitoring creeks and diversions on a daily basis for ice build-up during cold periods
- Completing minor repairs and clearing debris and ice from ditches

- Completing road and culvert maintenance as needed, including seasonal snow removal

3.2.2 Vangorda/Grum Area Hydraulic Components

3.2.2.1 Vangorda Creek Diversion

Since the VCD was constructed, it has generally been successful in conveying Vangorda Creek flows around the Vangorda Pit during normal runoff events (SRK, 2010a). The VCD has, however, experienced two flood events within the last 10 years that have caused the water levels in the VCD to exceed the level of its half-round CSP culvert component (CH2M HILL, 2013a). Both events resulted in damage to the VCD. Damage caused by the June 2004 event required extensive channel repairs and the installation of an overflow spillway in the VCD headworks structure to redirect excess flow into Vangorda Pit. The VCD has also experienced slope failures and ice buildup impacts that have compromised the diversion and resulted in significant maintenance requirements. Icing conditions and uplift of the CSP flume in VCD sections with low gradients have resulted in chronic maintenance issues (SRK, 2010a).

Since mining operations ceased in 1998, the VCD has been maintained to limit the flow of runoff to the Vangorda Pit until a long-term management plan for the diversion is developed. The following points summarize current conditions and maintenance issues, which support the need for a long term management plan:

- Existing flume structures require ongoing maintenance and repair to limit plugging of the diversion and erosion of roadway, which would result in discharge to Vangorda Pit.
- Drop structure at the roadway requires ongoing maintenance to limit the risk of plugging and overtopping.
- The VCD does not have capacity to convey peak flows in excess of 10 m^3/sec, which is the 100-year design peak flow event.
- Bank slopes associated with the half-round CSP culvert component of the VCD are at risk of instability and slumping.
- Ice damage impacts the instability of the diversion structures.
- Potential pit wall instability threatens the VCD.
- A stable diversion is a requisite to sustainably support the downstream aquatic habitat provided by the Vangorda flows.

In general, maintaining the function of the existing VCD includes the following tasks:

- Excavating ice from the VCD and defrosting it throughout winter months to prevent overflow
- Excavating ice from the drop box to maintain adequate flow
- Removing debris at the trash racks (at the entrance to the drop box inflow culvert) and at the flume headworks to maintain capacity
- Annually repairing ice-damaged flume sections after freshet, including cross-braces and holes in the CSP
- Repairing VCD slopes to prevent slope instability
- Periodically removing debris from the flume

3.2.2.2 Vangorda Northeast Interceptor Ditch

SRK inspected the Vangorda Northeast Interceptor Ditch uphill of the Vangorda Pit in 2011 and noted it generally performed well (SRK, 2011b). However, the inspection also noted a number of areas along the ditch (primarily in the overburden till) where there have been a number of subsidences that, over time, may restrict the flow in the ditch (SRK, 2011b).

Flow in the Vangorda Northeast Interceptor Ditch is noted to have been intermittent, historically (GLL, 2007). Maintenance takes place as necessary, to remove debris that would compromise the conveyance capacity required for the intermittent flow during significant runoff periods. Maintenance work was performed on the

ditch from 2002 to 2004 (GLL, 2007). In 2010, maintenance work took place to remove slumped gravel (DES, 2010).

3.2.2.3 Vangorda Northwest Interceptor Ditch

Maintenance work takes place, as required, to remove debris and maintain the necessary conveyance capacity.

3.2.2.4 Grum Interceptor Ditch

The 2011 annual geotechnical inspection stated the channel and sideslopes of the GID were stable with light vegetation growth along some portions (Klohn Crippen Berger, 2012). Maintaining the GID includes periodically placing new material to re-armour sections (GLL, 2007).

3.2.2.5 Vangorda Waste Rock Dump Seepage Collection Ditch

The Vangorda WRD Seepage Collection Ditch is an open ditch around the toe of the WRD, which intercepts local runoff and seepage that would otherwise enter Vangorda Creek directly. The ditch directs this surface water to the LCP, where it becomes part of the treatment system (GLL, 2007).

Observations of ditch performance note that ice removal, sediment removal, and bank-grading are necessary to maintain the required capacity. The ditch was also further excavated along the west side of the WRD to provide a more positive gradient to LCP and to improve flow (DES, 2010).

3.2.2.6 V-15 Seepage Collection Ditch and Moose Pond

In 2006, increasing concentrations of zinc were observed at the V-15 seep. Historically, a collection ditch conveyed local runoff and V-15 water to the confluence with Grum Creek and, from there, to Moose Pond. Moose Pond is a natural depression formed in porous sands and gravels that was used by the mine operators as a collection pond for seep water originating from the Grum WRD. Water exfiltrated from the base of the pond, where subsurface attenuation of zinc occurred, before the water re-emerged as a compliant seep near Vangorda Creek. The embankment that separates Moose Pond from Vangorda Creek has been experiencing progressive slumping on its downstream face for several years. In 2011, an excessive meltwater event during freshet caused abundant sedimentation in the pond. These combined events have compromised the stability of Moose Pond to the point that a surface water collection system is now in use to prevent high flow events from entering the pond. The collection system was originally intended to transfer small volumes of seep water to Vangorda Pit; however, it has been necessary to upgrade the collection system so that it can also contain and transfer larger volumes of meltwater that are generated in the vicinity of the Grum WRD during freshet.

3.2.2.7 Little Creek Dam and Pond

A 2011 geotechnical inspection of the LCD revealed that the water level in the pond on May 24, 2011, had been recorded at about 1,109 m (SRK, 2011). This is the normal water level operating condition between about elevation 1,108 m and 1,110 m. No cracks or major settlement were observed and no seepage was observed along the downstream toe of the pond. The inspection revealed that although erosion rills were evident on both the upstream and downstream slopes of the LCD, its upstream and downstream faces did not show evidence of surficial movement, bulging, or instability. The 900-mm CSP emergency spillway and the associated plunge pool were inspected and were found to be in good condition.

Another 2011 geotechnical inspection noted the LCD crest was stable, and slopes with rill erosions had developed on both the downstream and upstream crest shoulders and slopes (Klohn Crippen Berger, 2012). This report also noted that the culvert spillway was in good condition.

As *Stability of Major Existing Facilities, Faro Mine Interim Works* (CH2M HILL, 2013b) discusses, the LCD is inspected daily during the summer months and the pond level is not operated at full supply level. The minimum freeboard (except for short-duration exceedances) is 4.5 m on the 10-m-high dam. Based on observations from periodic dam safety reviews and the annual dam safety inspections, the dam is considered to be stable (Klohn Crippen Berger, 2008, 2012).

3.2.2.8 Sheep Pad Ponds

A 2010 geotechnical inspection indicated the SPP dike had no sign of slope instability, settlement, or cracking (SRK, 2011a). Similarly, a 2011 inspection indicated that the retaining dike embankment was stable (Klohn Crippen Berger, 2012). General maintenance on the upstream section of the spillway channel includes riprap cover replacement over underlying geotextile.

3.2.2.9 General Vangorda/Grum Area Care and Maintenance

Annual environmental monitoring programs and related reports provide valuable information about the operation and maintenance of hydraulic infrastructure at the FMC. Regular maintenance activities at the FMC take place, in part, to maintain hydraulic capacity of surface water conveyance components within the drainage system. This maintenance includes the following regular activities:

- Steaming road culverts and charging thaw pipes with glycol for de-icing if required
- Monitoring creeks and diversions on a daily basis for ice build-up during cold periods
- Completing minor repairs and clearing debris and ice from ditches
- Completing road and culvert maintenance as needed, including seasonal snow removal

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Figures



VICINITY MAP



LEGEND

- Major Road
- Road Unpaved
- Watercourse
- Faro Mine Complex

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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FIGURE 6B-1

Faro Mine Complex

Faro Mine Interim Works

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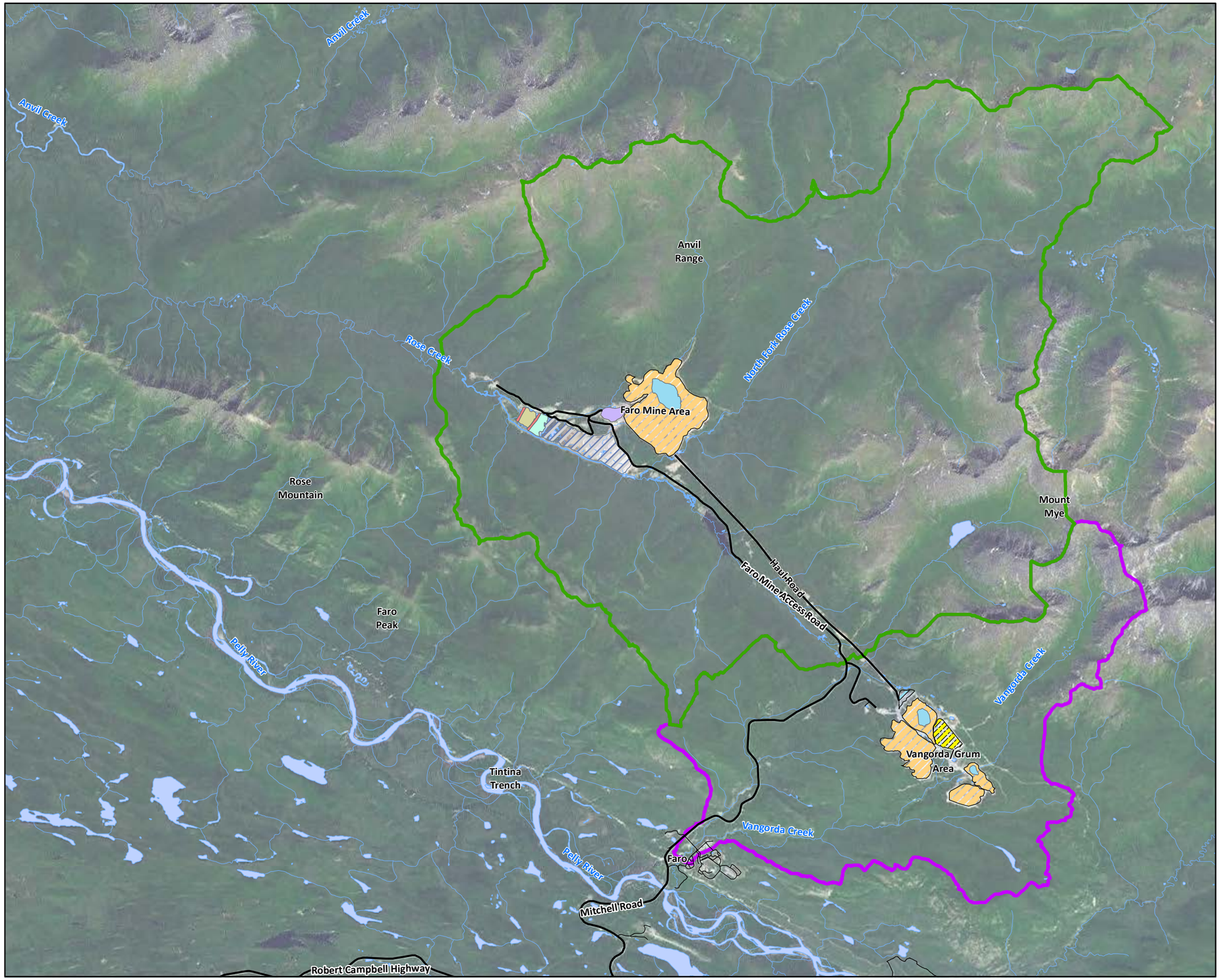

VICINITY MAP



LEGEND

- Major Road
- Minor Road
- Rose Creek Regional Catchment
- Vangorda Creek Regional Catchment

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

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CRITIGEN

FIGURE 6B-2

Faro Mine Complex Surface Water Catchment Boundary

Faro Mine Interim Works



VICINITY MAP



LEGEND

- Water to Pit or Treatment
- Seepage Bypassing Current Collection
- Treated Water Discharge
- Installed Groundwater or Surface Water Collection System
- Installed Surface Water Collection
- Interim Water Treatment System

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
3. Orthophotography prepared by Critigen Canada Corp.

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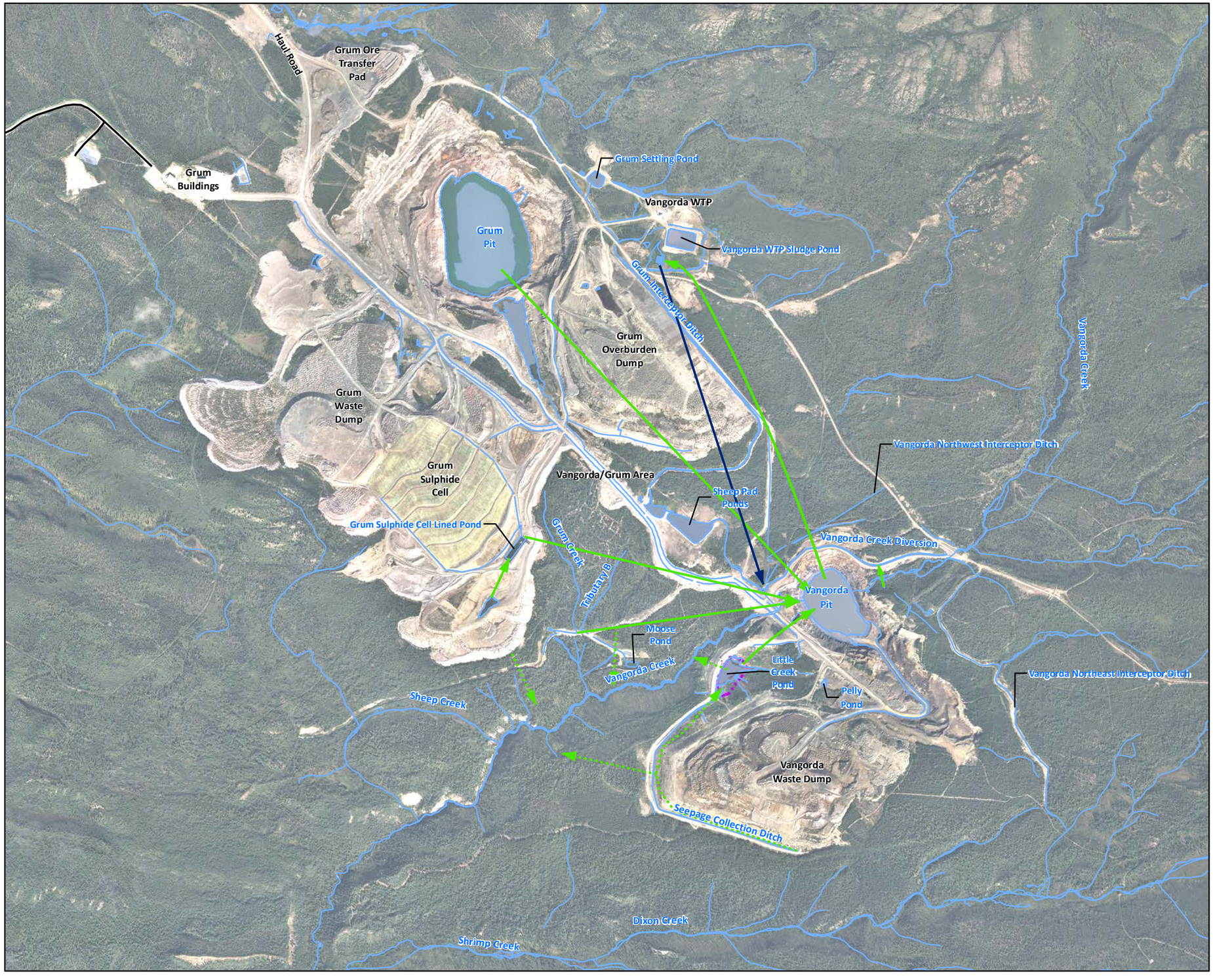
FIGURE 6B-3

Faro Mine Area Current Water Collection and Treatment

Faro Mine Interim Works



VICINITY MAP



LEGEND

- Water to Pit or Treatment
- Seepage Bypassing Current Collection
- Treated Water Discharge (via Grum Interceptor Ditch and Sheep Pad Ponds)
- Installed Surface Water Collection
- Water Treatment Plant

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Faro = Town of Faro

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FIGURE 6B-4
Vangorda/Grum Area Current Water Collection and Treatment
Faro Mine Interim Works

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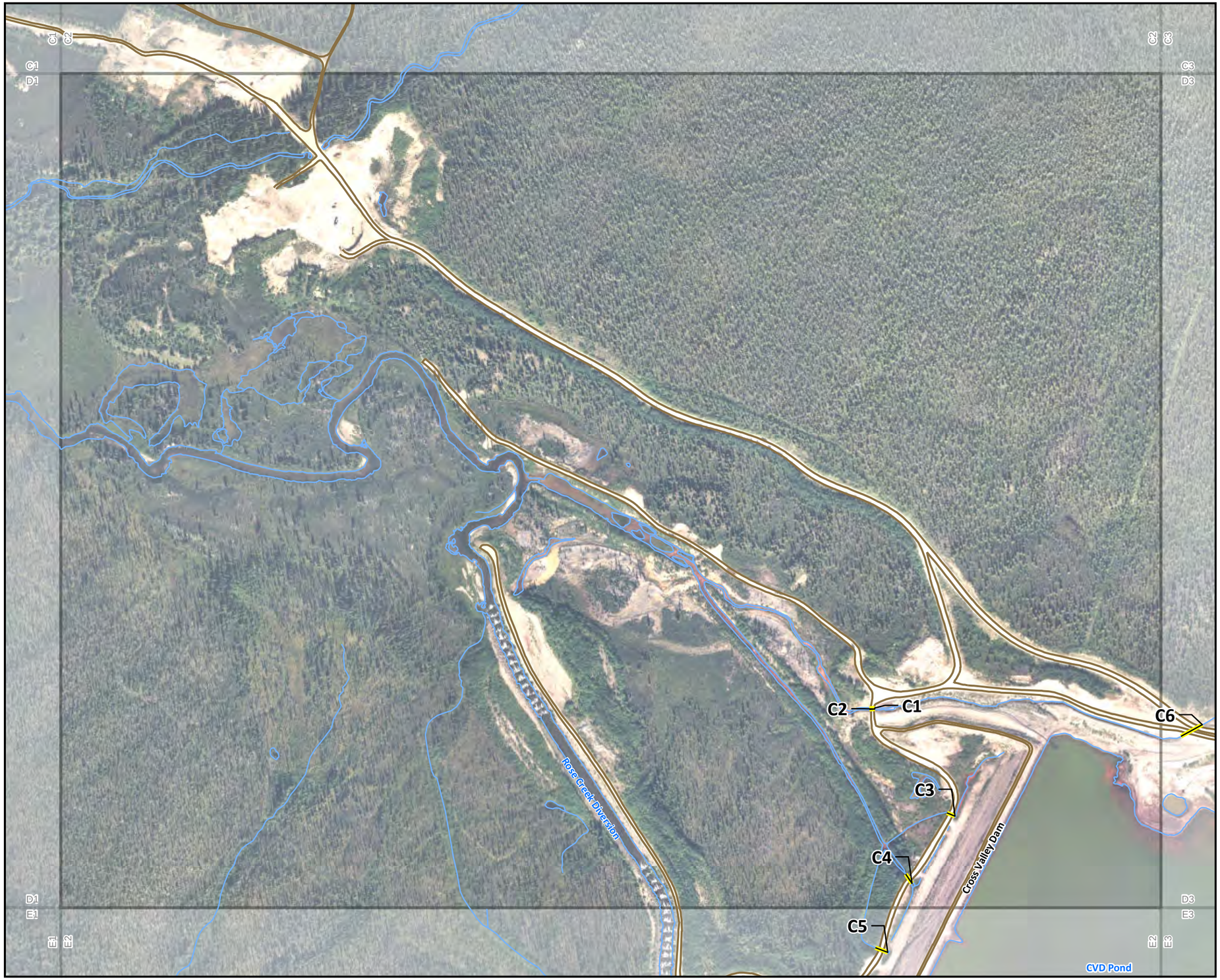
Attachment 6B-1
Culverts Survey Information



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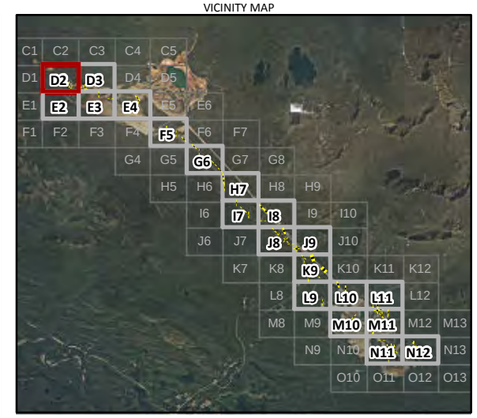

LEGEND

Culvert — Roads Unpaved — Grid

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C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
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C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

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Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

Page: 1 Map Grid: D2

Faro Mine Interim Works

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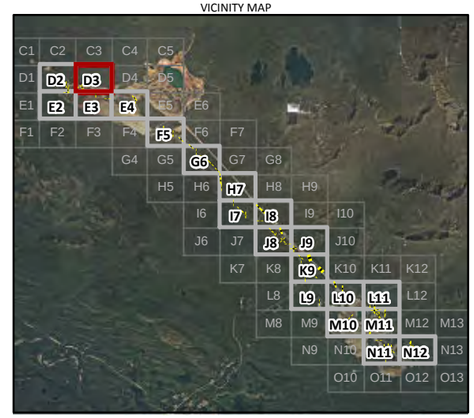
VICINITY MAP



LEGEND

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Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

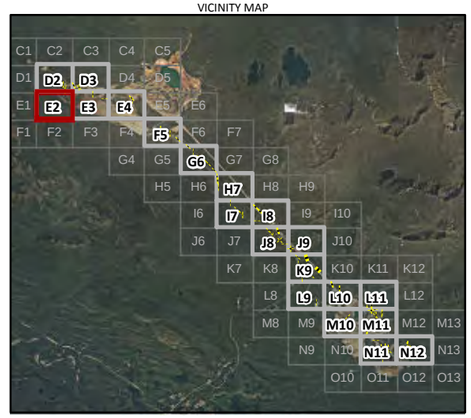
Page: 2 Map Grid: D3

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

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C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
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C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
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C24 - H7	C56 - N11	C82 - J8
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C26 - H7	C58 - L11	C84 - I8
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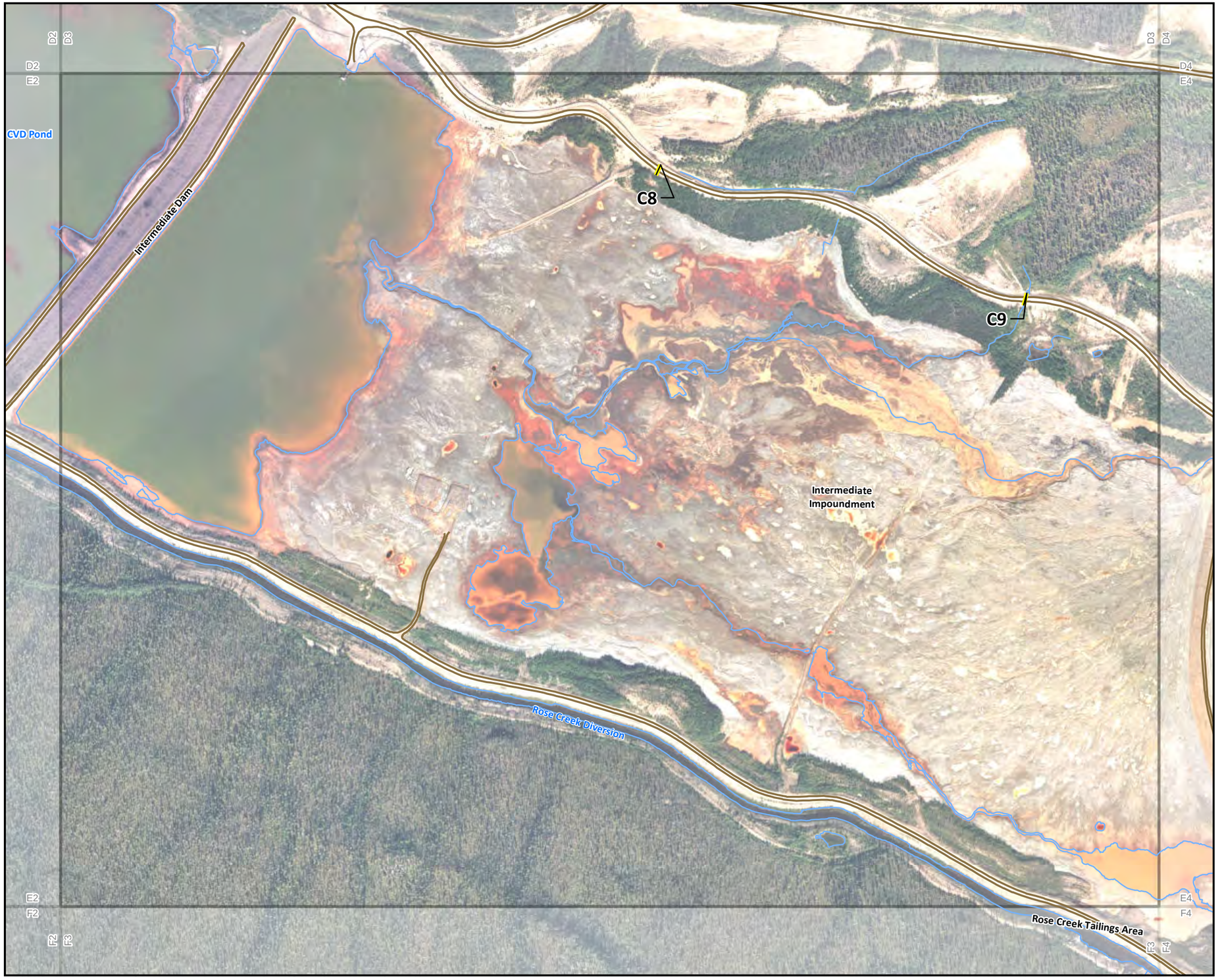
Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

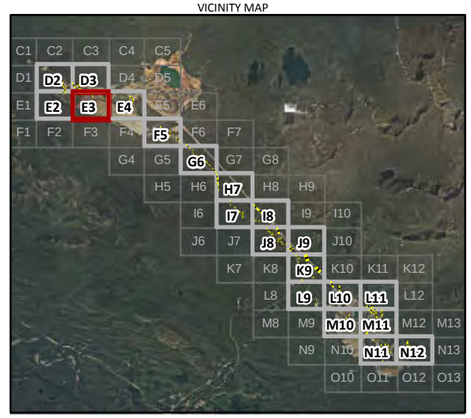
Page: 3 Map Grid: E2

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

Page: 4 Map Grid: E3

Faro Mine Interim Works

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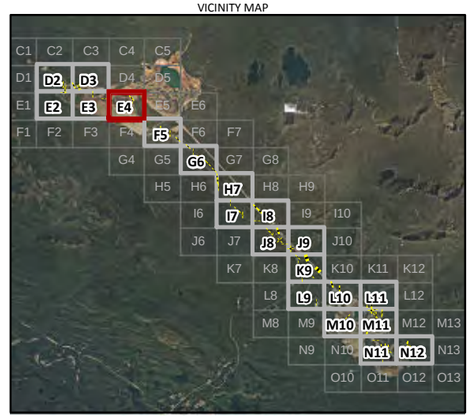
VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

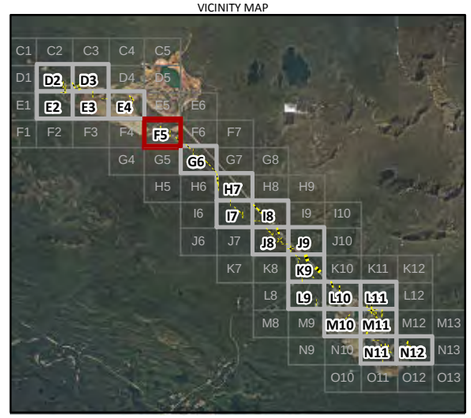
Page: 5 Map Grid: E4

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

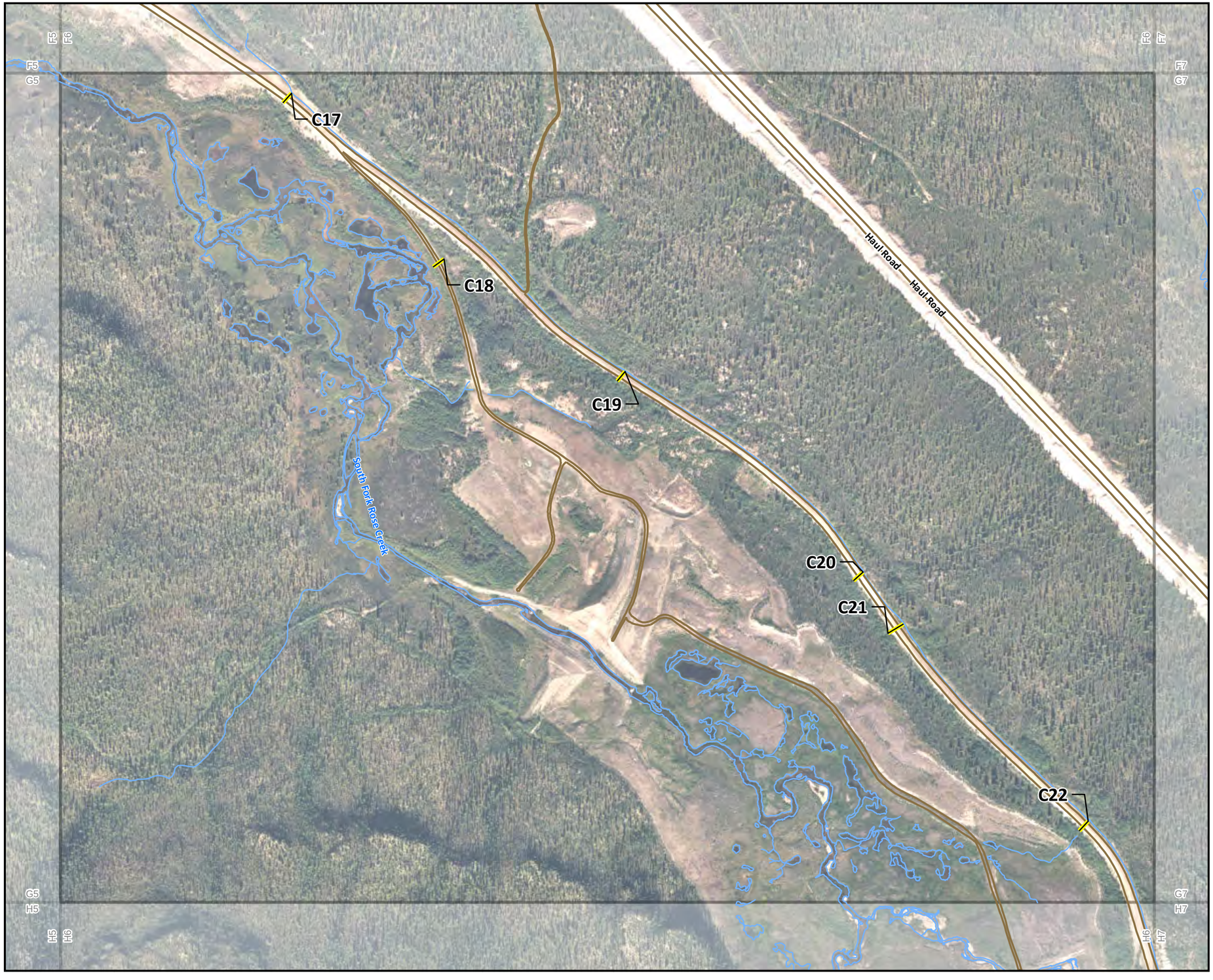
Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

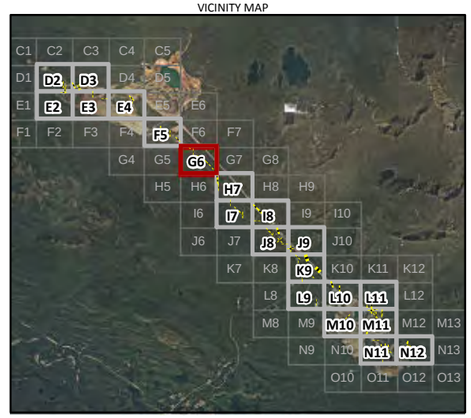
Page: 6 Map Grid: F5

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

Page: 7 Map Grid: G6

Faro Mine Interim Works

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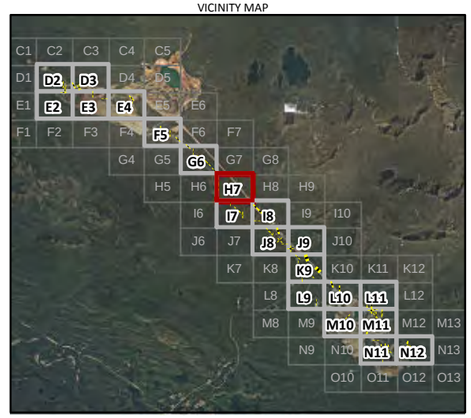
VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

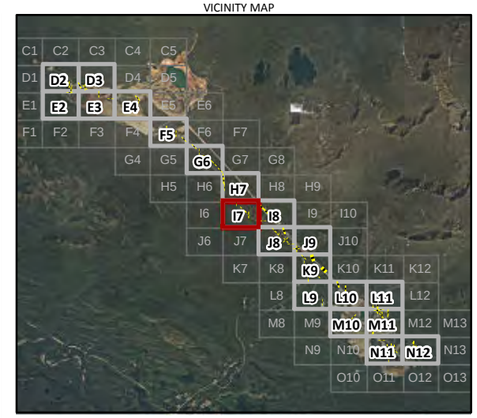
Page: 8 Map Grid: H7

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

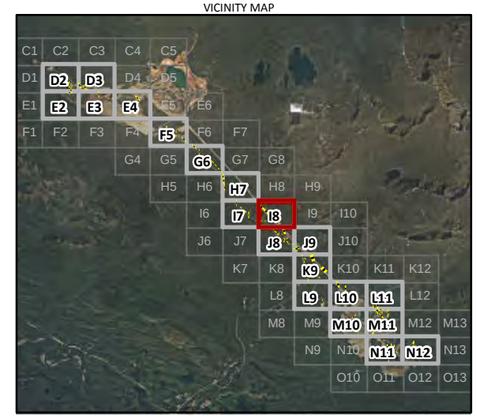
Page: 9 Map Grid: I7

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

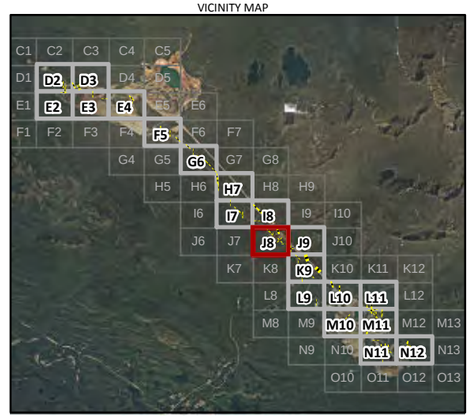
Page:10 Map Grid: I8

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

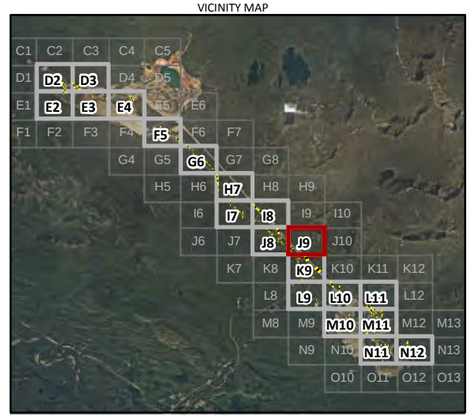
Page:11 Map Grid: J8

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

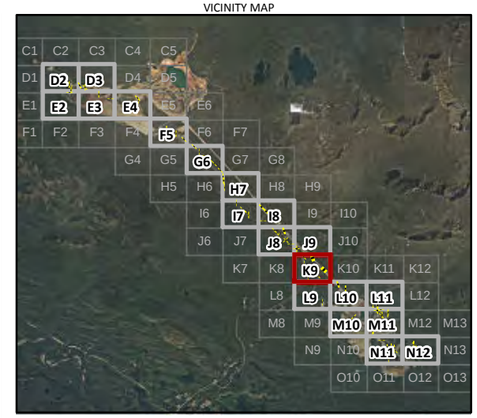
Page:12 Map Grid: J9

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

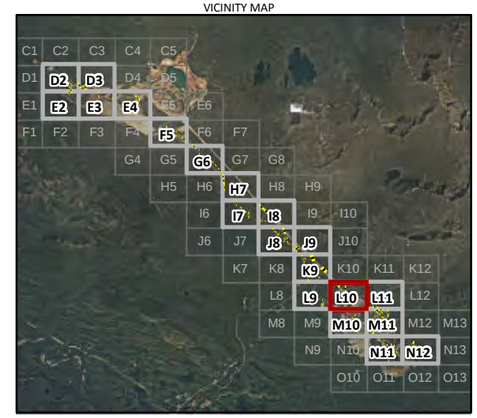
Page:13 Map Grid: K9

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert | Roads Unpaved | Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

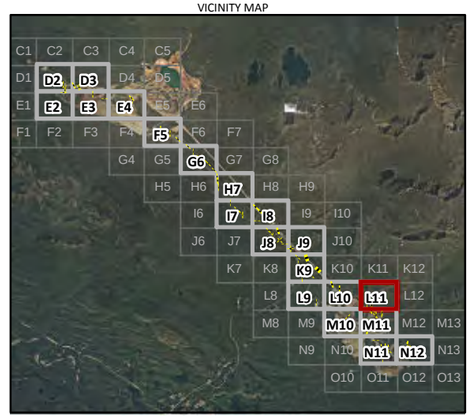
Page:14 Map Grid: L10

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

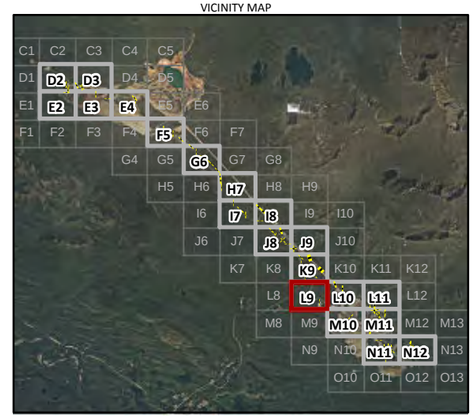
Page:15 Map Grid: L11

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

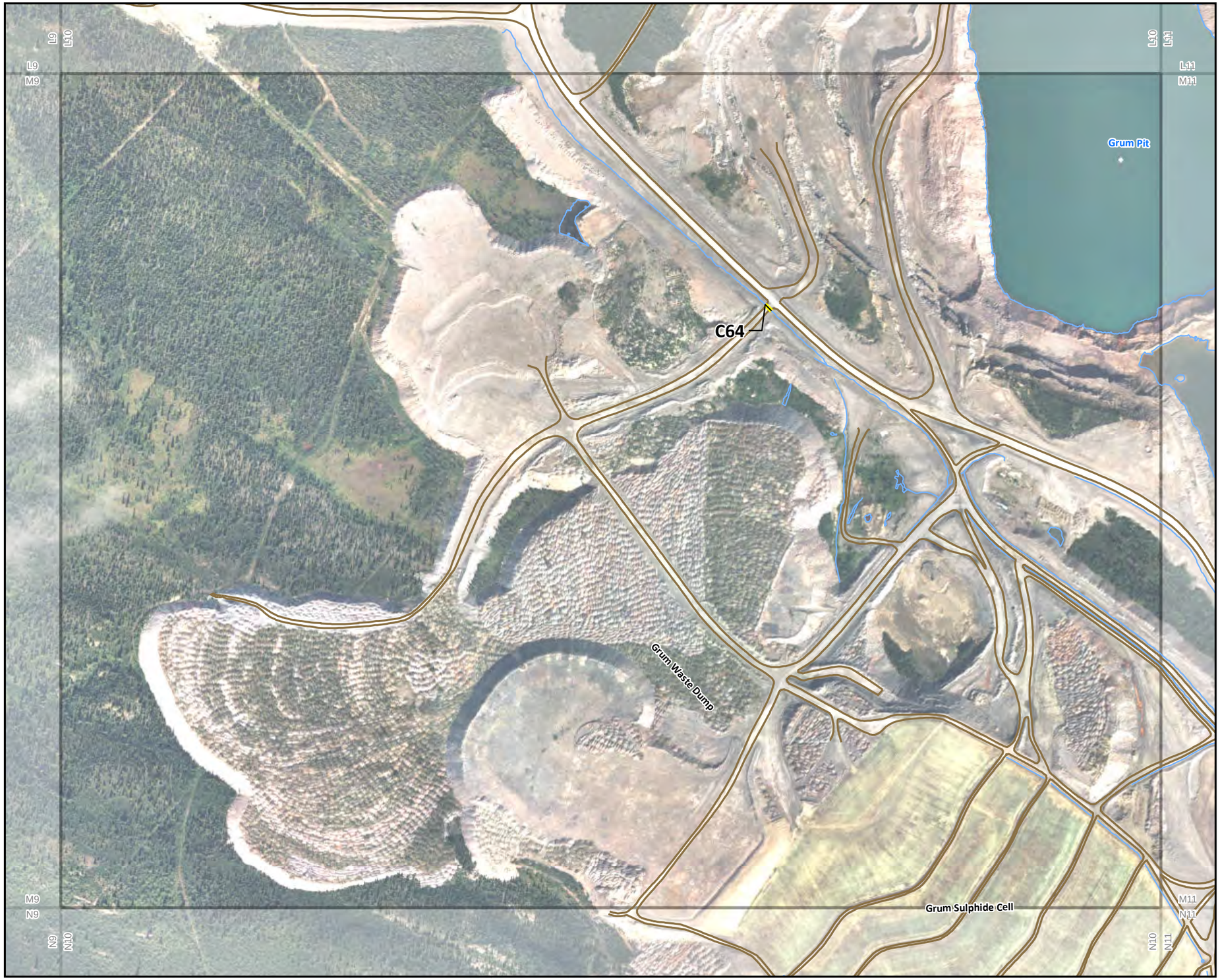
Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

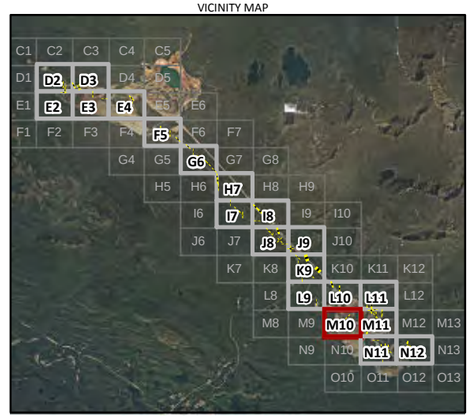
Page:16 Map Grid: L9

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

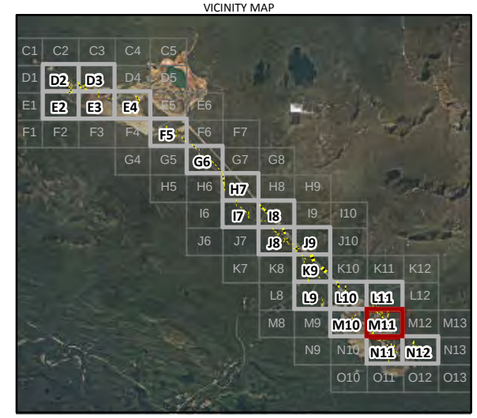
Page:17 Map Grid: M10

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert | Roads Unpaved | Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

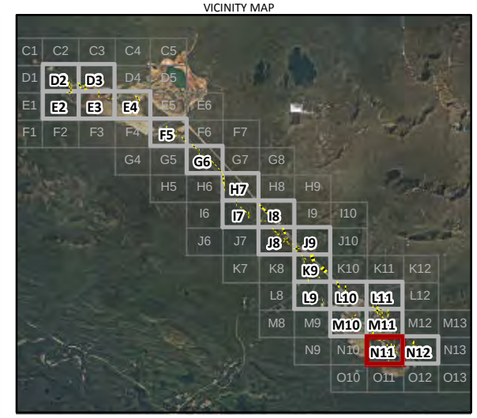
Page:18 Map Grid: M11

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

Attachment 6B-1-1

Existing Culvert Survey – Culverts Mapbook Grid

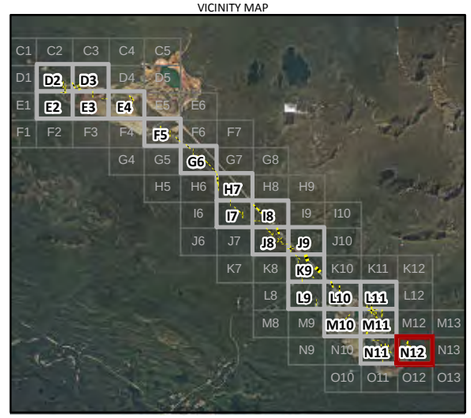
Page:19 Map Grid: N11

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL



VICINITY MAP



LEGEND

Culvert — Roads Unpaved — Grid

Culvert - Grid	Culvert - Grid	Culvert - Grid
C1 - D2	C34 - I7	C64 - M10
C2 - D2	C35 - I7	C65 - M11
C3 - D2	C36 - I7	C65 - M11
C4 - D2	C37 - I8	C66 - M11
C5 - E2	C38 - J8	C66A - M11
C6 - D3	C39 - J8	C66B - M11
C7 - E4	C40 - D3	C67 - M11
C8 - E3	C41 - D3	C68 - L10
C9 - E3	C42 - N11	C68A - L9
C10 - E4	C43 - N11	C69 - K9
C11 - E4	C44 - N11	C68B - L10
C12 - E4	C45 - N11	C70 - K9
C13 - F5	C45A - N11	C71 - K9
C14 - F5	C46 - N11	C72 - J8
C15 - F5	C47 - N11	C73 - J9
C16 - F5	C48 - N11	C74 - J9
C17 - G6	C49 - N11	C75 - K9
C18 - G6	C50 - N11	C76 - K9
C19 - G6	C51 - N12	C77 - K9
C20 - G6	C52 - N12	C78 - K9
C21 - G6	C53 - N12	C79 - K9
C22 - G6	C54 - N12	C80 - K9
C23 - H7	C55 - N11	C81 - K9
C24 - H7	C56 - N11	C82 - J8
C25 - H7	C57 - L11	C83 - J8
C26 - H7	C58 - L11	C84 - I8
C27 - H7	C59 - L11	C85 - I8
C28 - H7	C60 - M11	C86 - I8
C29 - H7	C61 - M11	C87 - J8
C30 - I7	C62 - M11	C88 - J8
C31 - I7	C63 - M11	C89 - J8
C32 - I7	C63A - M11	
C33 - I7	C63B - M11	

0 50 100 200 Metres

N

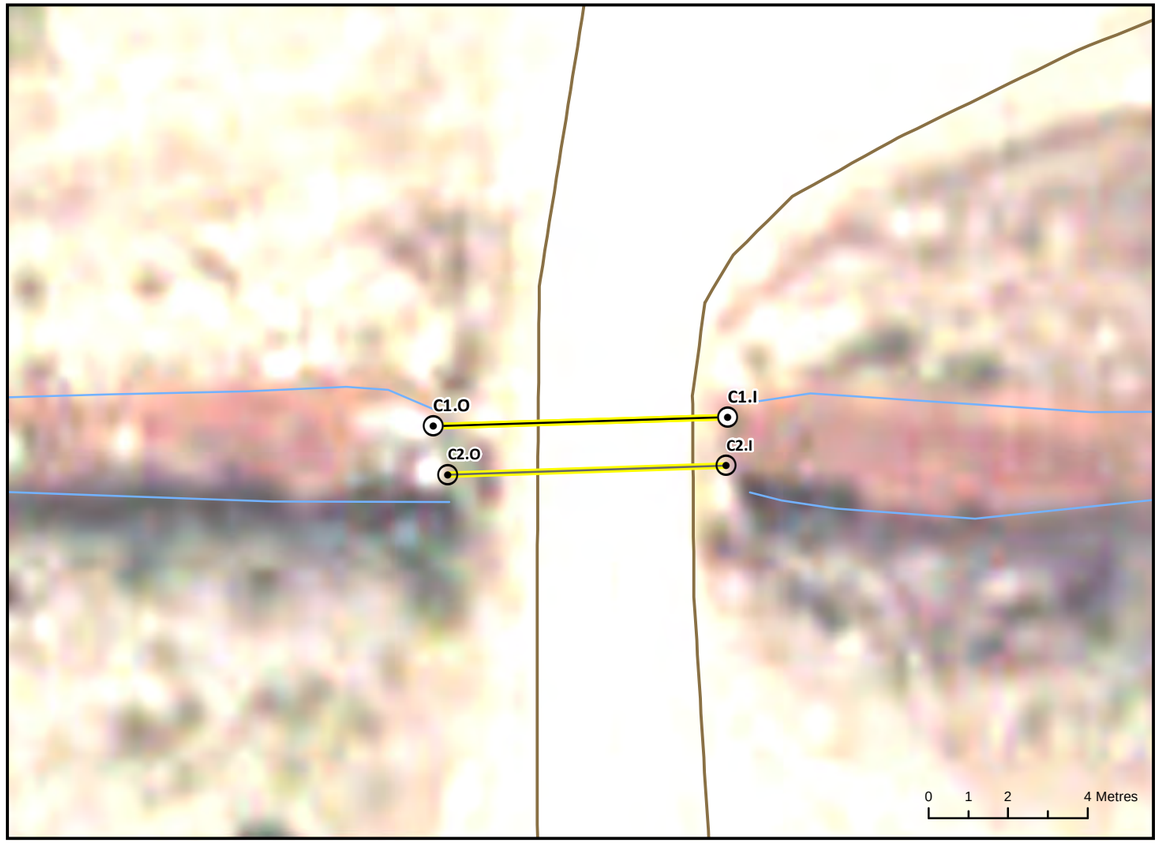
Attachment 6B-1-1

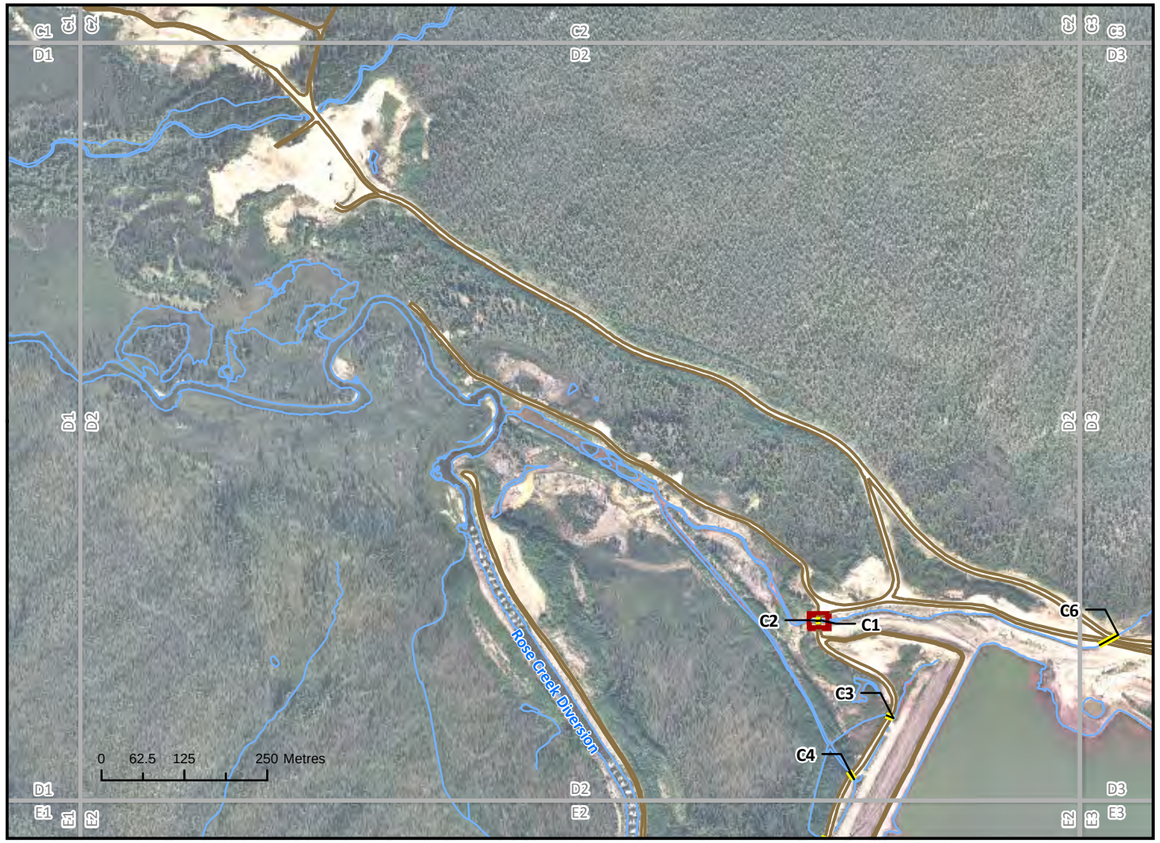
Existing Culvert Survey – Culverts Mapbook Grid

Page:20 Map Grid: N12

Faro Mine Interim Works

Created by: CRITIGEN CH2MHILL





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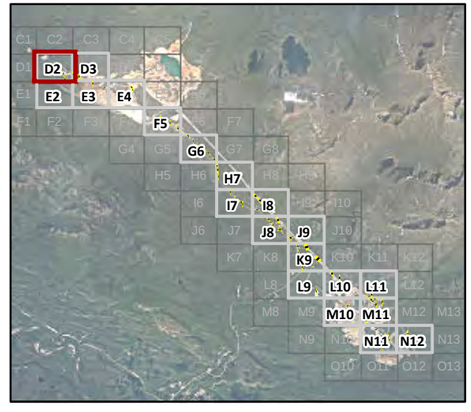


CULVERT C1 INLET

UPSTREAM (C1.IU)



DOWNSTREAM (C1.ID)



Northing: 6914620.23
Easting: 579959.13

Invert Elevation: 1015.50
Survey Date: 10/3/2012

Diameter (mm): 1000
Material Type: CMP: Corrugated

CULVERT C1 OUTLET

UPSTREAM (C1.OU)



DOWNSTREAM (C1.OD)



Northing: 6914620.01
Easting: 579951.72

Invert Elevation: 1015.22
Survey Date: 10/3/2012

Diameter (mm): 1000
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

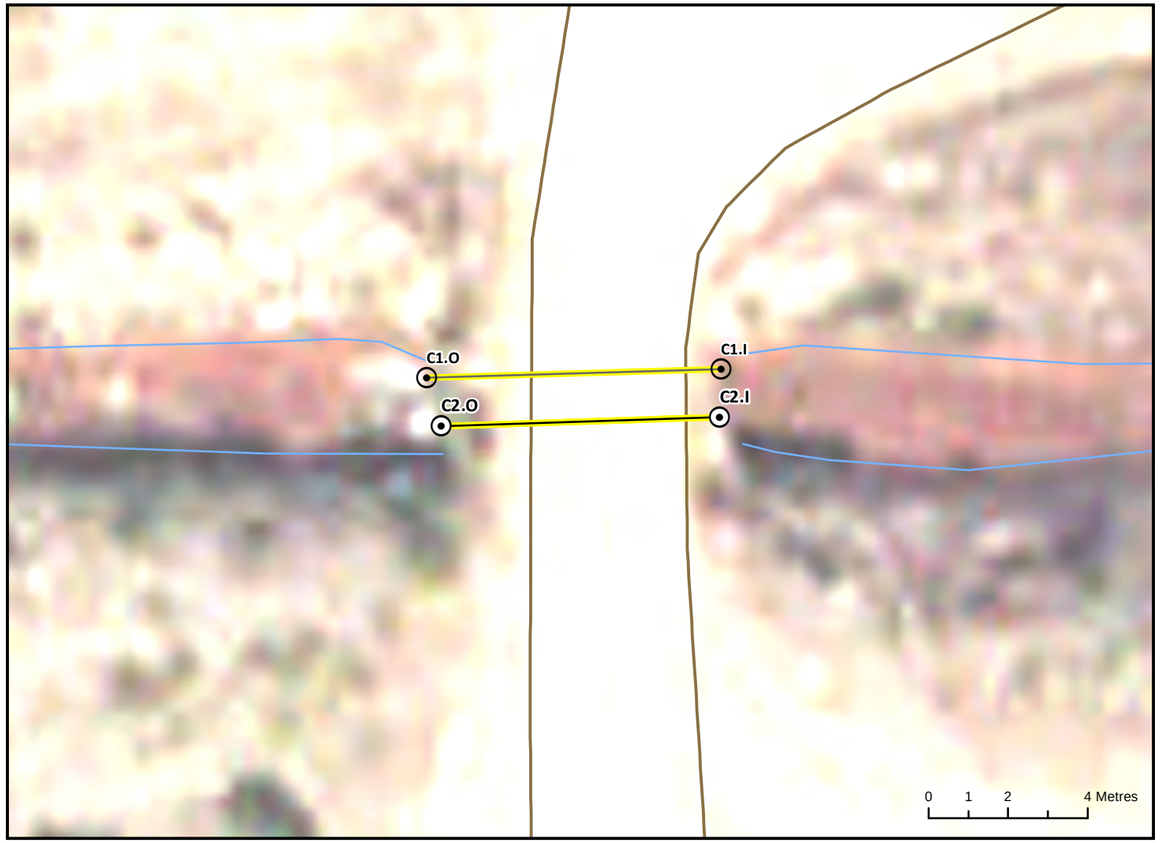
Culvert
Roads Unpaved
Culvert Grid

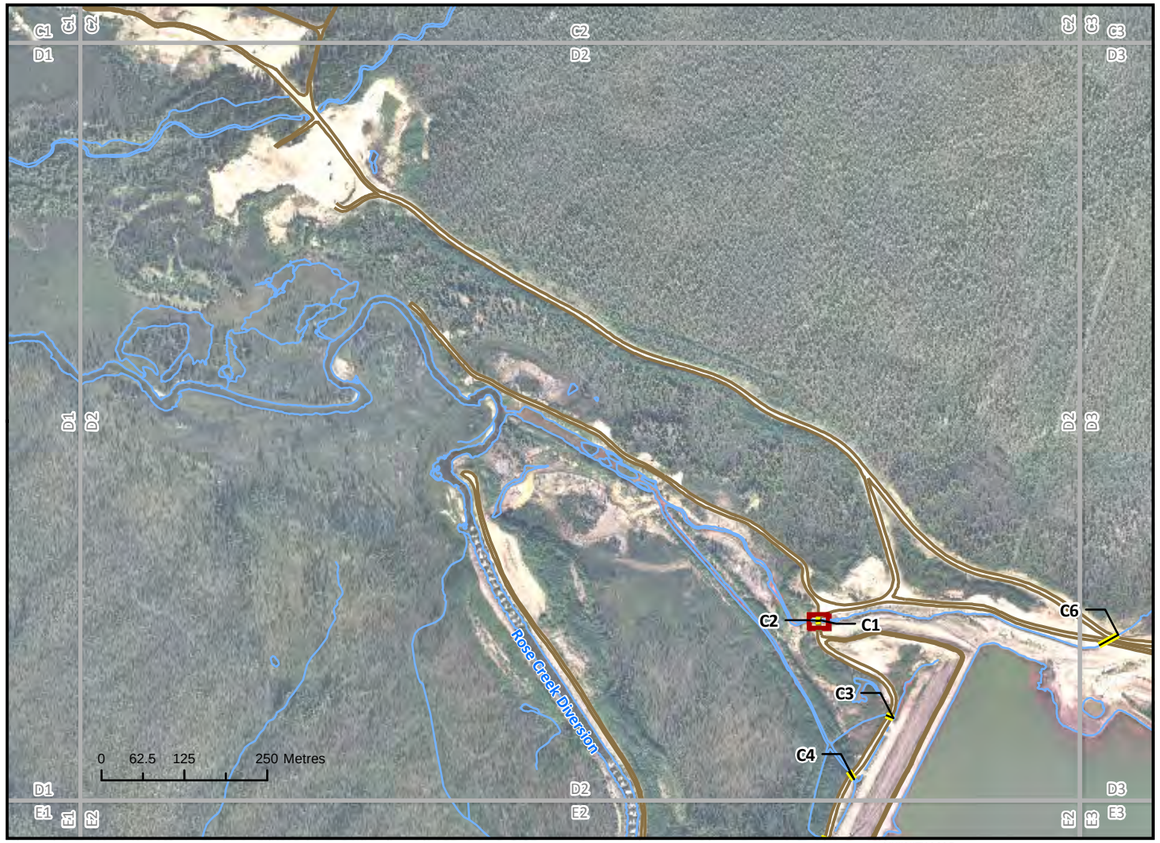
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

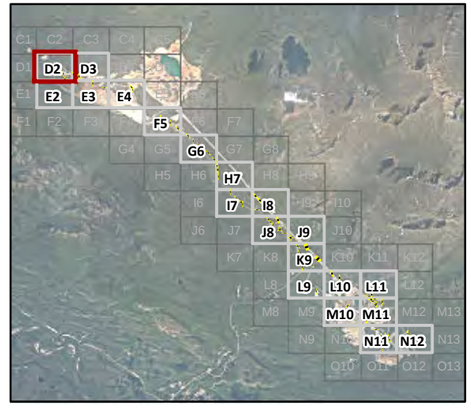
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 1 Culvert: C1 Map Grid: D2
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C2 INLET

UPSTREAM (C2.IU)



DOWNSTREAM (C2.ID)



Northing: 6914619.02
Easting: 579959.1

Invert Elevation: 1015.45
Survey Date: 10/3/2012

Diameter (mm): 1000
Material Type: CMP: Corrugated

CULVERT C2 OUTLET

UPSTREAM (C2.OU)



DOWNSTREAM (C2.OD)



Northing: 6914618.79
Easting: 579952.10

Invert Elevation: 1015.26
Survey Date: 10/3/2012

Diameter (mm): 1000
Material Type: CMP: Corrugated

Created by:
CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

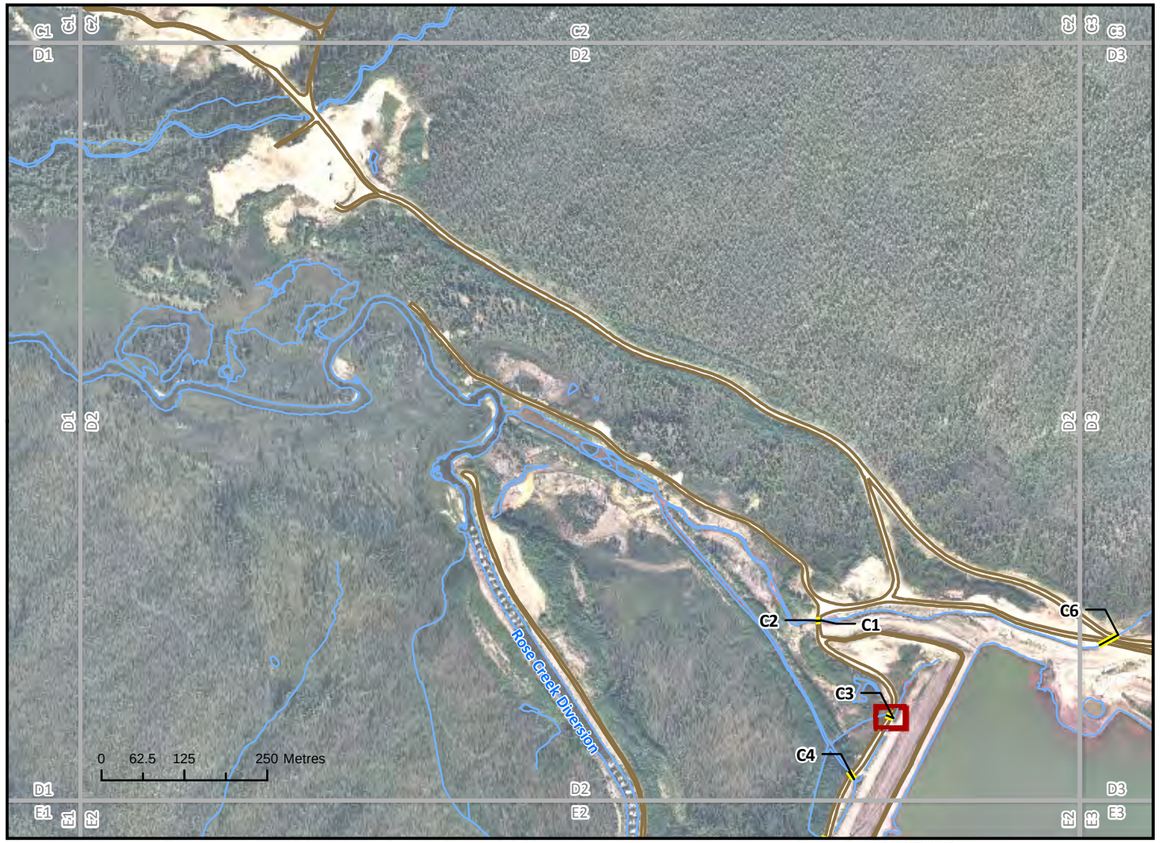
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

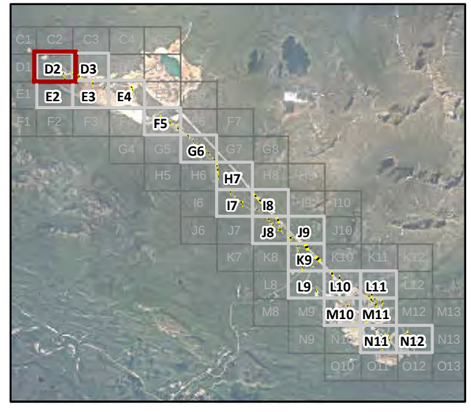
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 2 Culvert: C2 Map Grid: D2
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C3 INLET

UPSTREAM (C3.IU)



DOWNSTREAM (C3.ID)



Northing: 6914472.19
Easting: 580069.36

Invert Elevation: 1015.33
Survey Date: 10/3/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C3 OUTLET

UPSTREAM (C3.OU)



DOWNSTREAM (C3.OD)



Northing: 6914476.71
Easting: 580058.23

Invert Elevation: 1015.5
Survey Date: 10/3/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

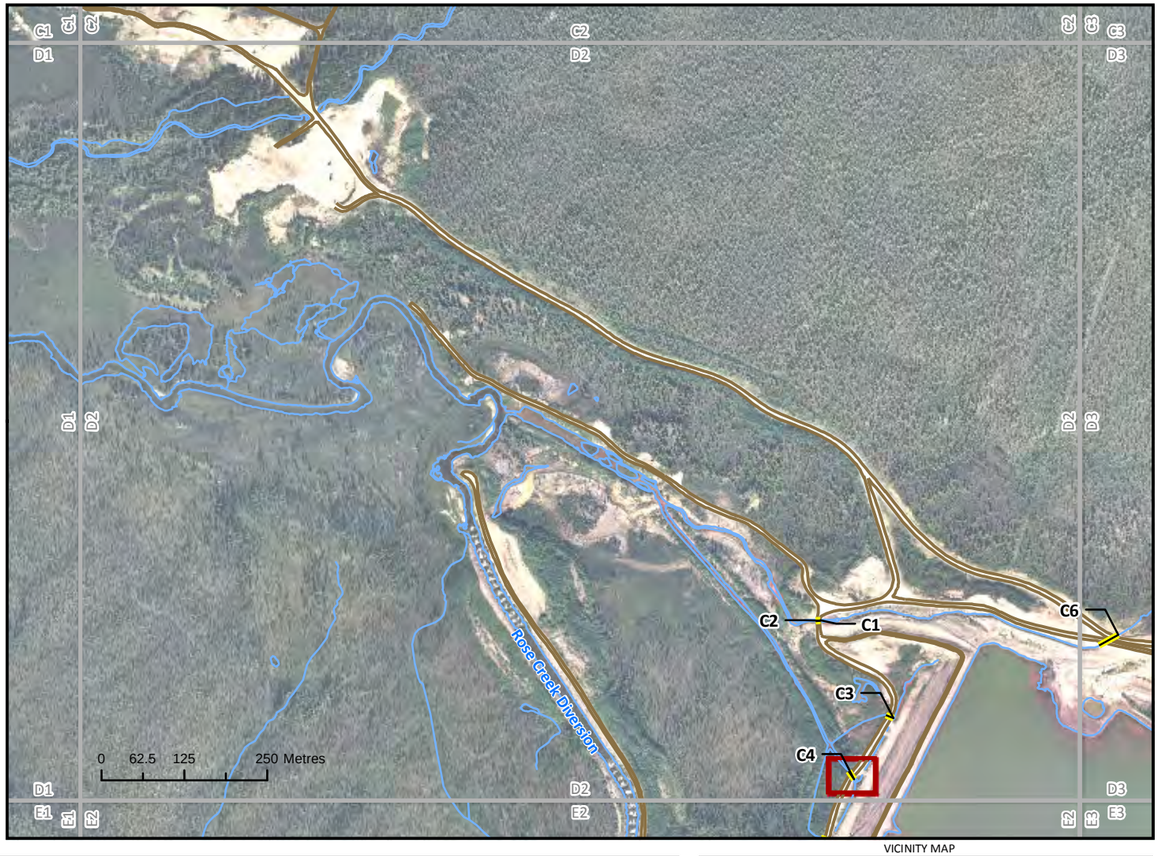
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

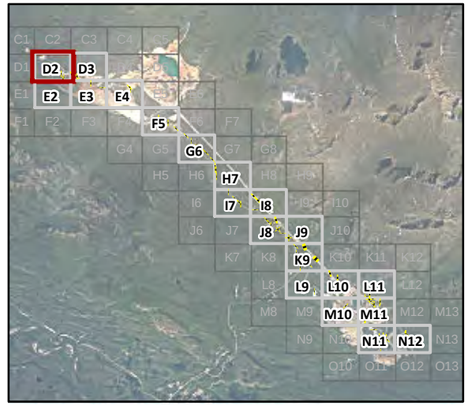
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 3 Culvert: C3 Map Grid: D2
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C4 INLET

UPSTREAM (C4.IU)



DOWNSTREAM (C4.ID)



Northing: 6914379.63
Easting: 580010.12

Invert Elevation: 1014.70
Survey Date: 10/3/2012

Diameter (mm): 1200
Material Type: CMP: Corrugated

CULVERT C4 OUTLET

UPSTREAM (C4.OU)



DOWNSTREAM (C4.OD)



Northing: 6914392.40
Easting: 580001.54

Invert Elevation: 1014.69
Survey Date: 10/3/2012

Diameter (mm): 1200
Material Type: CMP: Corrugated

Created by:
CRITIGEN

LEGEND

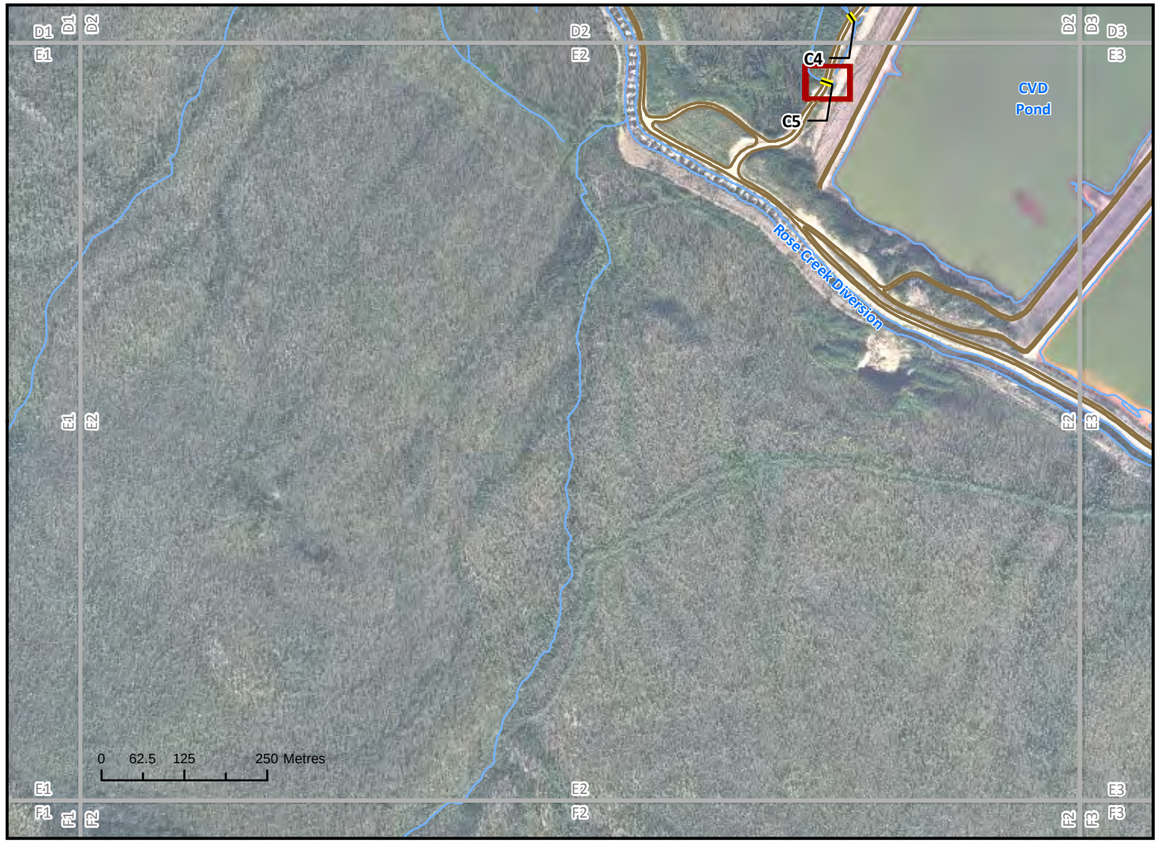
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 4 Culvert: C4 Map Grid: D2
Faro Mine Interim Works





CULVERT C5 INLET

UPSTREAM (C5.IU)



DOWNSTREAM (C5.ID)



Northing: 6914285.22
Easting: 579976.91

Invert Elevation: 1015.26
Survey Date: 10/3/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C5 OUTLET

UPSTREAM (C5.OU)



DOWNSTREAM (C5.OD)

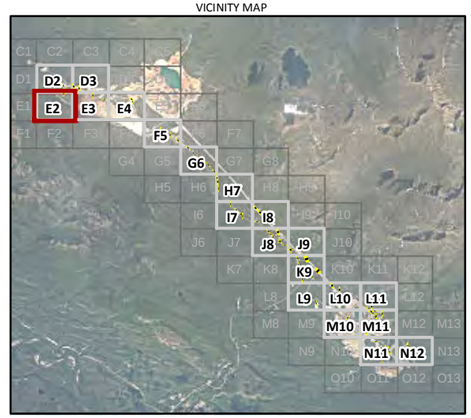


Northing: 6914291.77
Easting: 579959.95

Invert Elevation: 1015.01
Survey Date: 10/3/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

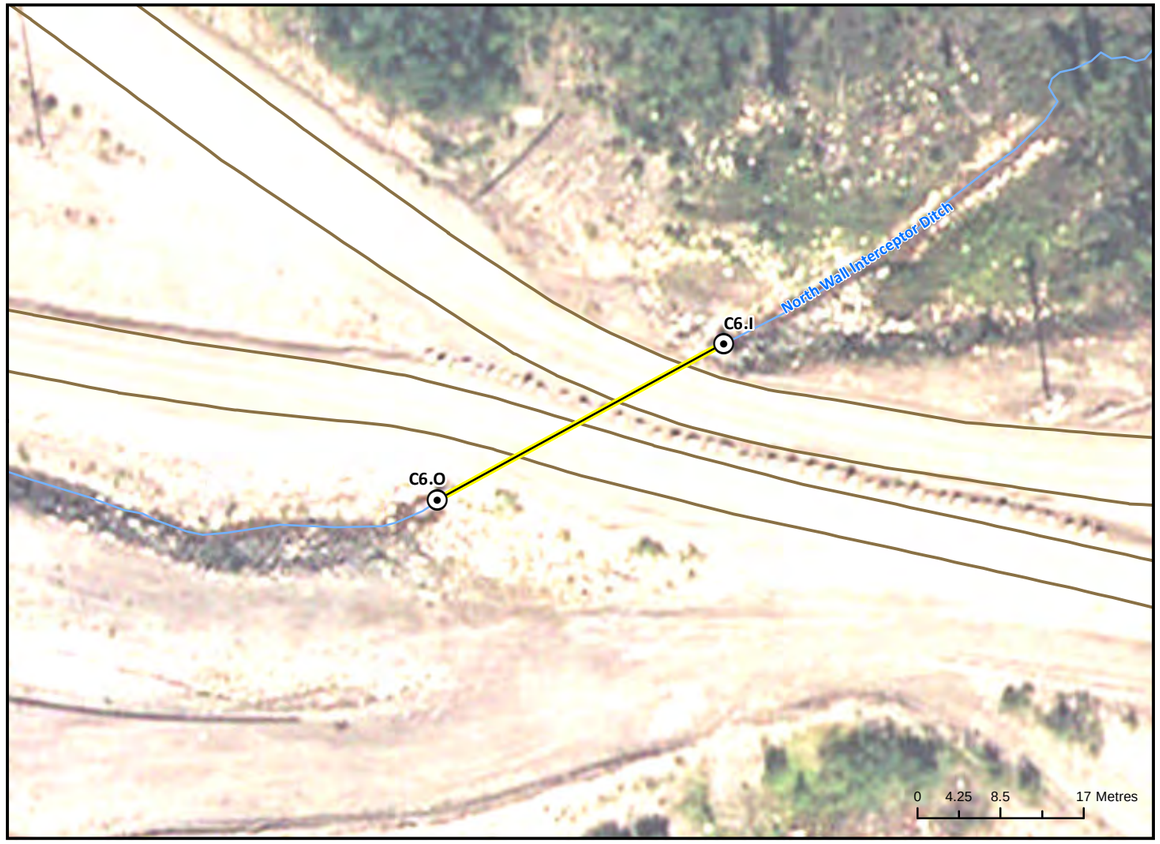
LEGEND

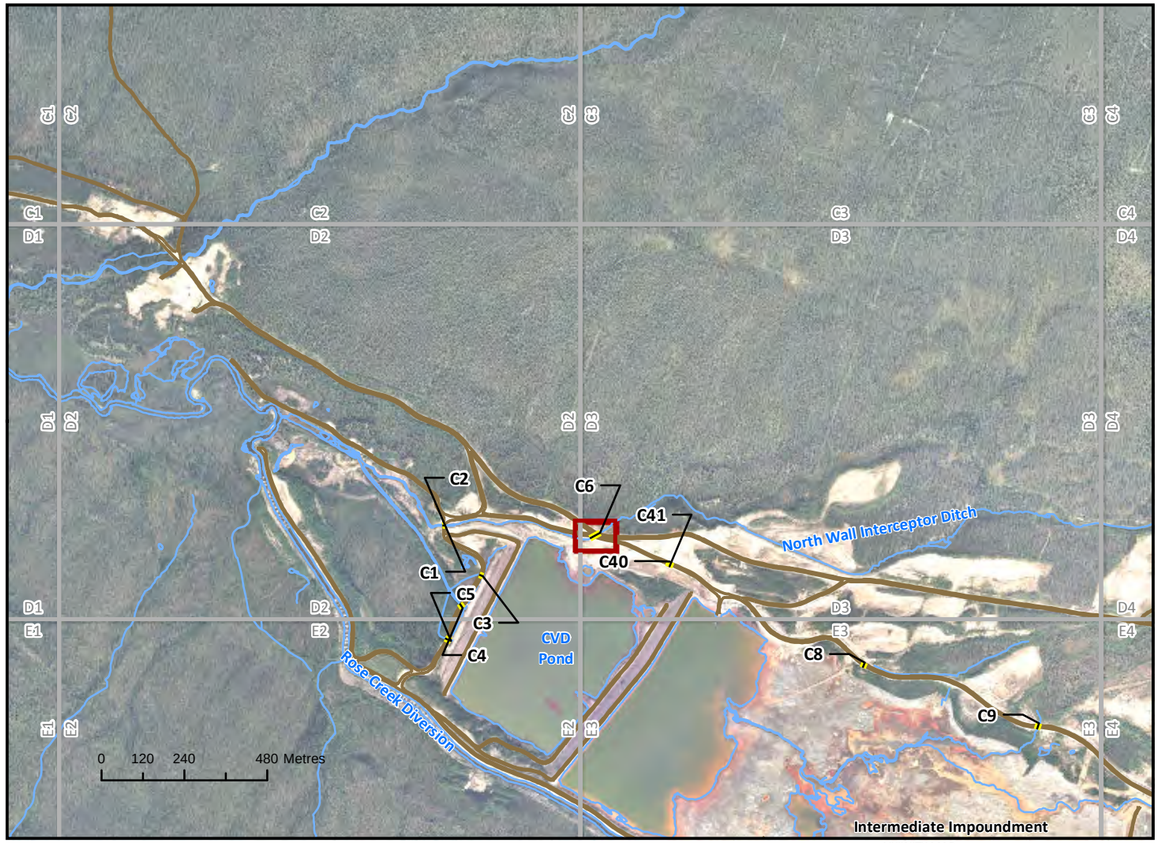
Culvert
Roads Unpaved
Culvert Grid

N

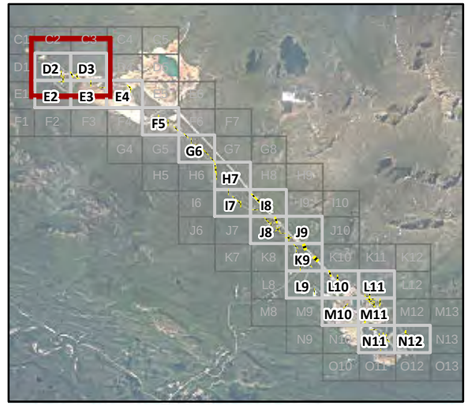
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 5 Culvert: C5 Map Grid: E2
Faro Mine Interim Works





VICINITY MAP



CULVERT C6 INLET

UPSTREAM (C6.IU)



DOWNSTREAM (C6.ID)



Northing: 6914597.61
Easting: 580408.44

Invert Elevation: 1044.50
Survey Date: 10/3/2012

Diameter (mm): 2200
Material Type: CMP: Corrugated

CULVERT C6 OUTLET

UPSTREAM (C6.OU)



DOWNSTREAM (C6.OD)



Northing: 6914581.63
Easting: 580379.15

Invert Elevation: 1043.02
Survey Date: 10/3/2012

Diameter (mm): 2200
Material Type: CMP: Corrugated

Created by: CRITIGEN

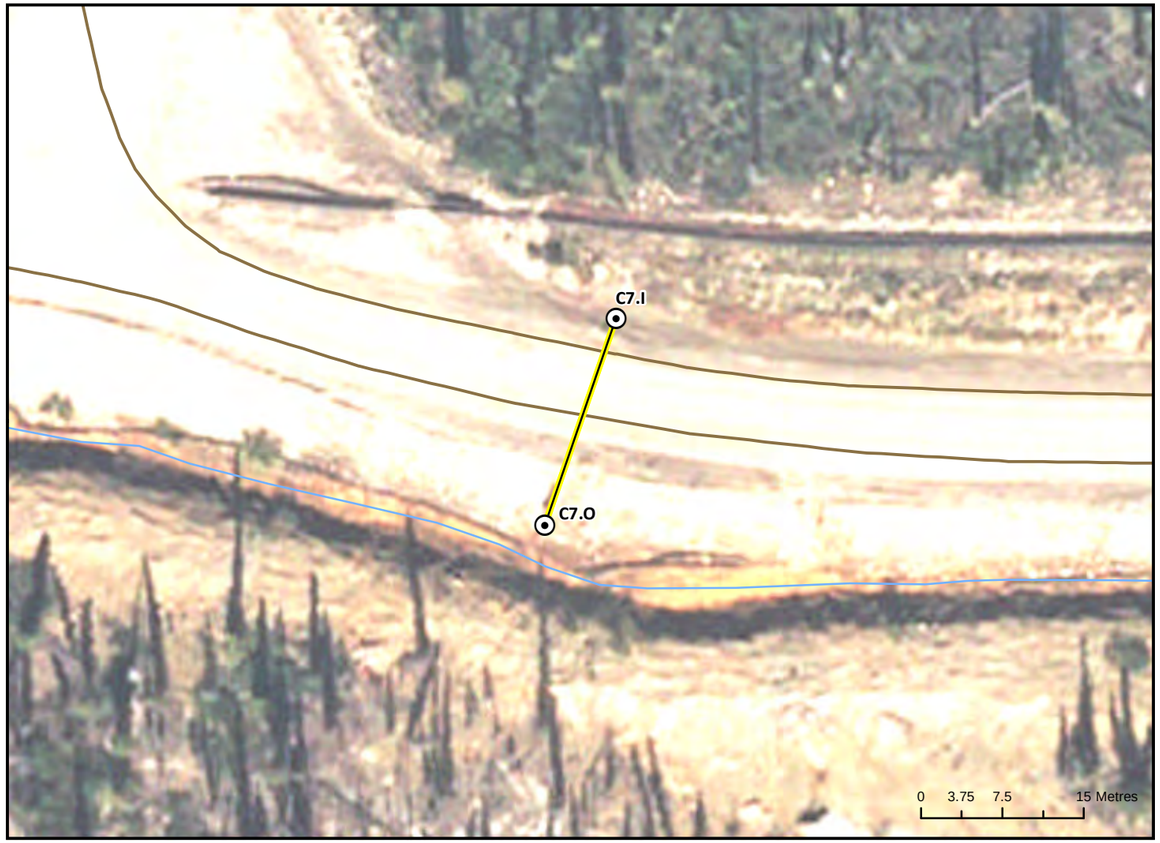
LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

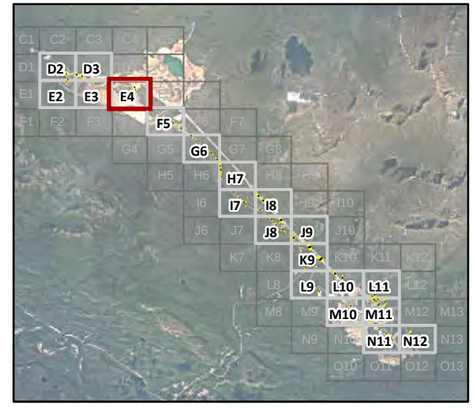
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 6 Culvert: C6 Map Grid: D3
Faro Mine Interim Works





VICINITY MAP



CULVERT C7 INLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (N/A)

Photo Not Available

Northing: 6913748.32
Easting: 582298.38

Invert Elevation: 1069.36
Survey Date: 10/3/2012

Diameter (mm): 450
Material Type: Hard Rubber

CULVERT C7 OUTLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (N/A)

Photo Not Available

Northing: 6913729.23
Easting: 582291.85

Invert Elevation: 1068.8
Survey Date: 10/3/2012

Diameter (mm): 450
Material Type: CMP: Smooth

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

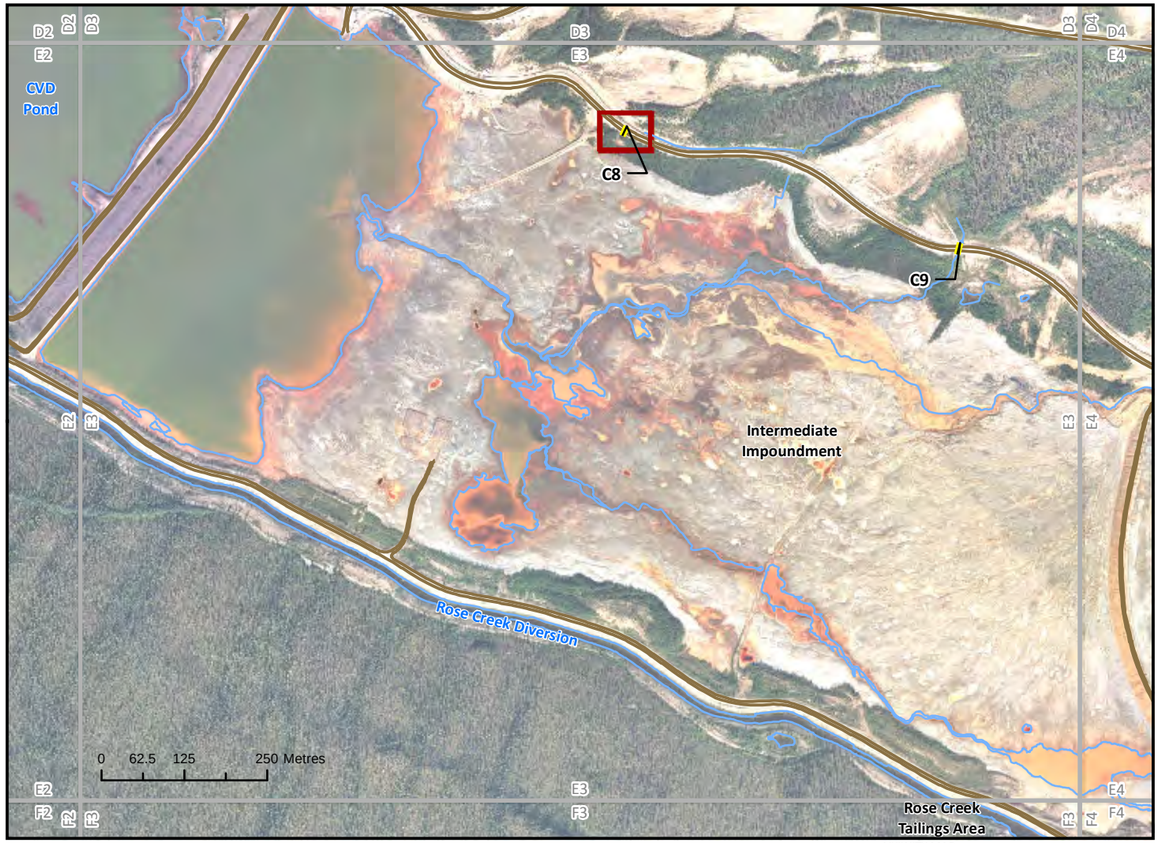
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 7 Culvert: C7 Map Grid: E4
Faro Mine Interim Works

CH2MHILL





VICINITY MAP

CULVERT C8 INLET

UPSTREAM (C8.IU)



DOWNSTREAM (C8.ID)



Northing: 6914221.84
Easting: 581175.15

Invert Elevation: 1056.82
Survey Date: 10/3/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C8 OUTLET

UPSTREAM (C8.OU)



DOWNSTREAM (C8.OD)



Northing: 6914207.87
Easting: 581168.56

Invert Elevation: 1056.26
Survey Date: 10/3/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

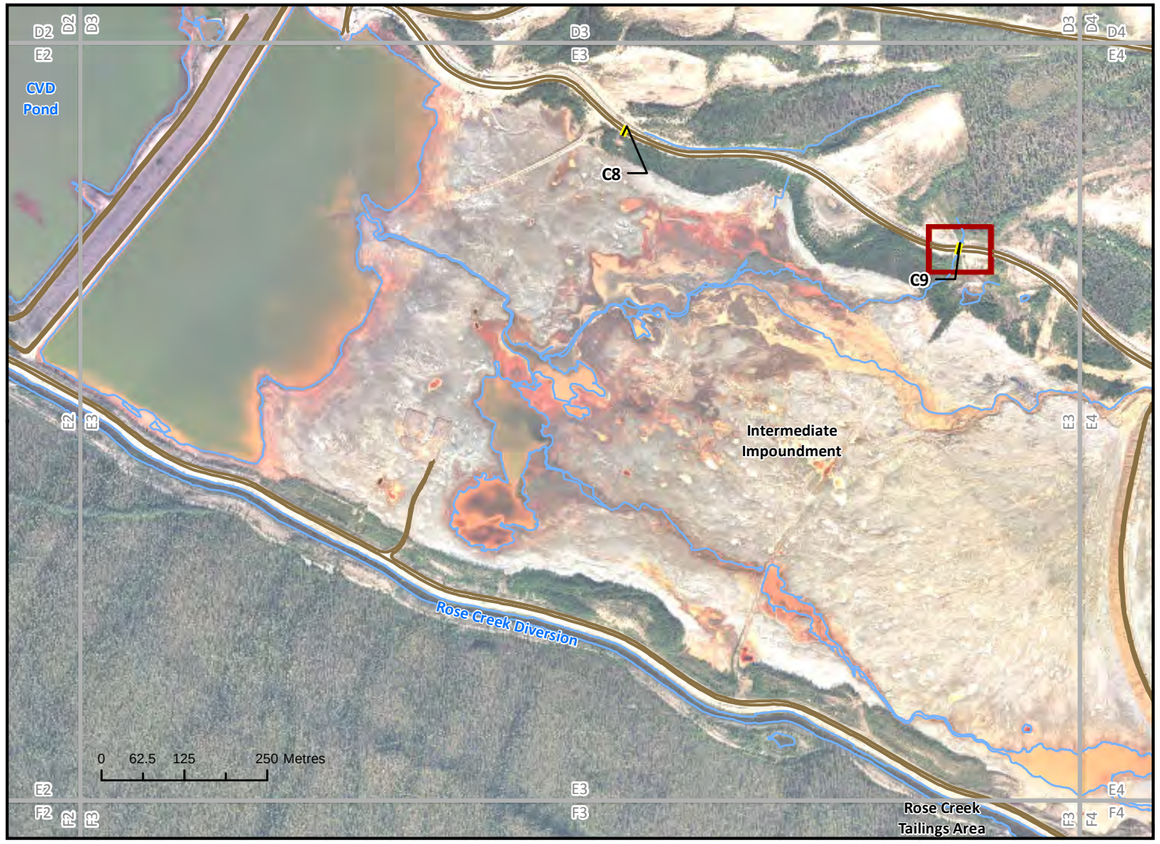
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

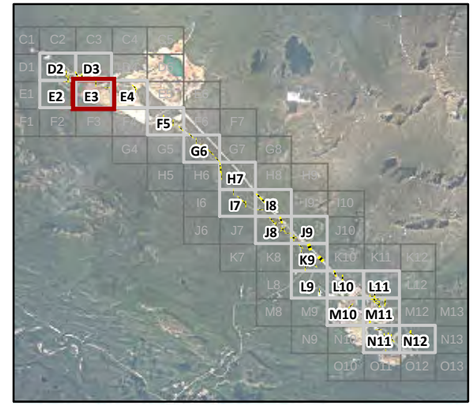
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 8 Culvert: C8 Map Grid: E3
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C9 INLET

UPSTREAM (C9.IU)



DOWNSTREAM (C9.ID)



Northing: 6914045.97
Easting: 581678.36

Invert Elevation: 1062.30
Survey Date: 10/3/2012

Diameter (mm): 1000
Material Type: CMP: Corrugated

CULVERT C9 OUTLET

UPSTREAM (C9.OU)



DOWNSTREAM (C9.OD)



Northing: 6914028.70
Easting: 581673.60

Invert Elevation: 1059.88
Survey Date: 10/3/2012

Diameter (mm): 1000
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

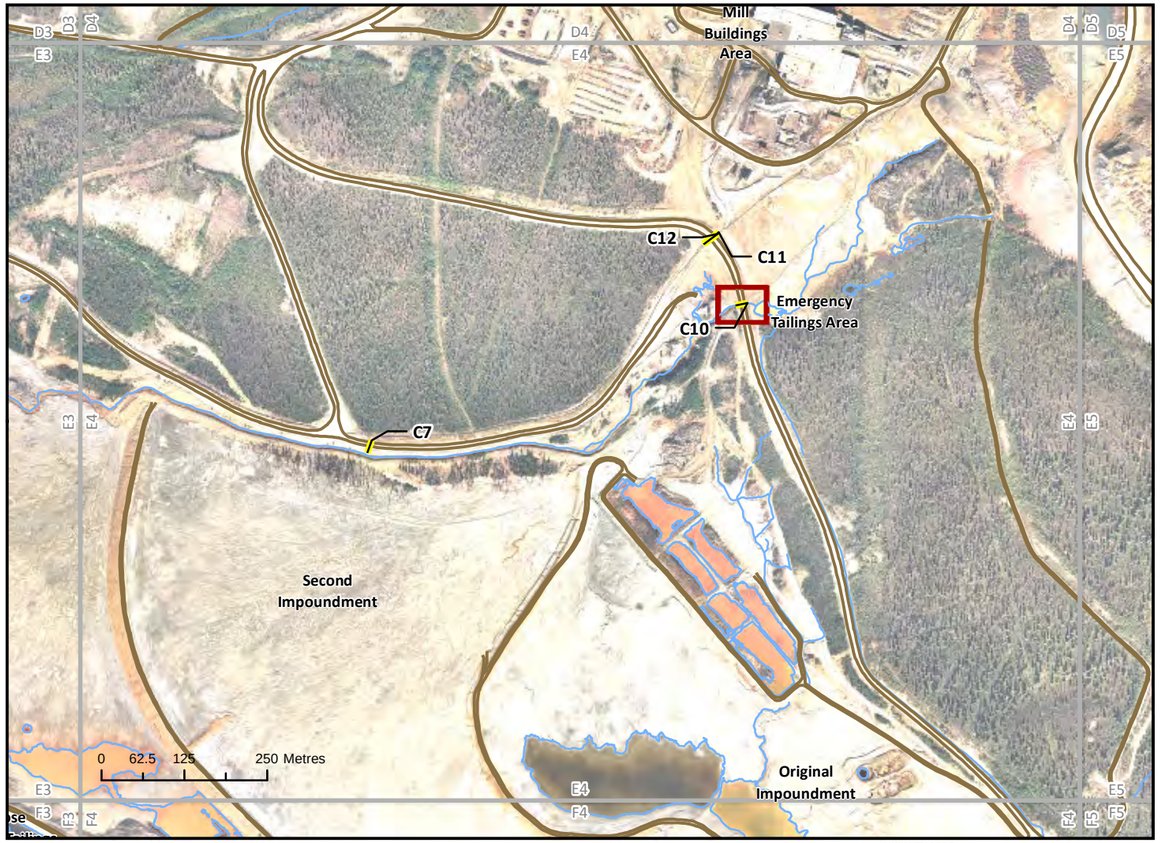
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page: 9 Culvert: C9 Map Grid: E3
Faro Mine Interim Works





CULVERT C10 INLET

UPSTREAM (C10.IU)



DOWNSTREAM (C10.ID)



Northing: 6913955.17
Easting: 582865.49

Invert Elevation: 1103.23
Survey Date: 10/4/2012

Diameter (mm): 1800
Material Type: CMP: Corrugated

CULVERT C10 OUTLET

UPSTREAM (C10.OU)



DOWNSTREAM (C10.OD)

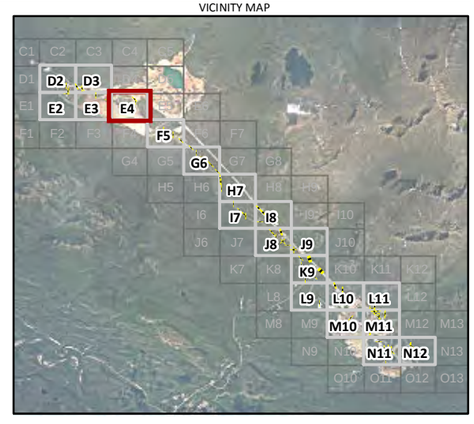


Northing: 6913951.44
Easting: 582847.23

Invert Elevation: 1102.27
Survey Date: 10/4/2012

Diameter (mm): 1800
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

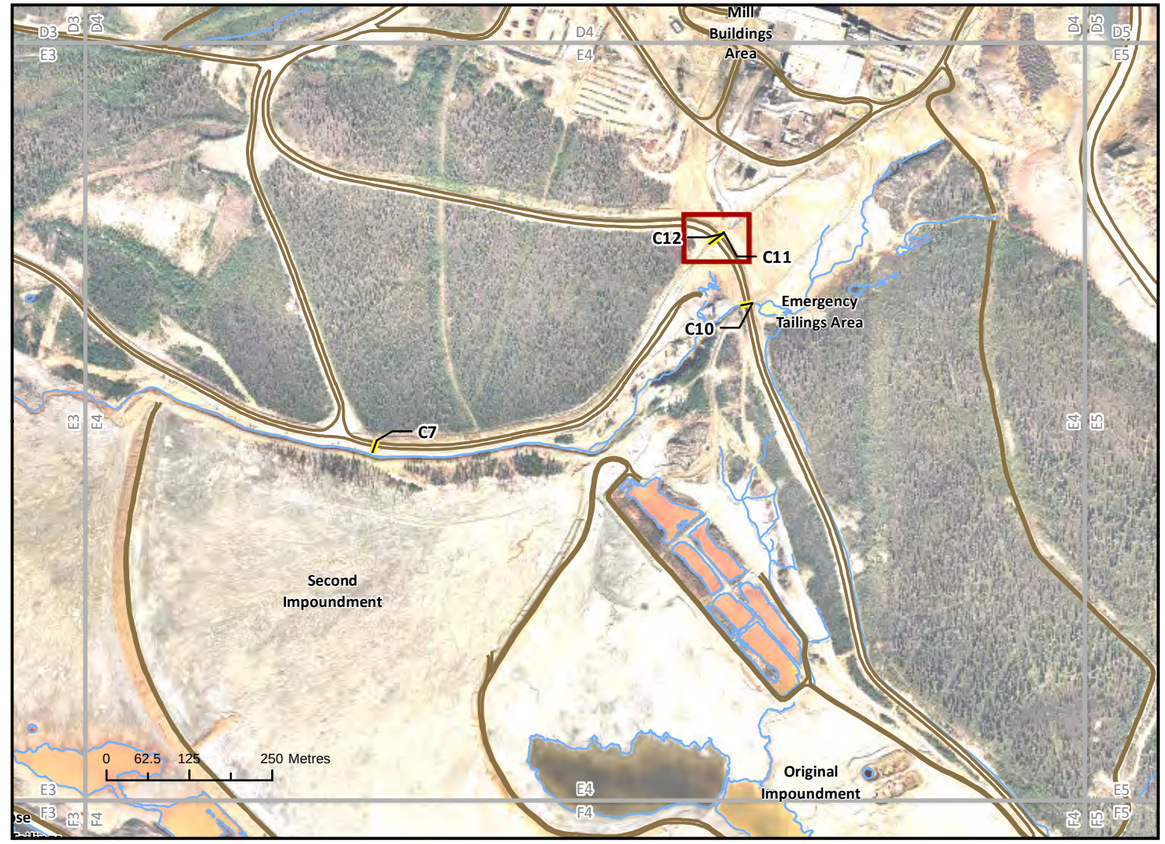
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

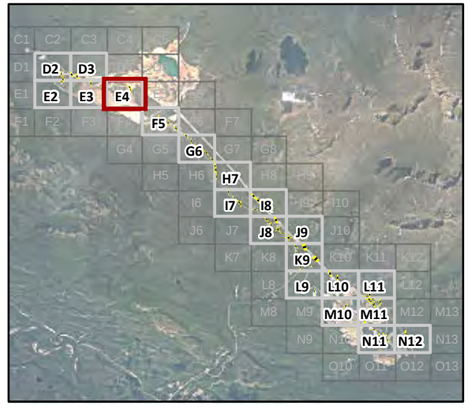
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:10 Culvert: C10 Map Grid: E4
Faro Mine Interim Works

CH2MHILL



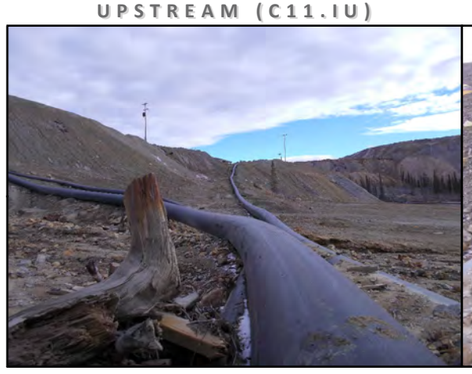


VICINITY MAP



CULVERT C11 INLET

UPSTREAM (C11.IU)



DOWNSTREAM (C11.ID)



Northing: 6914062.54
Easting: 582822.19

Invert Elevation: 1108.33
Survey Date: 10/4/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C11 OUTLET

UPSTREAM (C11.OU)



DOWNSTREAM (C11.OD)



Northing: 6914044.82
Easting: 582798.23

Invert Elevation: 1105.43
Survey Date: 10/4/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

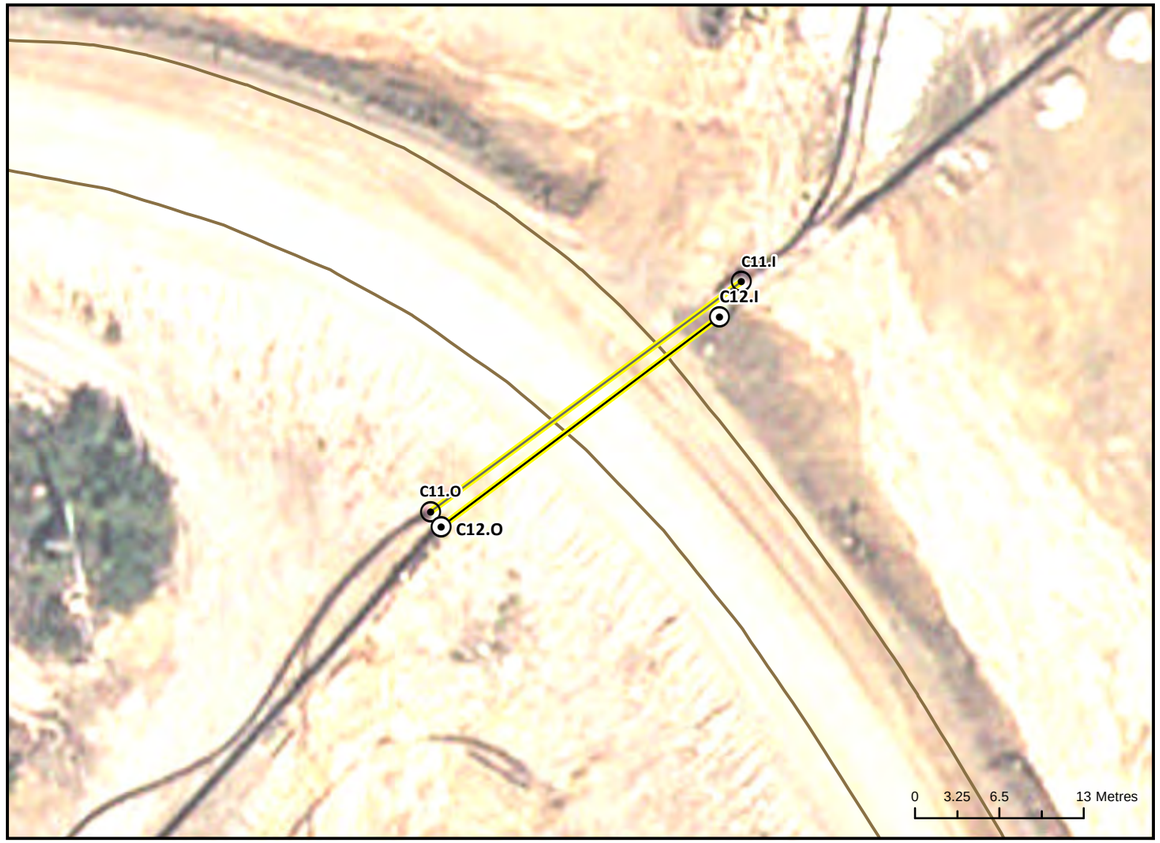
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

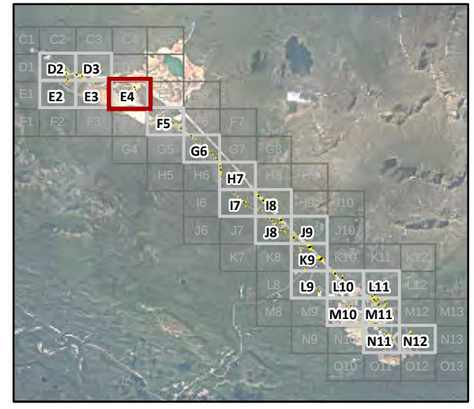
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:11 Culvert: C11 Map Grid: E4
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C12 INLET

UPSTREAM (C12.IU)



DOWNSTREAM (C12.ID)



Northing: 6914059.82
Easting: 582820.53

Invert Elevation: 1107.81
Survey Date: 10/4/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C12 OUTLET

UPSTREAM (C12.OU)



DOWNSTREAM (C12.OD)



Northing: 6914043.65
Easting: 582799.06

Invert Elevation: 1105.04
Survey Date: 10/4/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

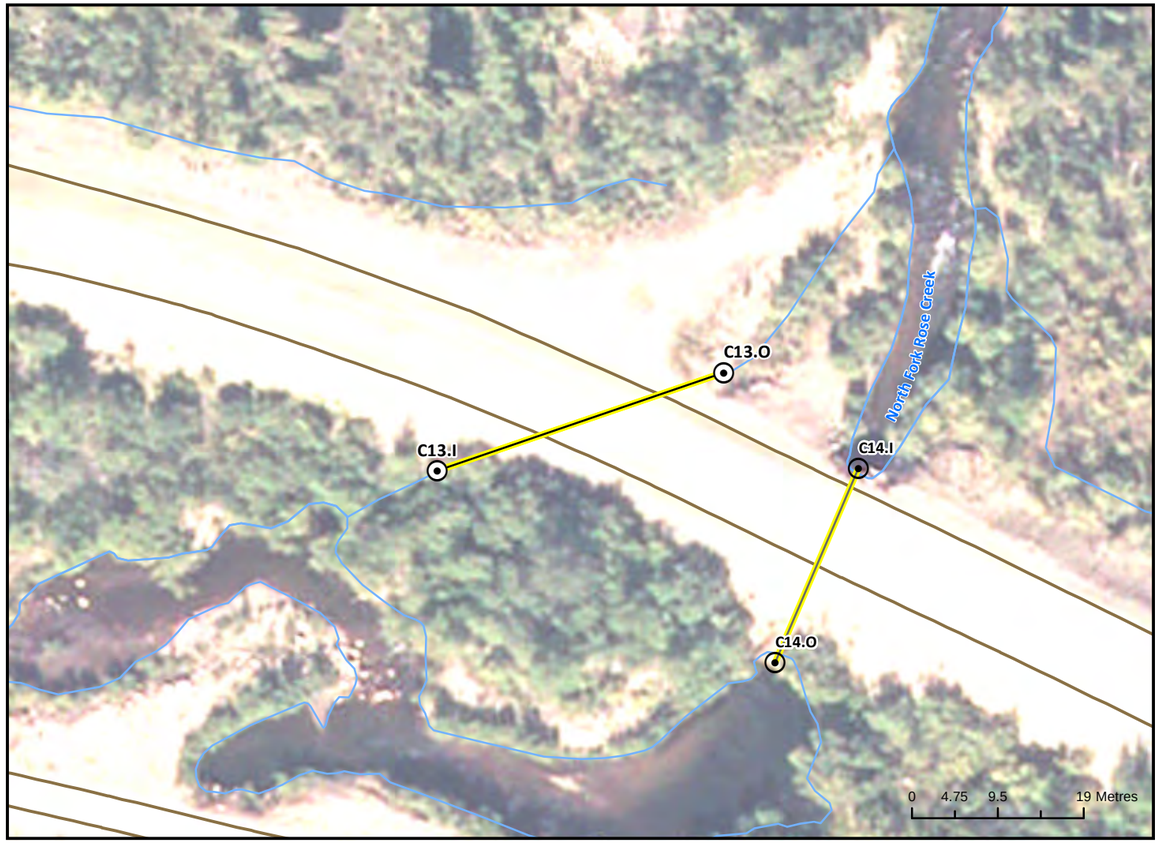
Culvert
Roads Unpaved
Culvert Grid

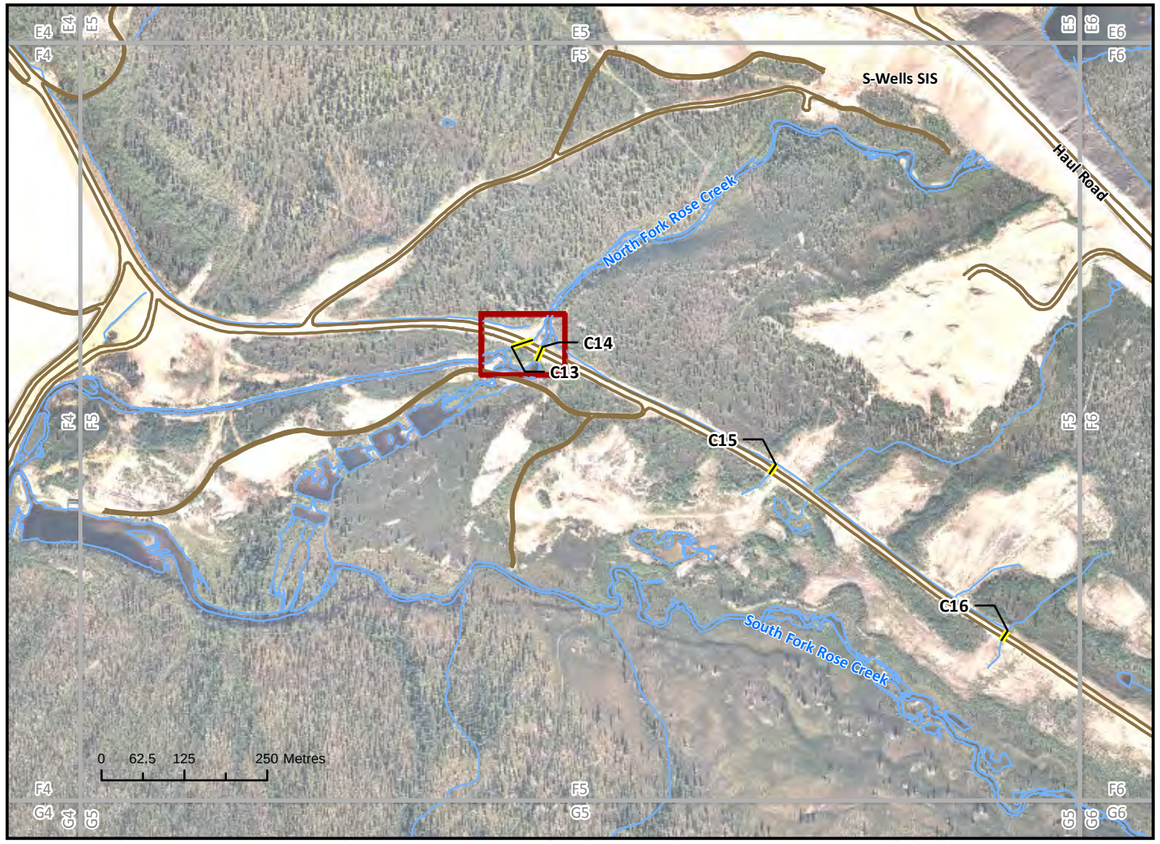
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:12 Culvert: C12 Map Grid: E4
Faro Mine Interim Works

CH2MHILL





CULVERT C13 INLET

UPSTREAM (C13.IU)



DOWNSTREAM (C13.ID)



Northing: 6912745.82
Easting: 584017.68

Invert Elevation: 1071.55
Survey Date: 10/4/2012

Diameter (mm): 1800
Material Type: CMP: Corrugated

CULVERT C13 OUTLET

UPSTREAM (C13.OU)



DOWNSTREAM (C13.OD)

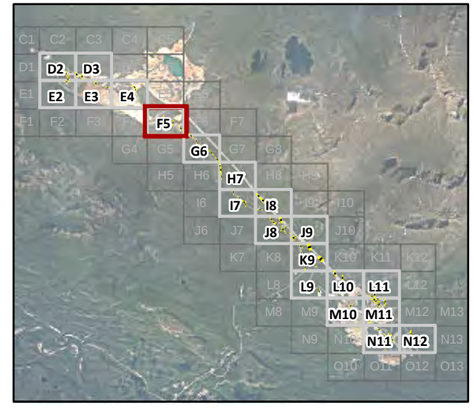


Northing: 6912756.71
Easting: 584049.34

Invert Elevation: 1072.8
Survey Date: 10/4/2012

Diameter (mm): 1800
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

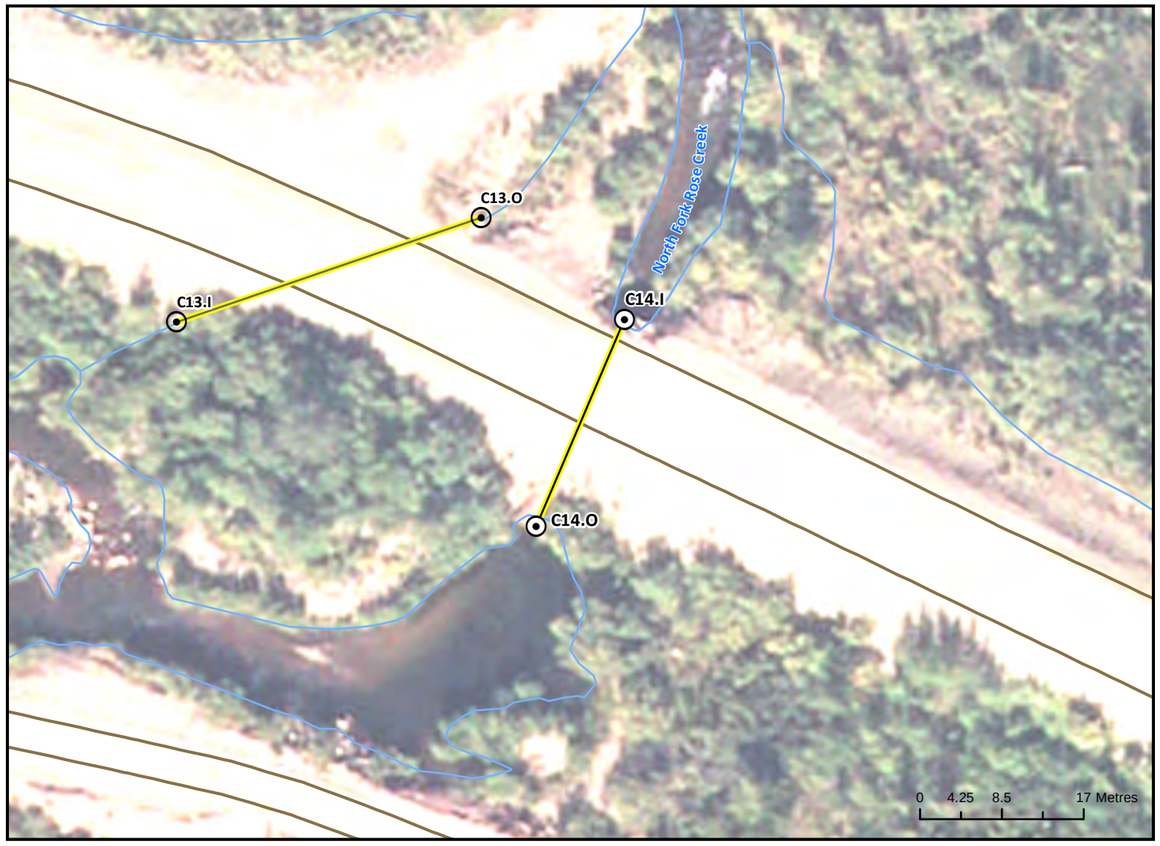
Culvert
Roads Unpaved
Culvert Grid

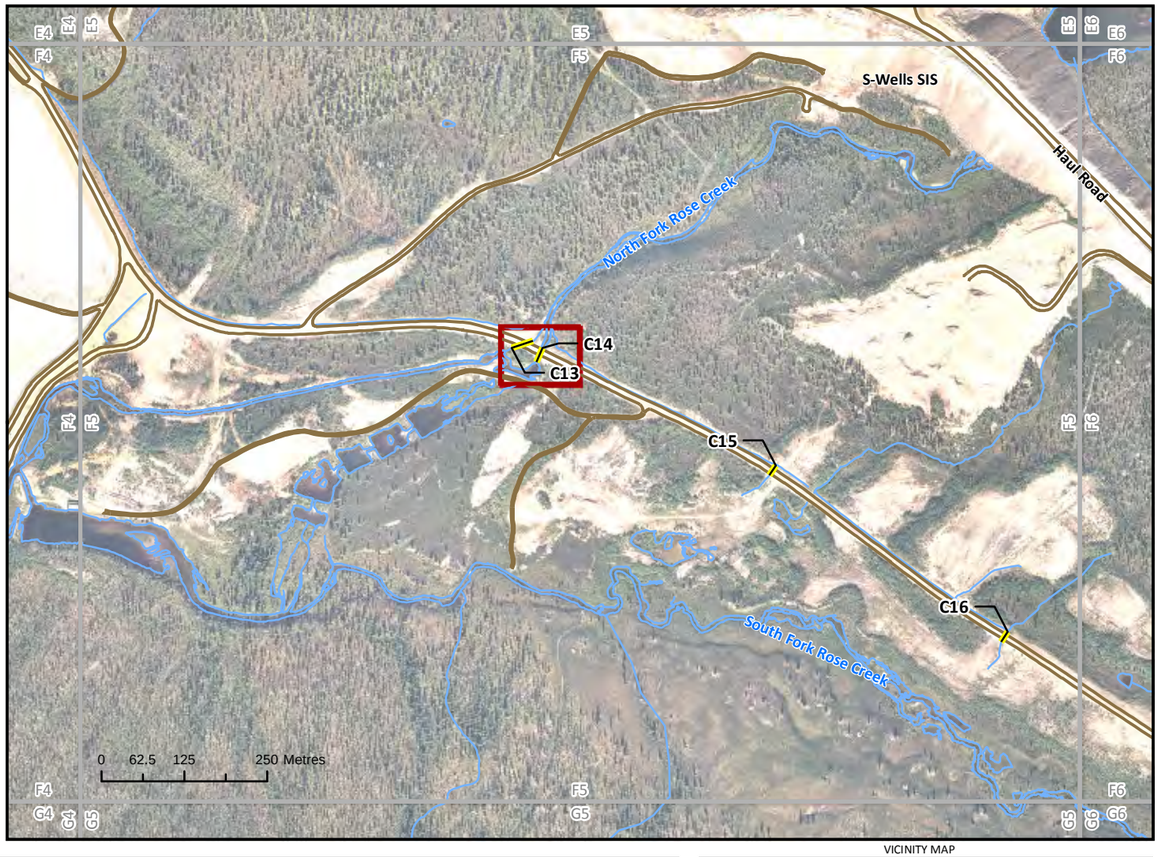
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:13 Culvert: C13 Map Grid: F5
Faro Mine Interim Works

CH2MHILL





CULVERT C14 INLET

UPSTREAM (C14.IU)



DOWNSTREAM (C14.ID)



Northing: 6912746.14
Easting: 584064.28

Invert Elevation: 1072.9
Survey Date: 10/4/2012

Diameter (mm): 3600
Material Type: CMP: Corrugated

CULVERT C14 OUTLET

UPSTREAM (C14.OU)



DOWNSTREAM (C14.OD)

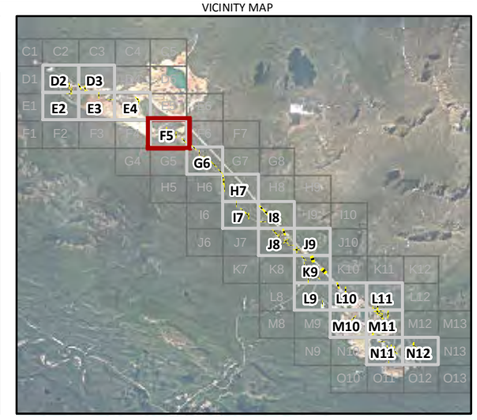


Northing: 6912724.63
Easting: 584055.05

Invert Elevation: 1072.54
Survey Date: 10/4/2012

Diameter (mm): 3600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

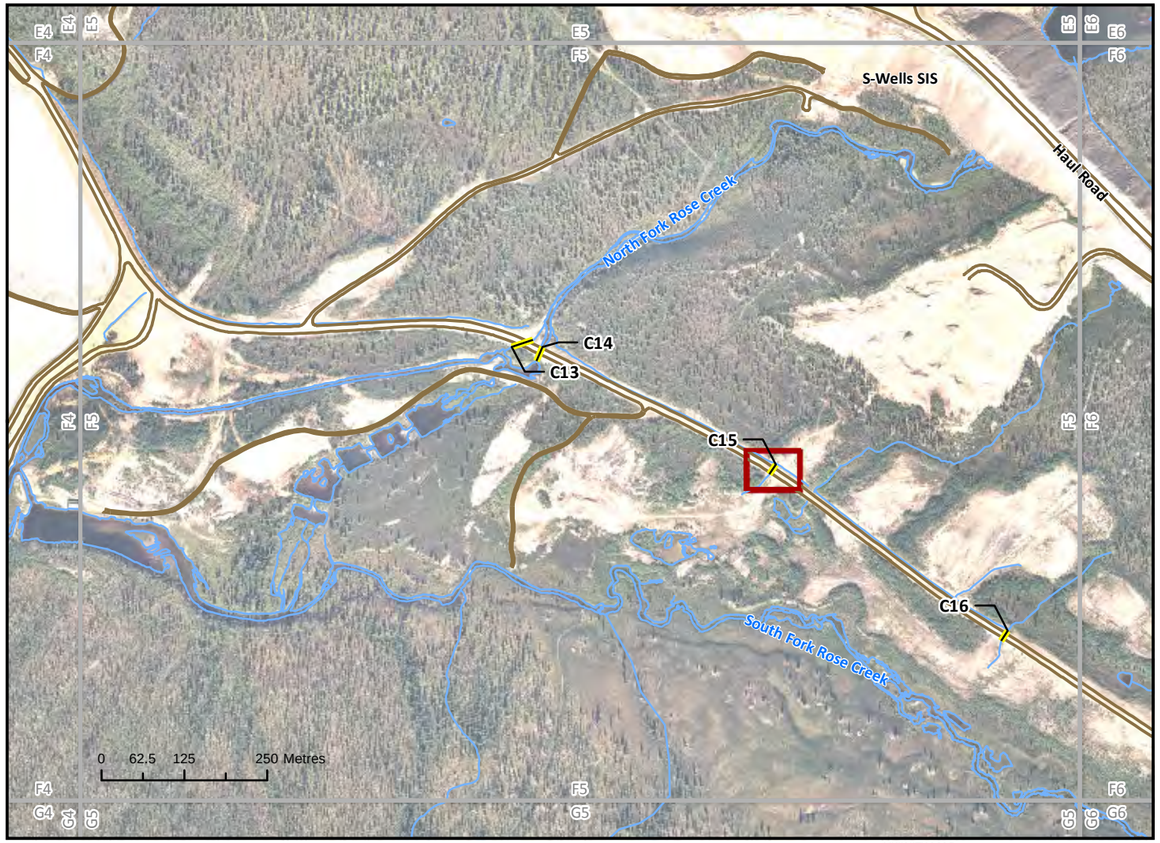
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:14 Culvert: C14 Map Grid: F5
Faro Mine Interim Works

CH2MHILL





CULVERT C15 INLET

UPSTREAM (C15.IU)



DOWNSTREAM (C15.ID)



Northing: 6912568.55
Easting: 584416.26

Invert Elevation: 1073.55
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C15 OUTLET

UPSTREAM (C15.OU)



DOWNSTREAM (C15.OD)

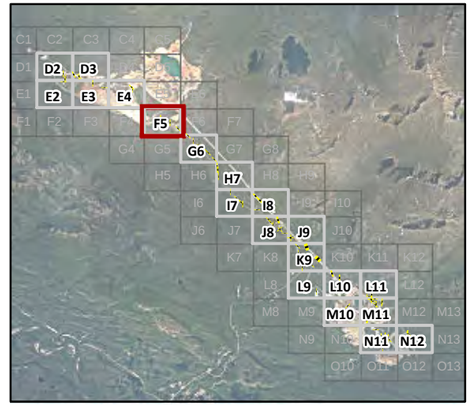


Northing: 6912553.99
Easting: 584406.07

Invert Elevation: 1073.08
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

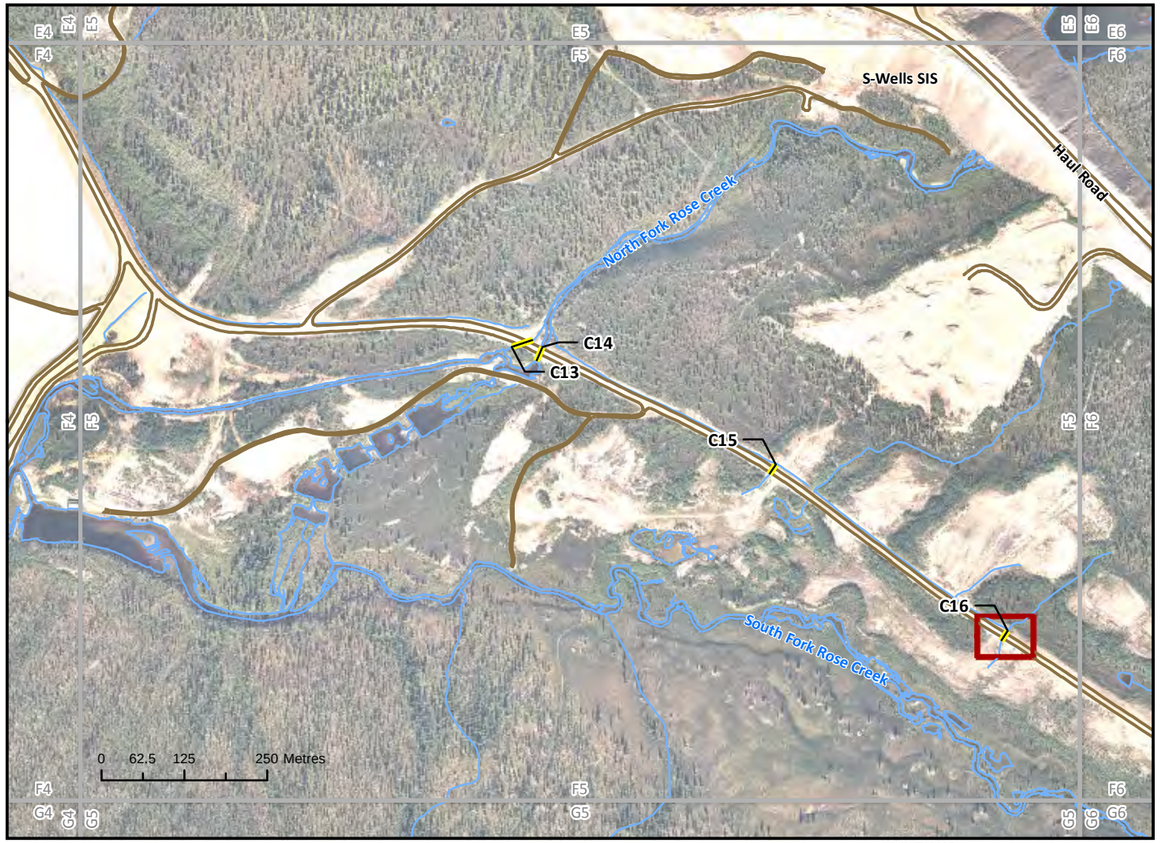
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

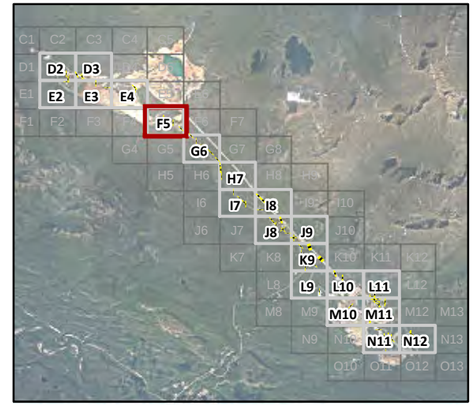
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:15 Culvert: C15 Map Grid: F5
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C16 INLET

UPSTREAM (C16.IU)



DOWNSTREAM (C16.ID)



Northing: 6912317.99
Easting: 584765.71

Invert Elevation: 1077.29
Survey Date: 10/4/2012

Diameter (mm): 300
Material Type: CMP: Corrugated

CULVERT C16 OUTLET

UPSTREAM (C16.OU)



DOWNSTREAM (C16.OD)



Northing: 6912302.76
Easting: 584756.40

Invert Elevation: 1076.77
Survey Date: 10/4/2012

Diameter (mm): 300
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

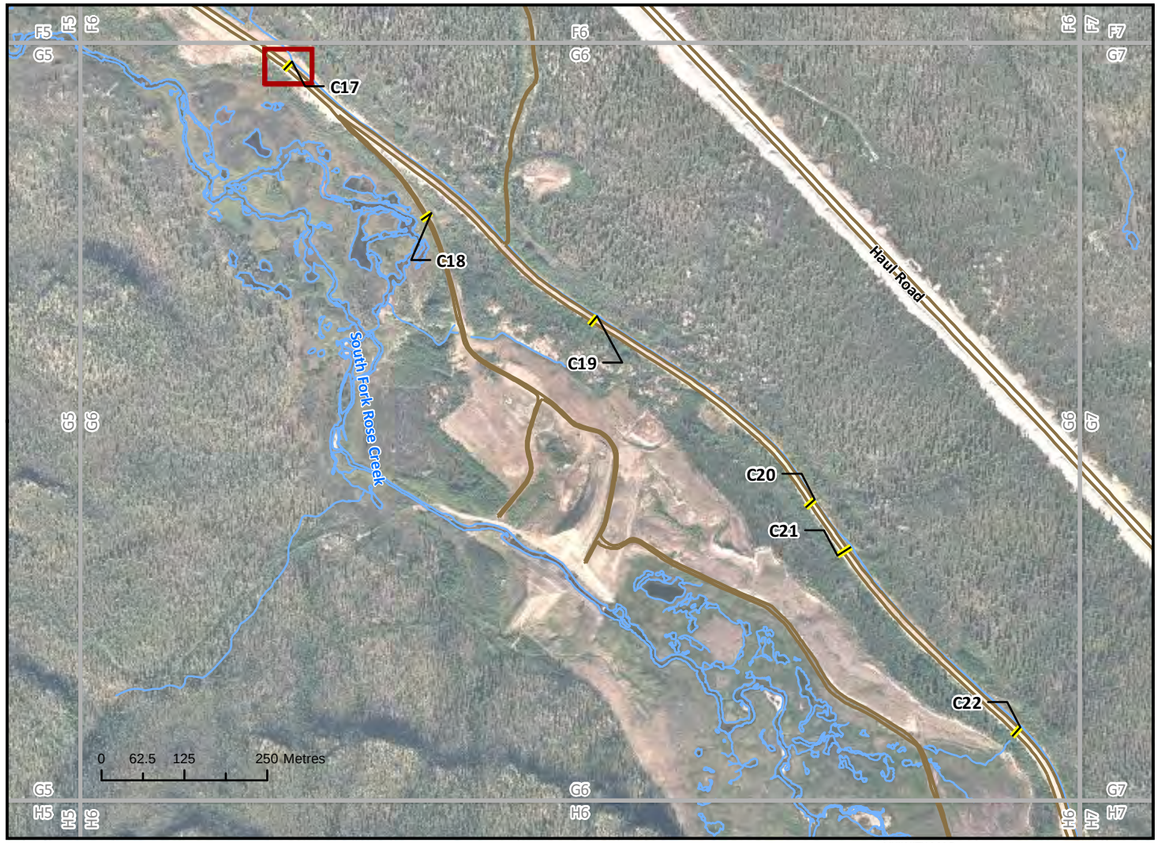
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

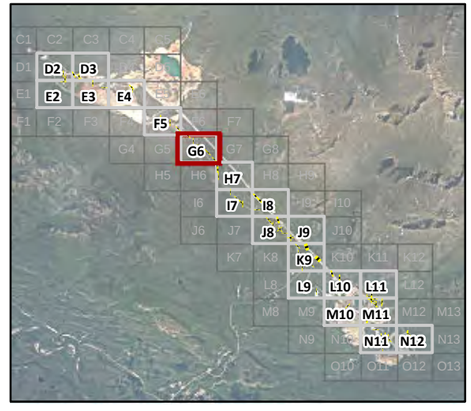
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:16 Culvert: C16 Map Grid: F5
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C17 INLET

UPSTREAM (C17.IU)



DOWNSTREAM (C17.ID)



Northing: 6912033.46
Easting: 585194.14

Invert Elevation: 1079.02
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

CULVERT C17 OUTLET

UPSTREAM (C17.OU)



DOWNSTREAM (C17.OD)



Northing: 6912020.62
Easting: 585182.24

Invert Elevation: 1078.18
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

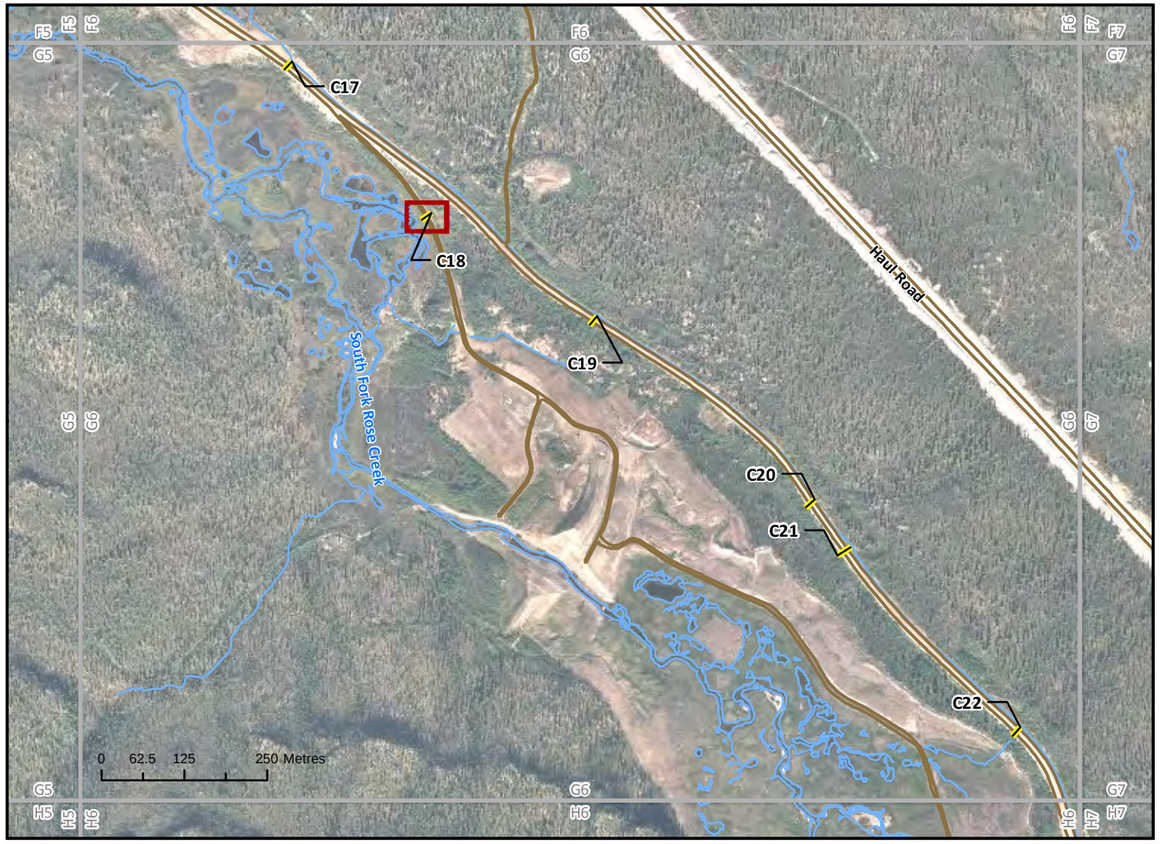
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

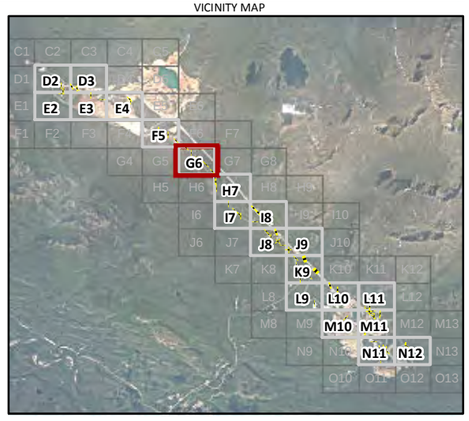
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:17 Culvert: C17 Map Grid: G6
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C18 INLET

UPSTREAM (C18.IU)



DOWNSTREAM (C18.ID)



Northing: 6911804.74
Easting: 585404.60

Invert Elevation: 1074.92
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C18 OUTLET

UPSTREAM (C18.OU)



DOWNSTREAM (C18.OD)



Northing: 6911794.09
Easting: 585389.54

Invert Elevation: 1073.81
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

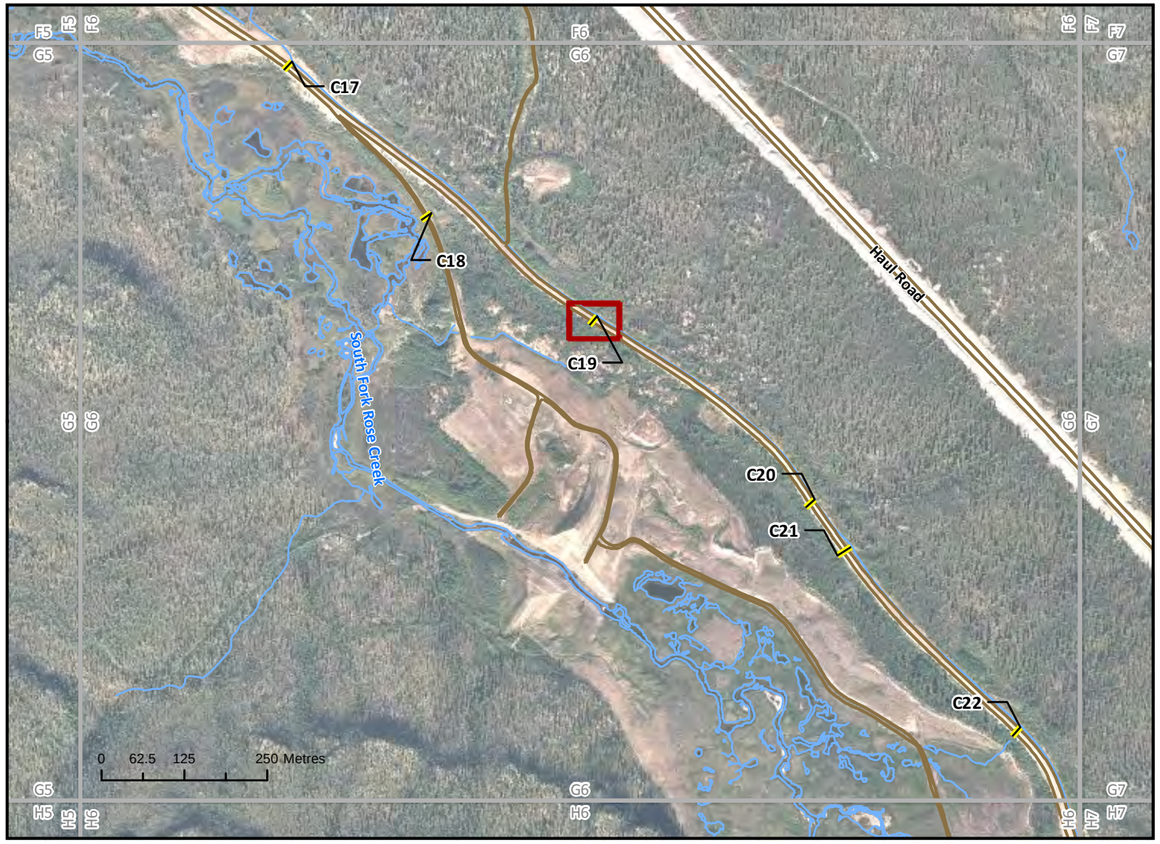
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:18 Culvert: C18 Map Grid: G6
Faro Mine Interim Works

CH2MHILL





VICINITY MAP

CULVERT C19 INLET

UPSTREAM (C19.IU)



DOWNSTREAM (C19.ID)



Northing: 6911649.76
Easting: 585654.59

Invert Elevation: 1108.44
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C19 OUTLET

UPSTREAM (C19.OU)



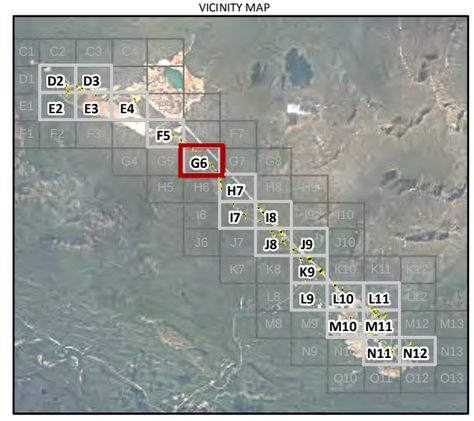
DOWNSTREAM (C19.OD)



Northing: 6911636.28
Easting: 585643.29

Invert Elevation: 1107.67
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

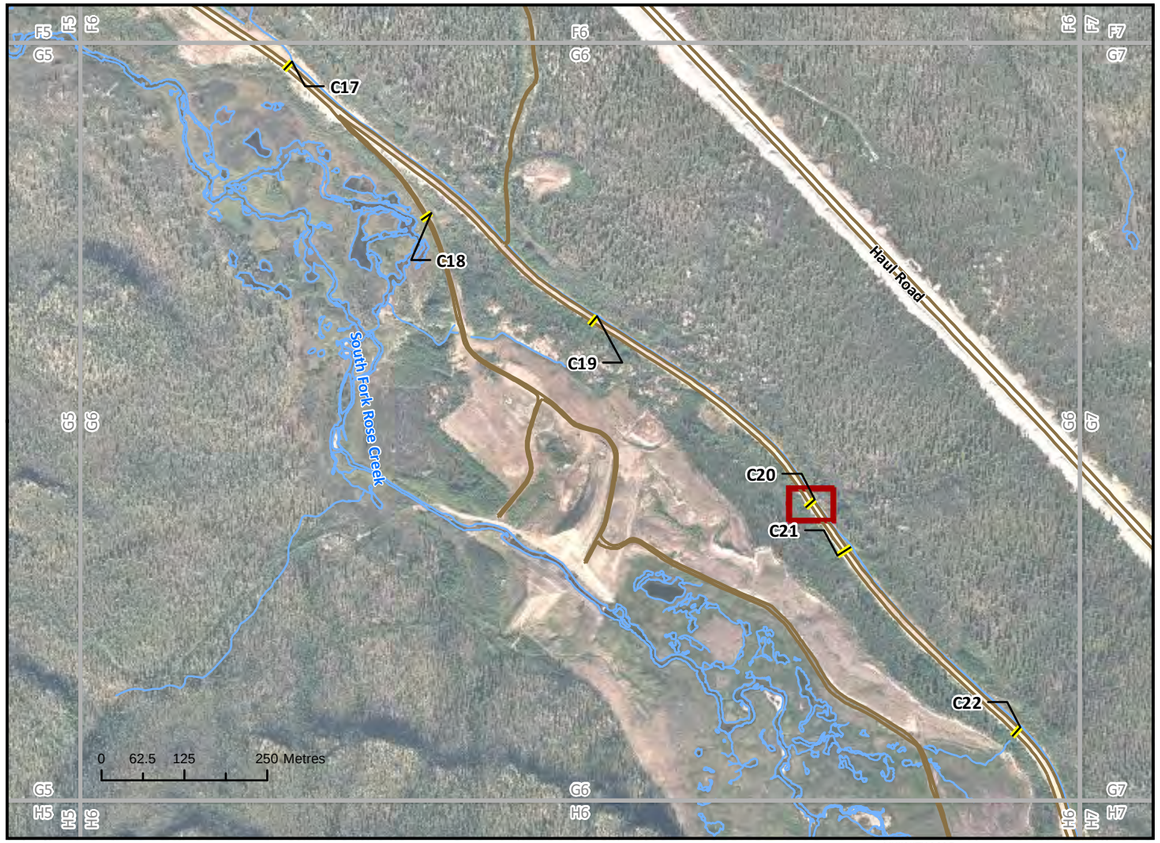
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

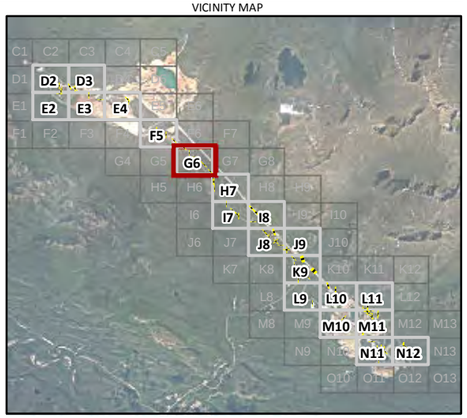
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:19 Culvert: C19 Map Grid: G6
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C20 INLET

UPSTREAM (C20.IU)



DOWNSTREAM (C20.ID)



Northing: 6911373.30
Easting: 585982.72
Invert Elevation: 1112.11
Survey Date: 10/4/2012
Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C20 OUTLET

UPSTREAM (C20.OU)



DOWNSTREAM (C20.OD)



Northing: 6911361.01
Easting: 585969.26
Invert Elevation: 1110.65
Survey Date: 10/4/2012
Diameter (mm): 450
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

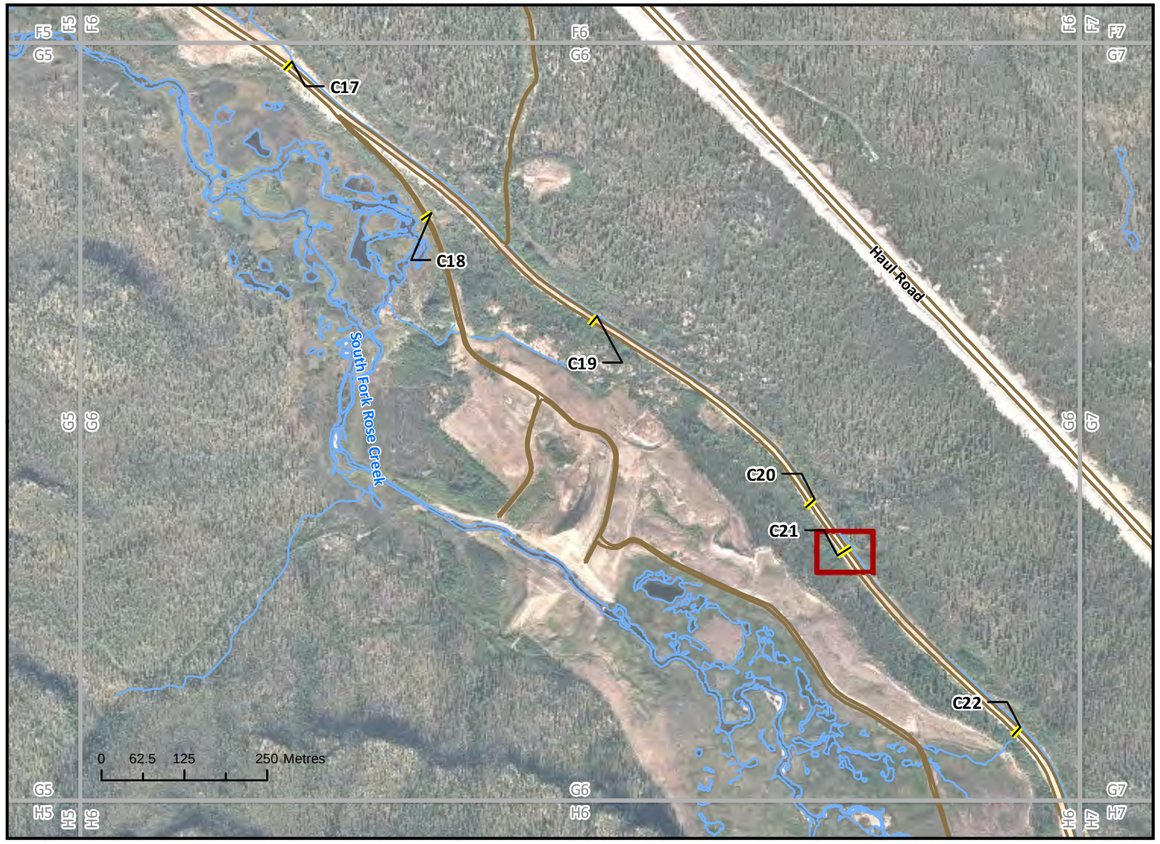
Culvert
Roads Unpaved
Culvert Grid

N

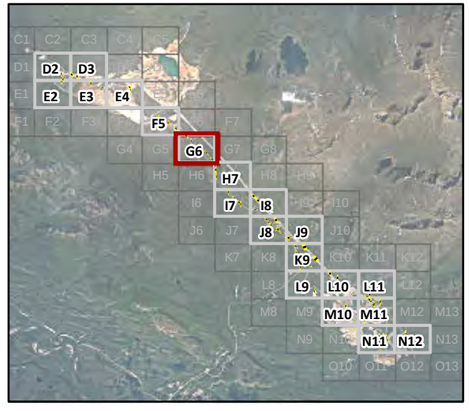
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:20 Culvert: C20 Map Grid: G6
Faro Mine Interim Works





VICINITY MAP



CULVERT C21 INLET

UPSTREAM (C21.IU)



DOWNSTREAM (C21.ID)



Northing: 6911288.53
Easting: 586016.95

Invert Elevation: 1105.75
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C21 OUTLET

UPSTREAM (C21.OU)



DOWNSTREAM (C21.OD)



Northing: 6911301.42
Easting: 586038.15

Invert Elevation: 1107.1
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

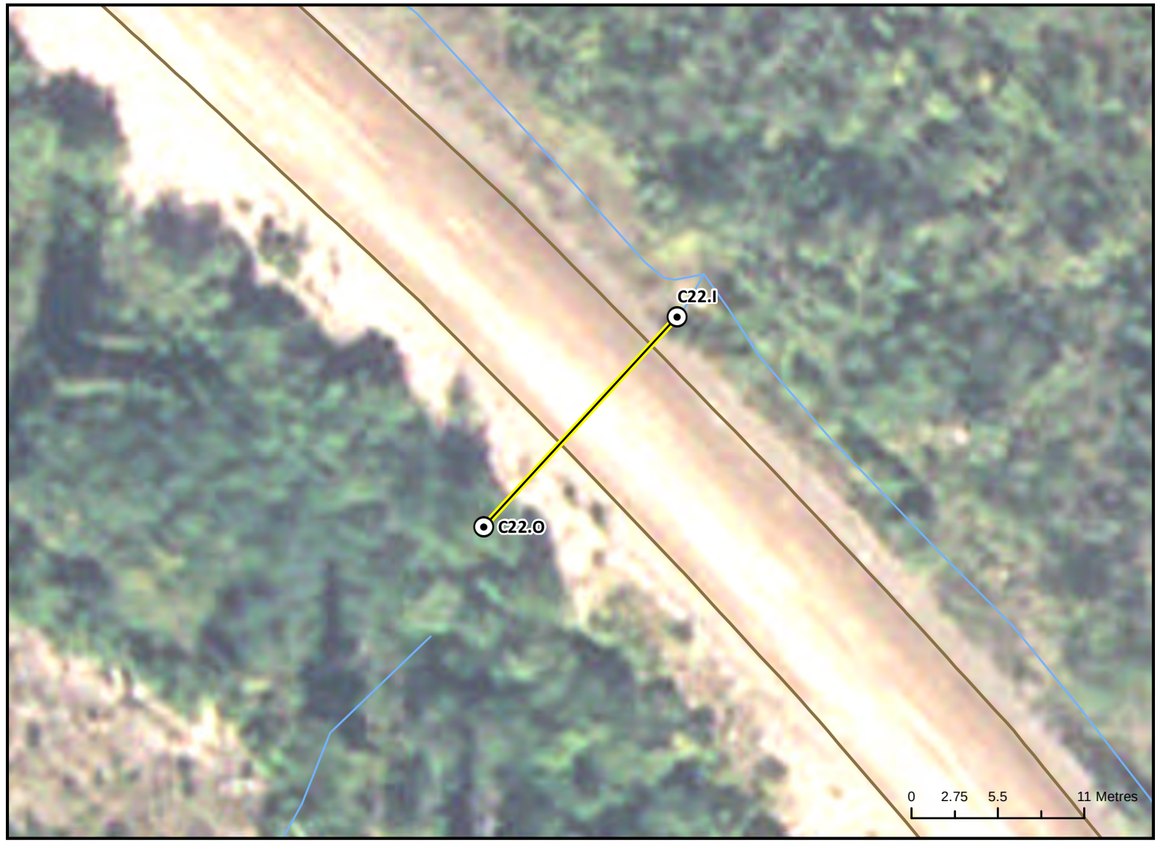
Culvert
Roads Unpaved
Culvert Grid

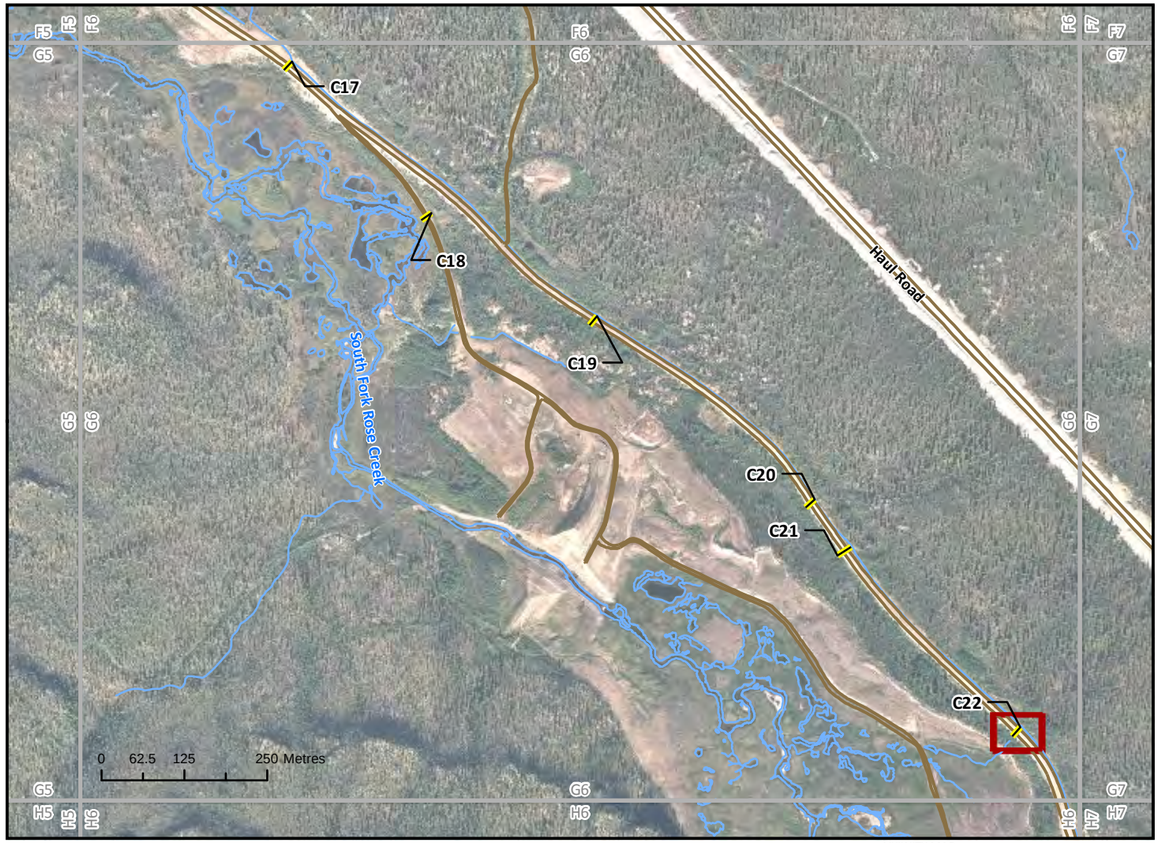
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:21 Culvert: C21 Map Grid: G6
Faro Mine Interim Works

CH2MHILL





VICINITY MAP

CULVERT C22 INLET

UPSTREAM (C22.IU)



DOWNSTREAM (C22.ID)



Northing: 6911029.34
Easting: 586293.06

Invert Elevation: 1107.60
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C22 OUTLET

UPSTREAM (C22.OU)



DOWNSTREAM (C22.OD)



Northing: 6911015.93
Easting: 586280.72

Invert Elevation: 1106.55
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

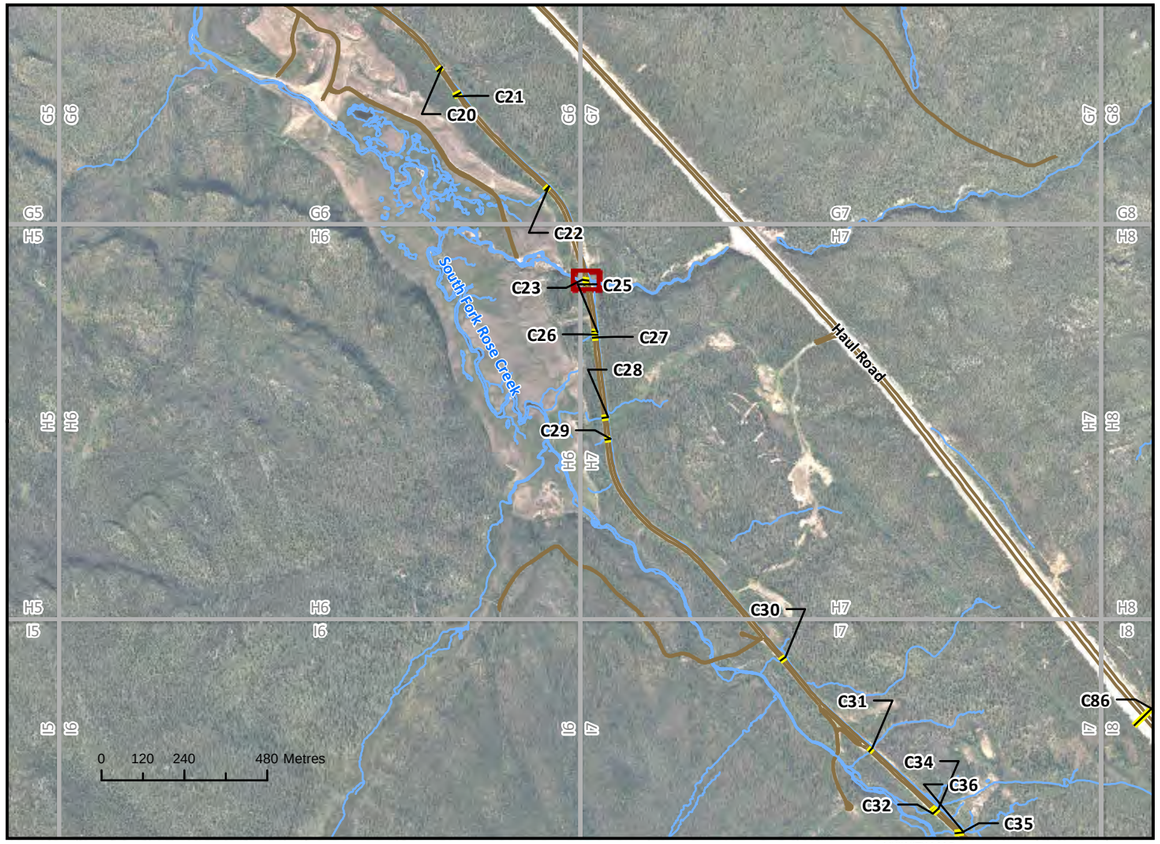
Culvert — Roads Unpaved — Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:22 Culvert: C22 Map Grid: G6
Faro Mine Interim Works





VICINITY MAP

CULVERT C23 INLET

UPSTREAM (C23.IU)



DOWNSTREAM (C23.ID)



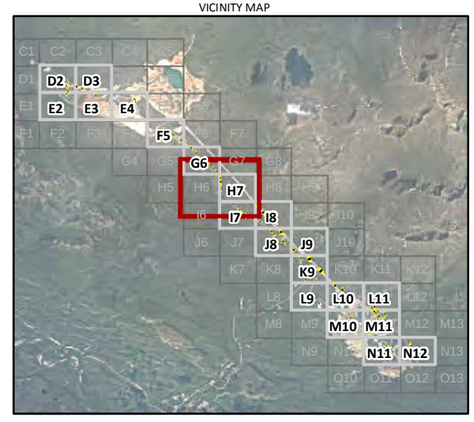
CULVERT C23 OUTLET

UPSTREAM (C23.OU)



DOWNSTREAM (C23.OD)





Northing: 6910758.17 ***Invert Elevation:*** 1104.18 ***Diameter (mm):*** 1200
Easting: 586389.22 ***Survey Date:*** 10/4/2012 ***Material Type:*** CMP: Corrugated

Northing: 6910755.98 ***Invert Elevation:*** 1107.32 ***Diameter (mm):*** 1200
Easting: 586408.09 ***Survey Date:*** 10/4/2012 ***Material Type:*** CMP: Corrugated

Created by: CRITIGEN

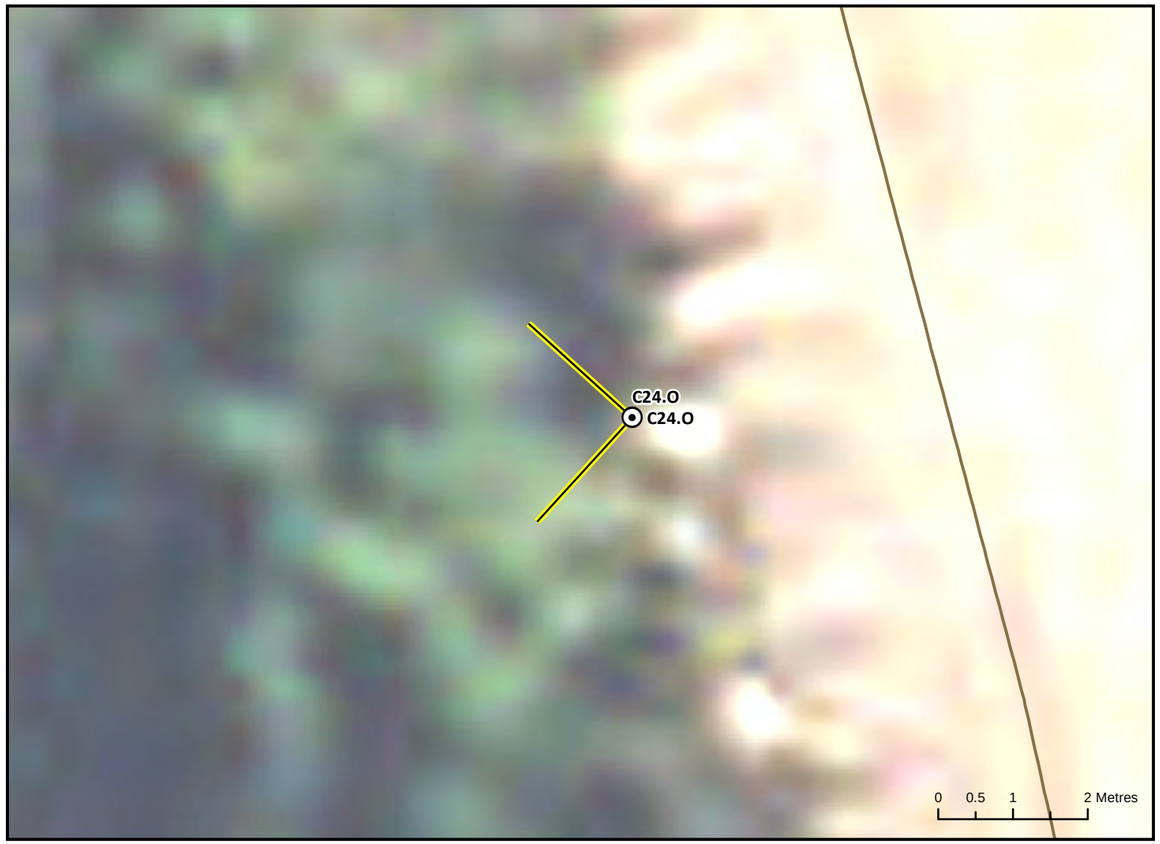
LEGEND

Culvert | Roads Unpaved | Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:23 Culvert: C23 Map Grid: H7
Faro Mine Interim Works





CULVERT C24 INLET

UPSTREAM (N/A)	DOWNSTREAM (N/A)
Photo Not Available	Photo Not Available

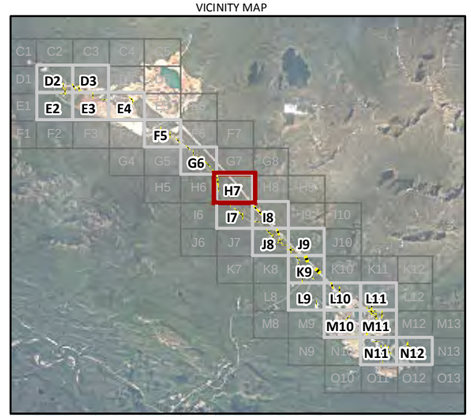
Northing: ***Invert Elevation:*** ***Diameter (mm):*** 0
Easting: ***Survey Date:*** ***Material Type:*** N/A

CULVERT C24 OUTLET

UPSTREAM (C24.OU)	DOWNSTREAM (C24.OD)
	

Northing: 6910741.77 ***Invert Elevation:*** 1106.51 ***Diameter (mm):*** 0
Easting: 586396.25 ***Survey Date:*** 10/4/2012 ***Material Type:*** CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND
Culvert — Roads Unpaved — Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:24 Culvert: C24 Map Grid: H7
Faro Mine Interim Works

CH2MHILL





CULVERT C25 INLET

UPSTREAM (C25.IU)



DOWNSTREAM (C25.ID)



Northing: 6910606.88
Easting: 586434.16

Invert Elevation: 1105.08
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

CULVERT C25 OUTLET

UPSTREAM (C25.OU)



DOWNSTREAM (C25.OD)

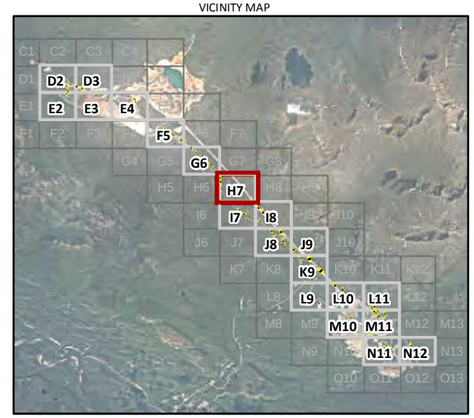


Northing: 6910607.12
Easting: 586416.56

Invert Elevation: 1104.61
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:25 Culvert: C25 Map Grid: H7
Faro Mine Interim Works





VICINITY MAP

CULVERT C26 INLET

UPSTREAM (C26.IU)



DOWNSTREAM (C26.ID)



Northing: 6910599.00
Easting: 586434.10

Invert Elevation: 1105.87
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C26 OUTLET

UPSTREAM (C26.OU)



DOWNSTREAM (C26.OD)



Northing: 6910596.48
Easting: 586416.84

Invert Elevation: 1105.58
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

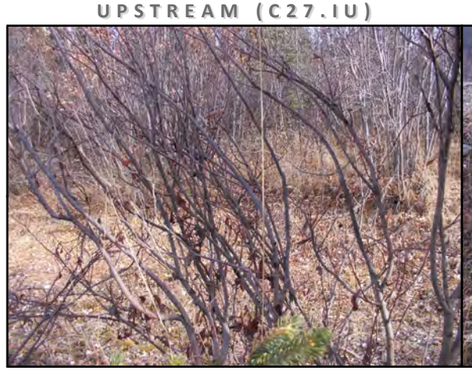
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:26 Culvert: C26 Map Grid: H7
Faro Mine Interim Works





CULVERT C27 INLET

UPSTREAM (C27.IU)



DOWNSTREAM (C27.ID)



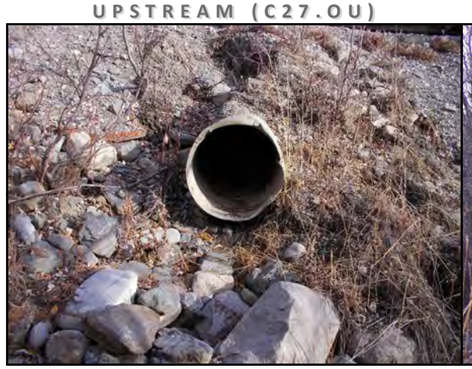
Northing: 6910591.89
Easting: 586435.13

Invert Elevation: 1106.18
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C27 OUTLET

UPSTREAM (C27.OU)



DOWNSTREAM (C27.OD)

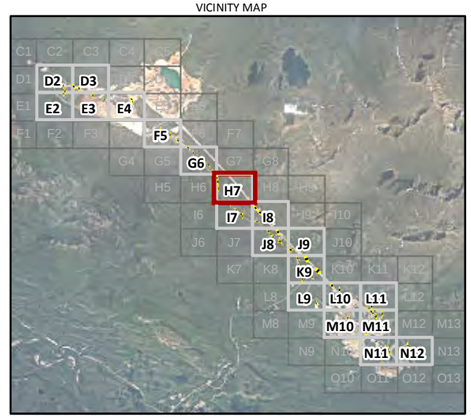


Northing: 6910590.60
Easting: 586417.93

Invert Elevation: 1105.01
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

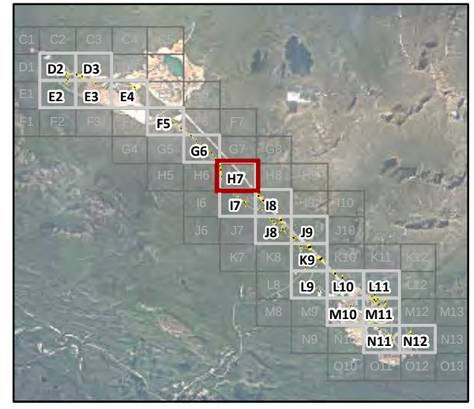
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:27 Culvert: C27 Map Grid: H7
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C28 INLET

UPSTREAM (C28.IU)



DOWNSTREAM (C28.ID)



Northing: 6910360.76
Easting: 586463.60

Invert Elevation: 1107.60
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

CULVERT C28 OUTLET

UPSTREAM (C28.OU)



DOWNSTREAM (C28.OD)



Northing: 6910357.20
Easting: 586445.61

Invert Elevation: 1106.3
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:28 Culvert: C28 Map Grid: H7
Faro Mine Interim Works

CH2MHILL





CULVERT C29 INLET

UPSTREAM (C29.IU)



DOWNSTREAM (C29.ID)



CULVERT C29 OUTLET

UPSTREAM (C29.OU)



DOWNSTREAM (C29.OD)



Northing: 6910297.24
Easting: 586471.77

Invert Elevation: 1107.44
Survey Date: 10/4/2012

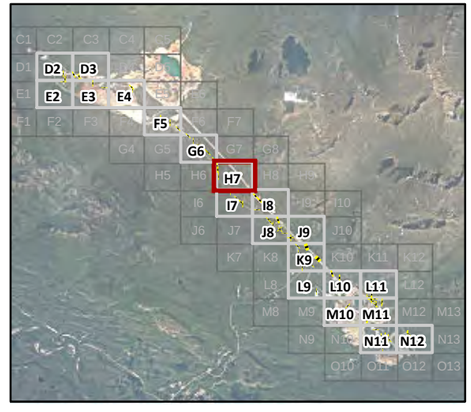
Diameter (mm): 550
Material Type: CMP: Corrugated

Northing: 6910295.01
Easting: 586454.19

Invert Elevation: 1106.86
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

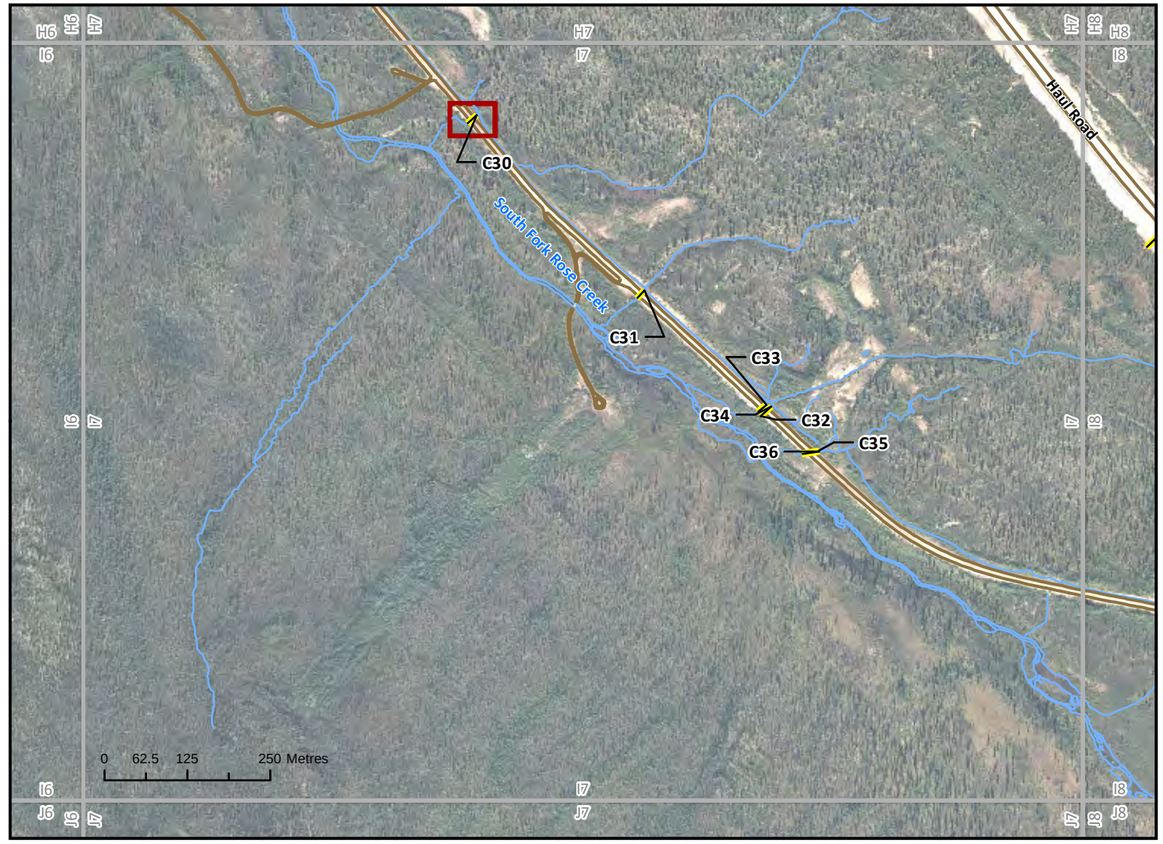
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:29 Culvert: C29 Map Grid: H7
Faro Mine Interim Works

CH2MHILL





CULVERT C30 INLET

UPSTREAM (C30.IU)



DOWNSTREAM (C30.ID)



Northing: 6909666.67
Easting: 586977.05

Invert Elevation: 1139.61
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

CULVERT C30 OUTLET

UPSTREAM (C30.OU)



DOWNSTREAM (C30.OD)

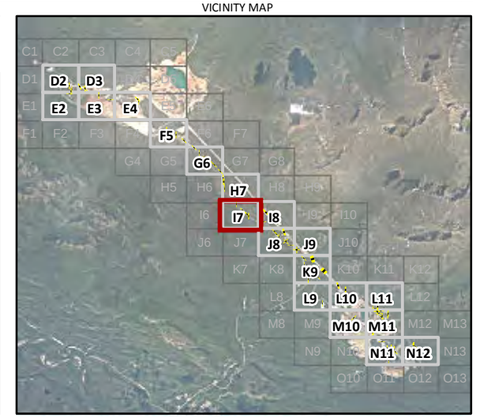


Northing: 6909654.29
Easting: 586962.03

Invert Elevation: 1138.47
Survey Date: 10/4/2012

Diameter (mm): 550
Material Type: CMP: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

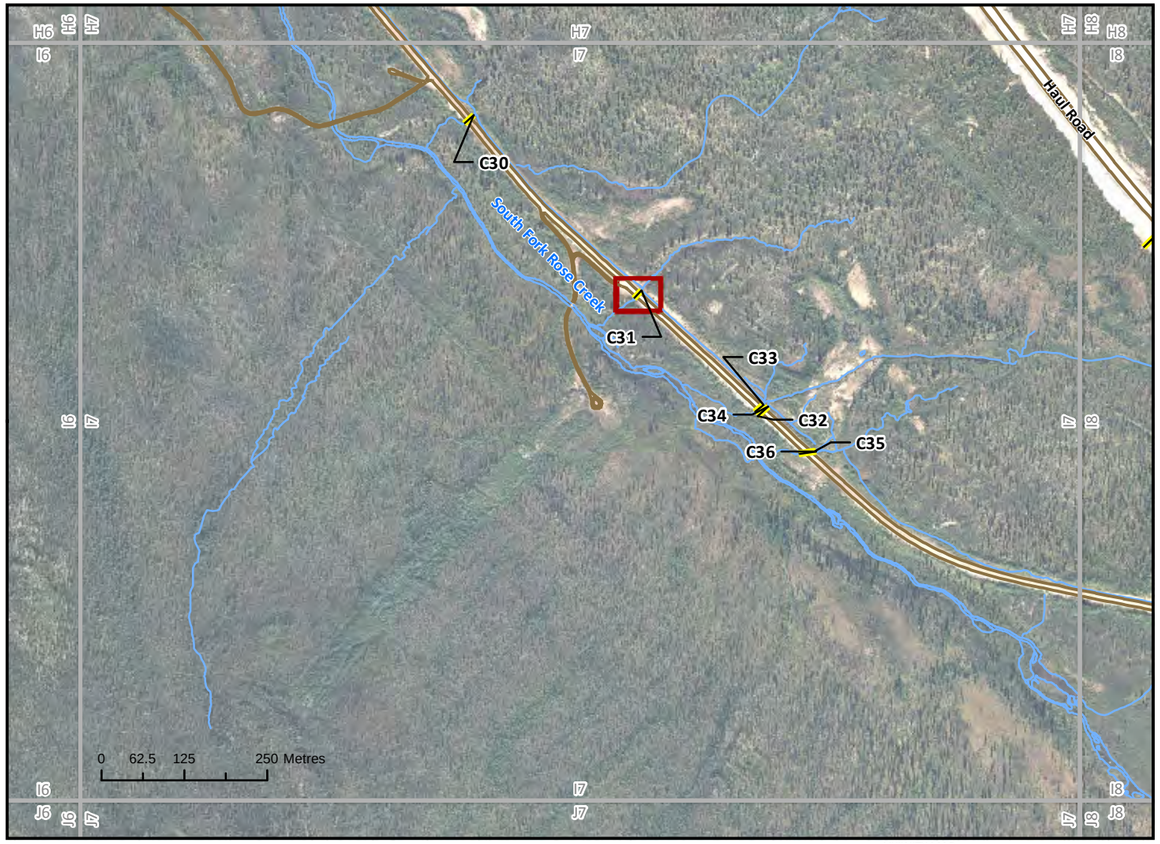
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:30 Culvert: C30 Map Grid: I7
Faro Mine Interim Works

CH2MHILL





CULVERT C31 INLET

UPSTREAM (C31.IU)



DOWNSTREAM (C31.ID)



Northing: 6909402.49
Easting: 587229.49

Invert Elevation: 1148.22
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C31 OUTLET

UPSTREAM (C31.OU)



DOWNSTREAM (C31.OD)

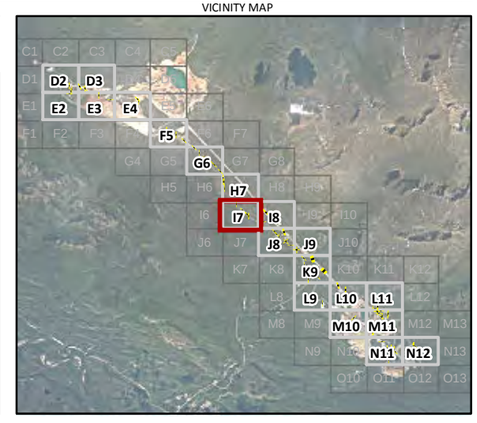


Northing: 6909390.40
Easting: 587218.62

Invert Elevation: 1147.51
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

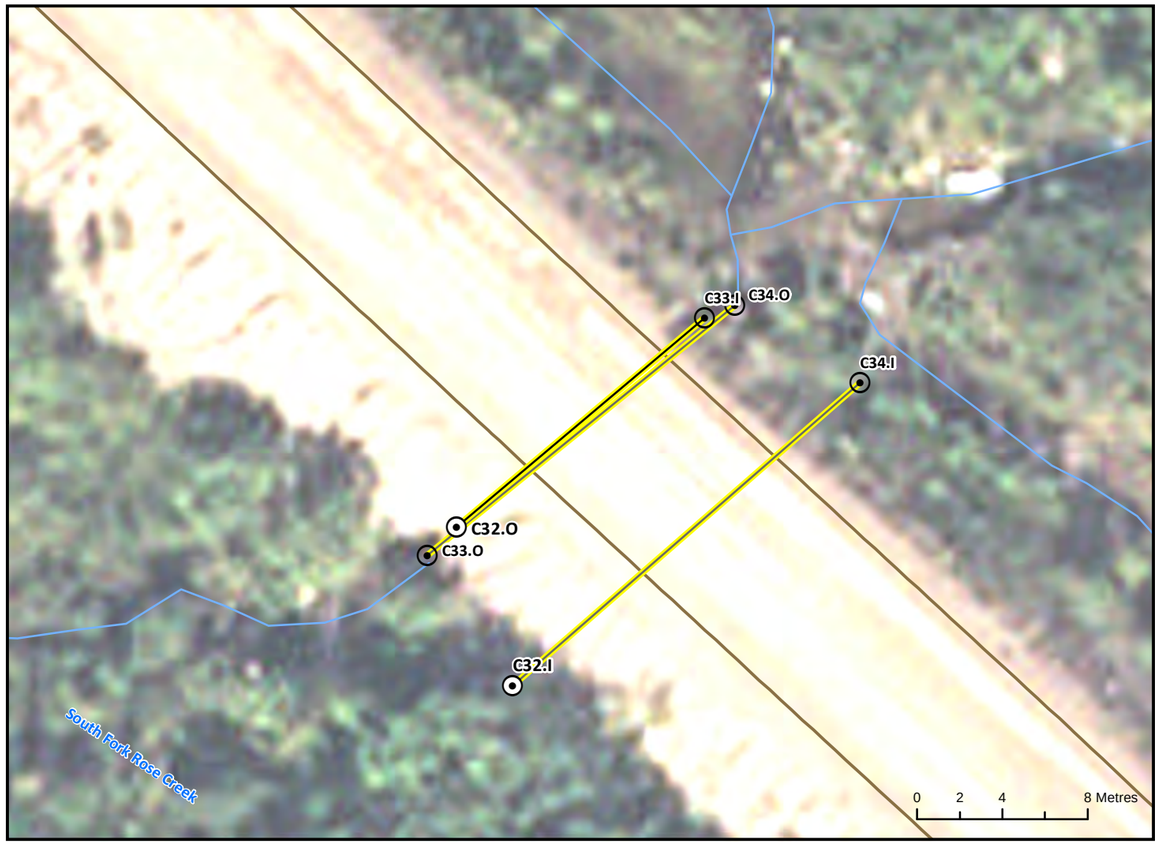
LEGEND

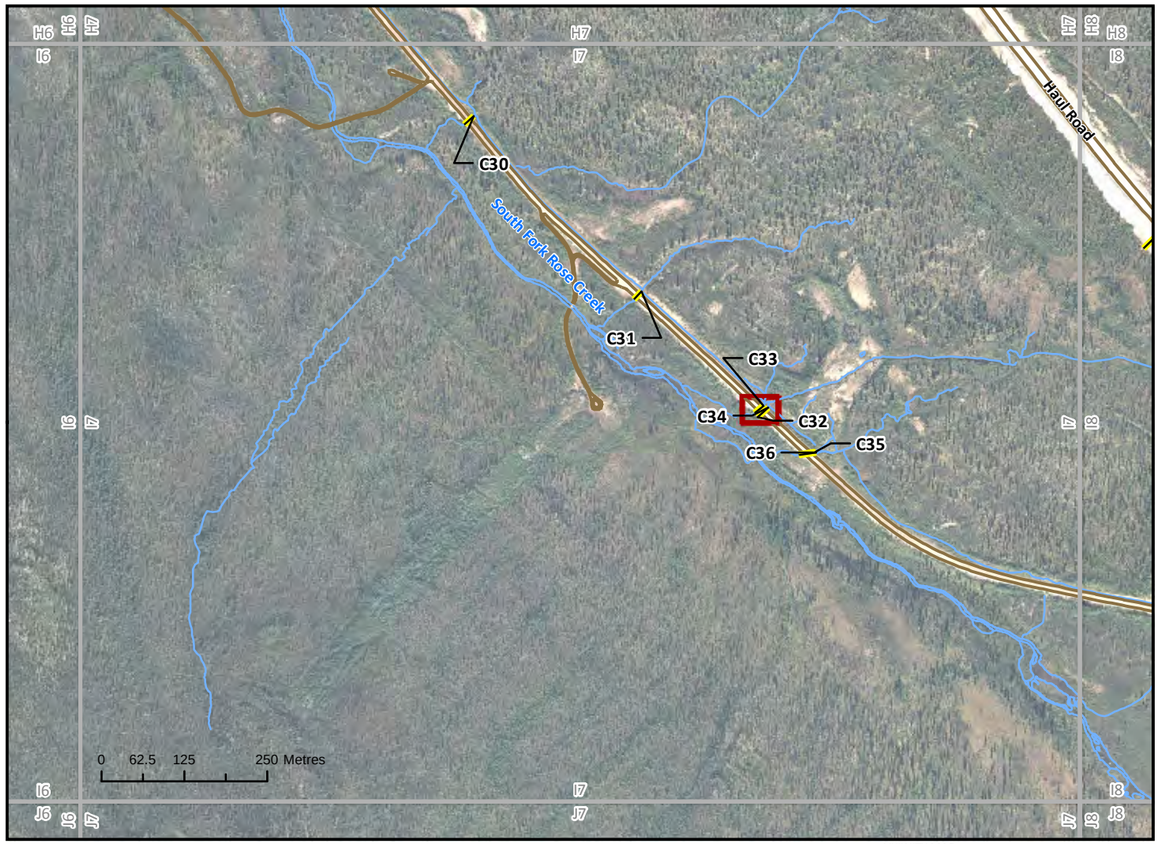
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:31 Culvert: C31 Map Grid: I7
Faro Mine Interim Works





CULVERT C32 INLET

UPSTREAM (C32.IU)



DOWNSTREAM (C32.ID)



Northing: 6909212.72
Easting: 587404.62

Invert Elevation: 1146.30
Survey Date: 10/4/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C32 OUTLET

UPSTREAM (C32.OU)



DOWNSTREAM (C32.OD)

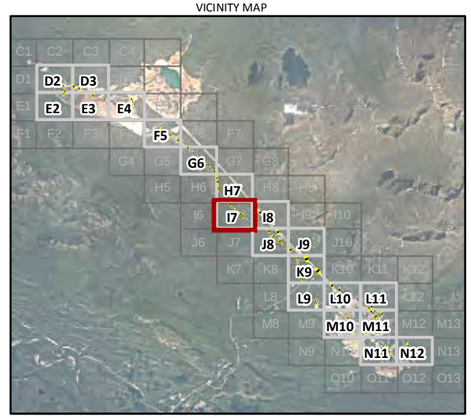


Northing: 6909220.16
Easting: 587401.99

Invert Elevation: 1148.43
Survey Date: 10/4/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

VICINITY MAP



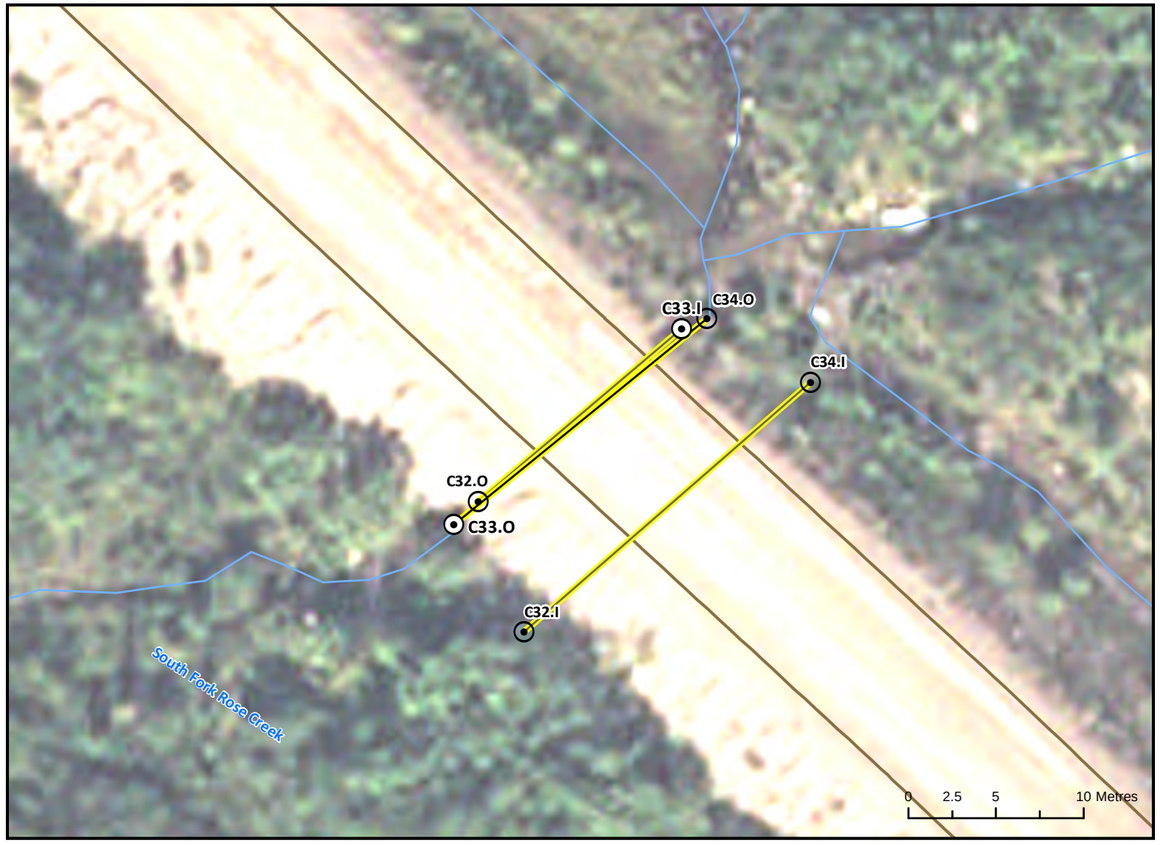
Created by:
CRITIGEN

LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:32 Culvert: C32 Map Grid: I7
Faro Mine Interim Works





CULVERT C33 INLET

UPSTREAM (C33.IU)



DOWNSTREAM (C33.ID)



Northing: 6909229.99
Easting: 587413.62

Invert Elevation: 1148.63
Survey Date: 10/4/2012

Diameter (mm): 1050
Material Type: CMP: Smooth

CULVERT C33 OUTLET

UPSTREAM (C33.OU)



DOWNSTREAM (C33.OD)

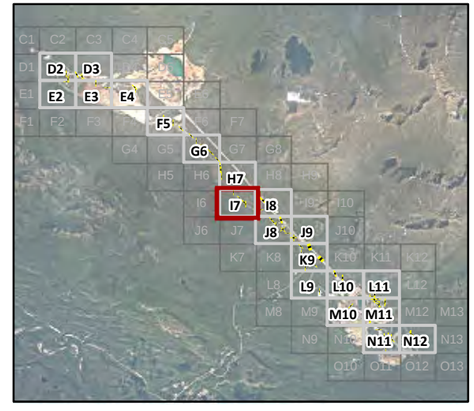


Northing: 6909218.83
Easting: 587400.62

Invert Elevation: 1146.36
Survey Date: 10/4/2012

Diameter (mm): 1050
Material Type: CMP: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

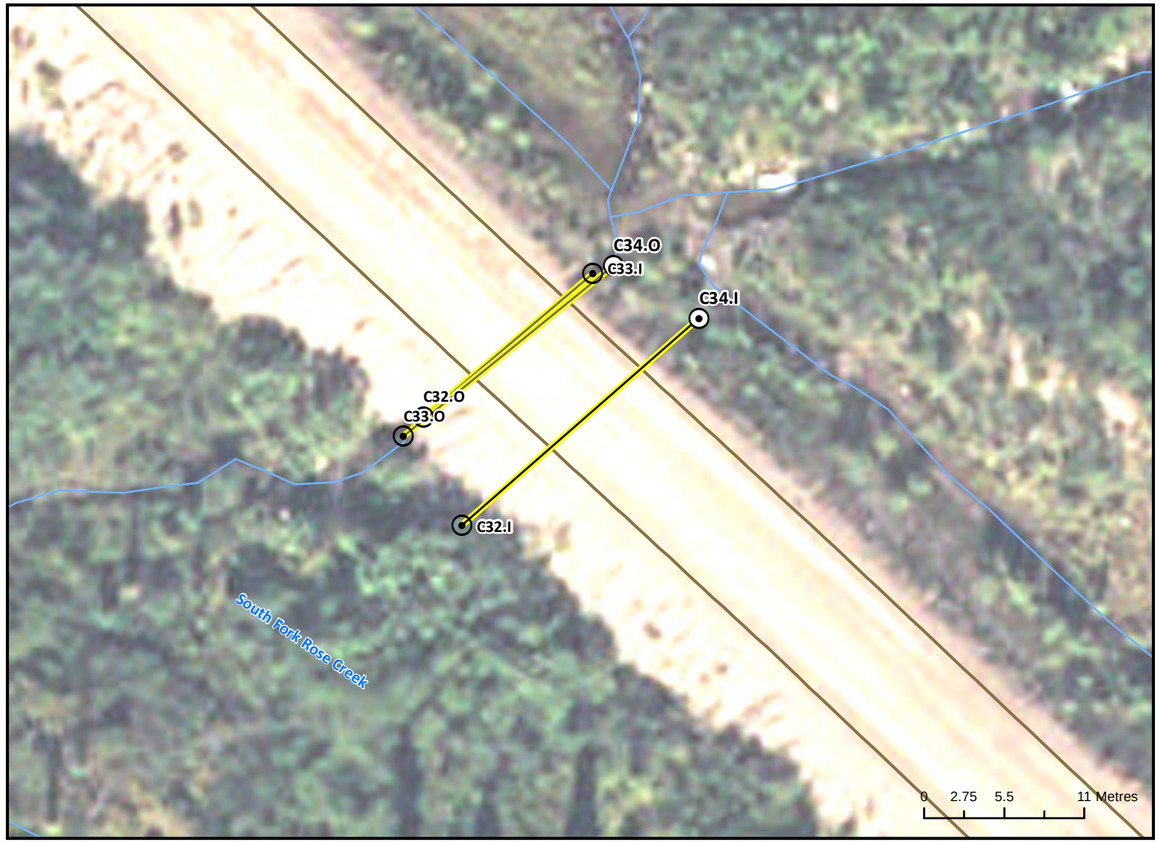
Culvert
Roads Unpaved
Culvert Grid

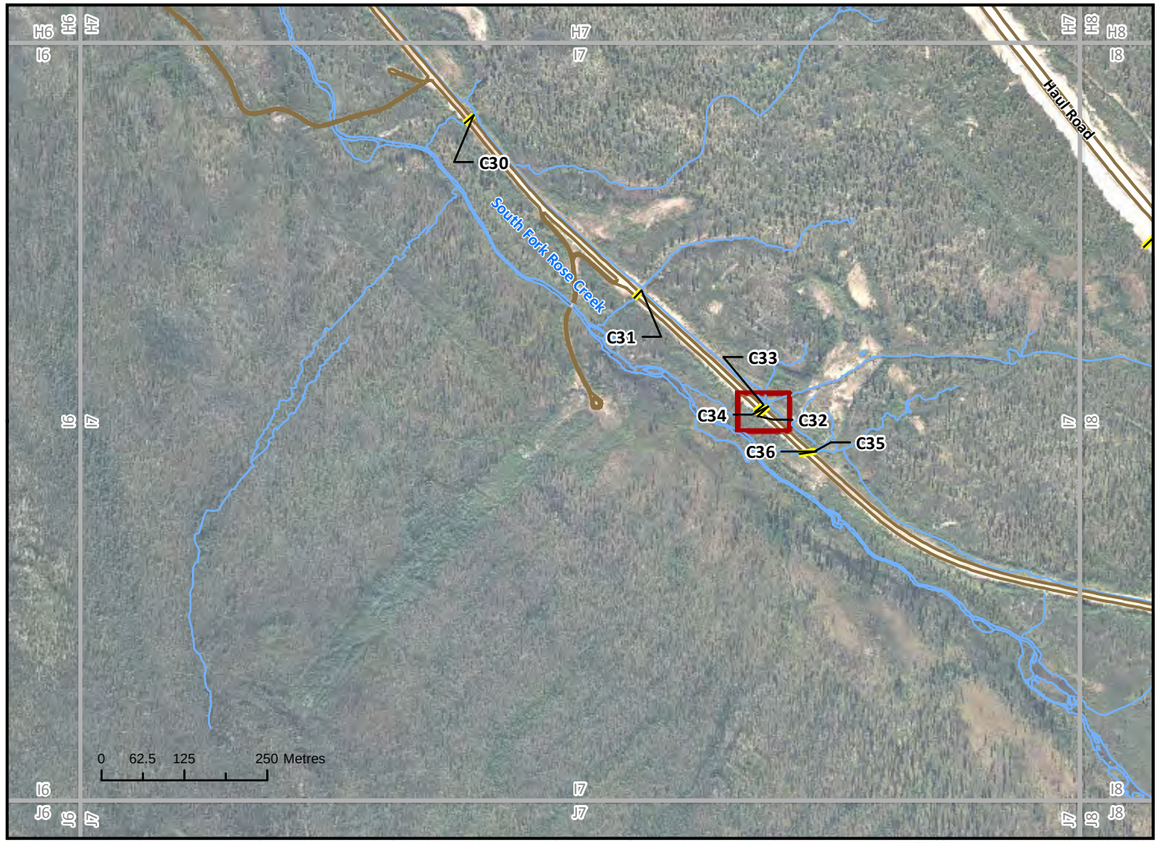
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:33 Culvert: C33 Map Grid: I7
Faro Mine Interim Works

CH2MHILL





CULVERT C34 INLET

UPSTREAM (C34.IU)



DOWNSTREAM (C34.ID)



Northing: 6909226.95
Easting: 587420.94

Invert Elevation: 1146.47
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C34 OUTLET

UPSTREAM (C34.OU)



DOWNSTREAM (C34.OD)

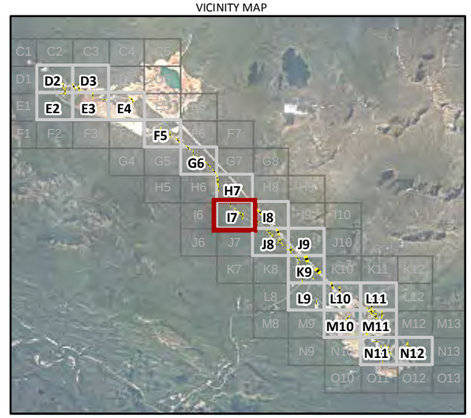


Northing: 6909230.57
Easting: 587415.06

Invert Elevation: 1147.91
Survey Date: 10/4/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

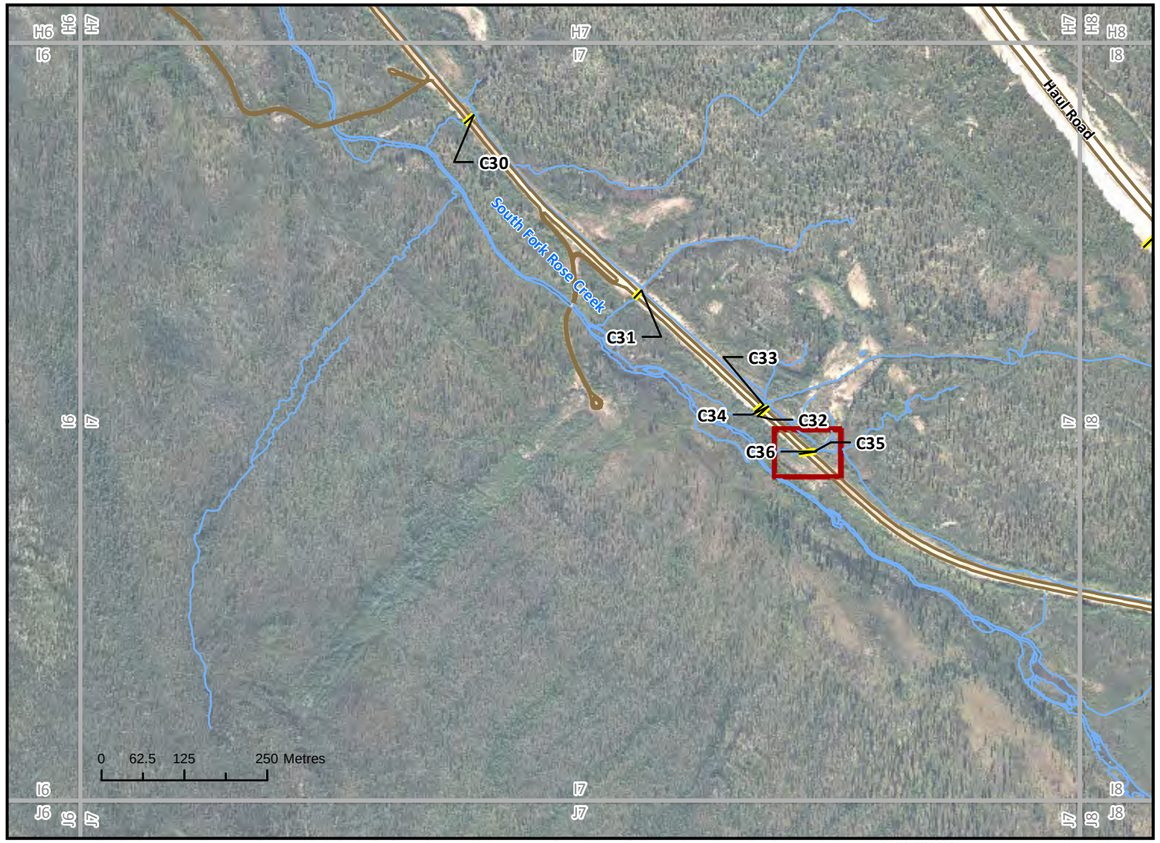
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:34 Culvert: C34 Map Grid: I7
Faro Mine Interim Works





CULVERT C35 INLET

UPSTREAM (C35.IU)



DOWNSTREAM (C35.ID)



Northing: 6909159.88
Easting: 587491.68

Invert Elevation: 1152.46
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C35 OUTLET

UPSTREAM (C35.OU)



DOWNSTREAM (C35.OD)

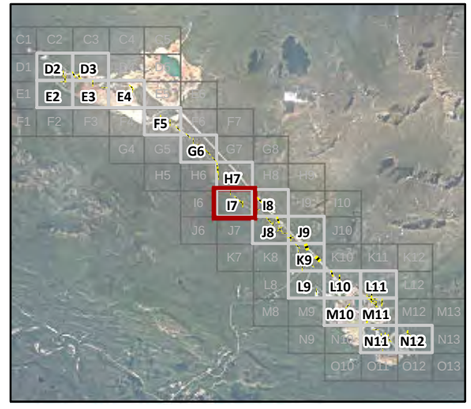


Northing: 6909156.78
Easting: 587466.90

Invert Elevation: 1151.56
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

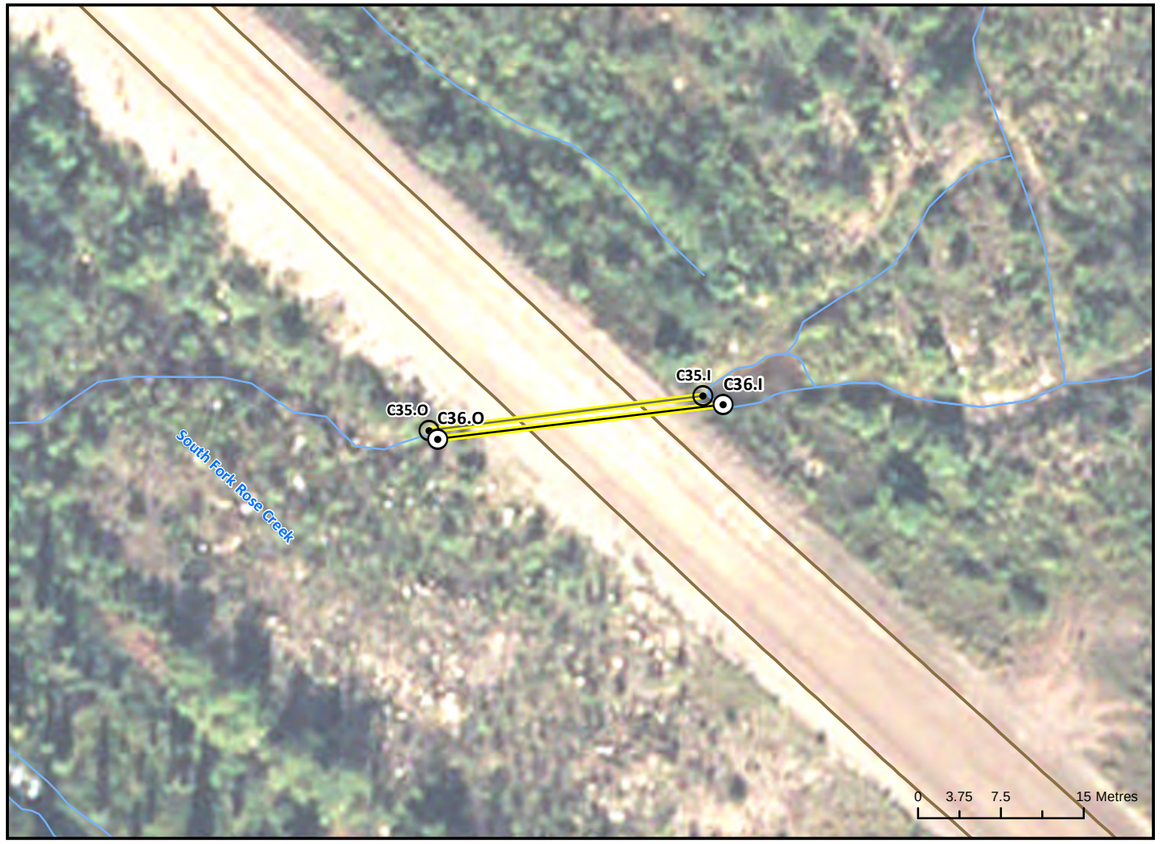
Culvert
Roads Unpaved
Culvert Grid

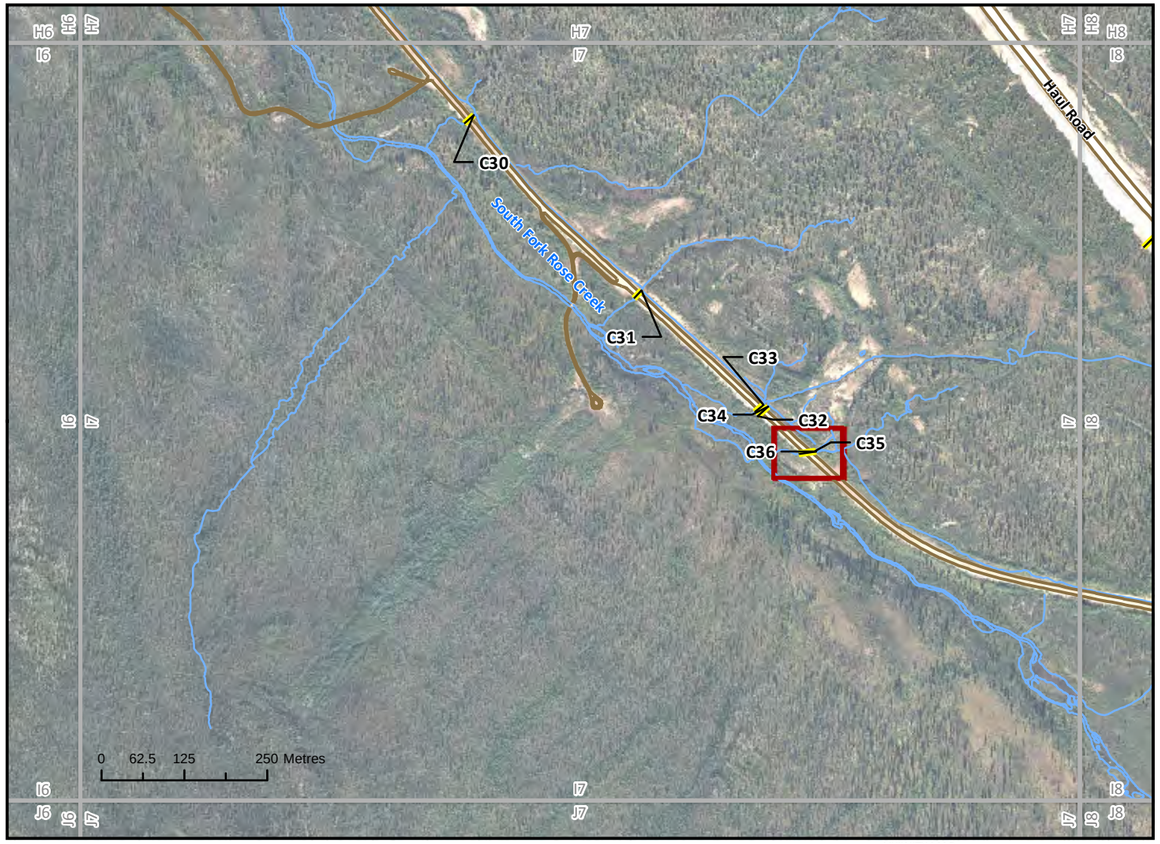
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:35 Culvert: C35 Map Grid: I7
Faro Mine Interim Works

CH2MHILL





CULVERT C36 INLET

UPSTREAM (C36.IU)



DOWNSTREAM (C36.ID)



Northing: 6909159.08
Easting: 587493.54

Invert Elevation: 1151.98
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C36 OUTLET

UPSTREAM (C36.OU)



DOWNSTREAM (C36.OD)

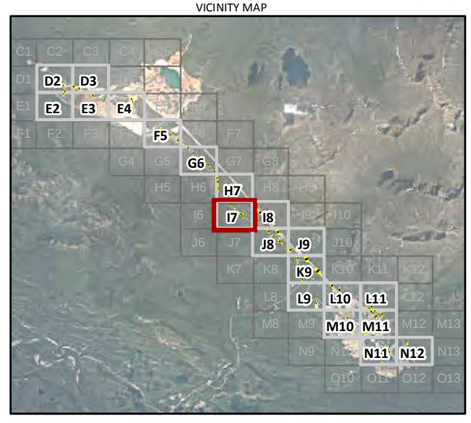


Northing: 6909156.00
Easting: 587467.66

Invert Elevation: 1151.54
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

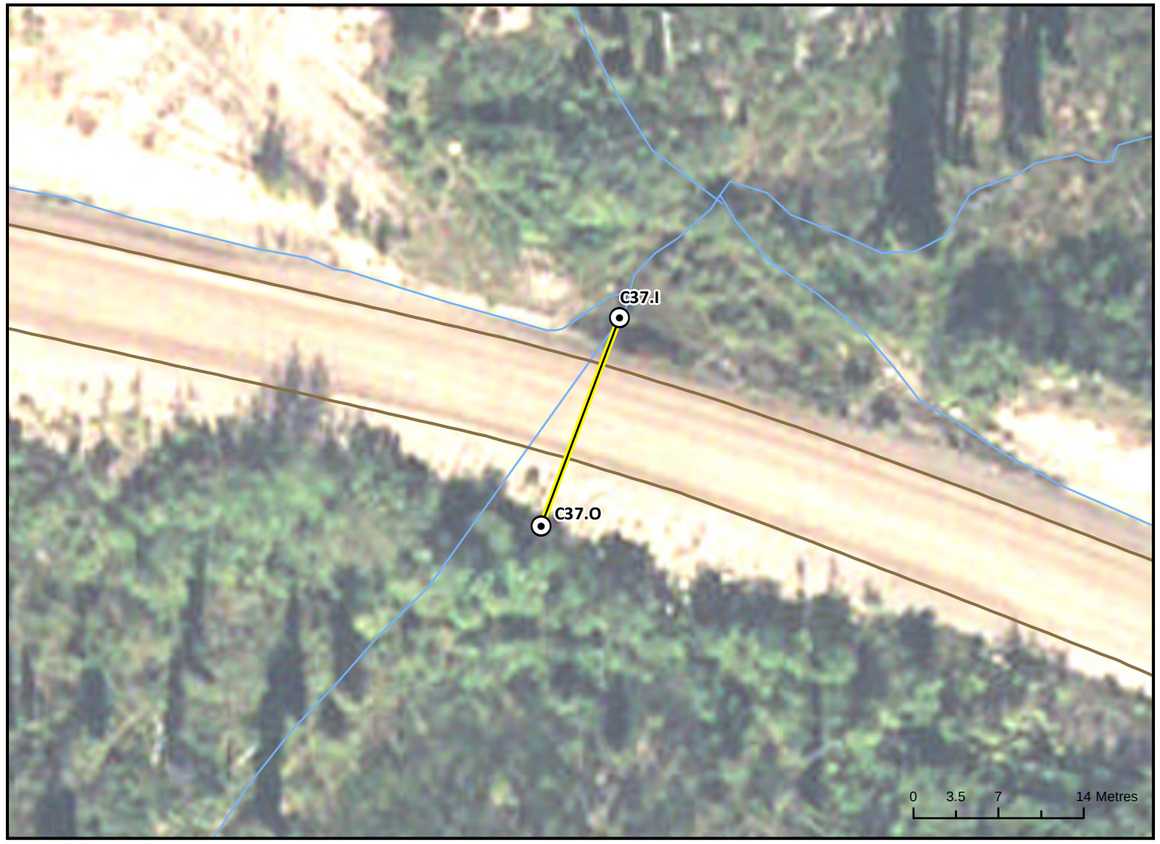
Culvert
Roads Unpaved
Culvert Grid

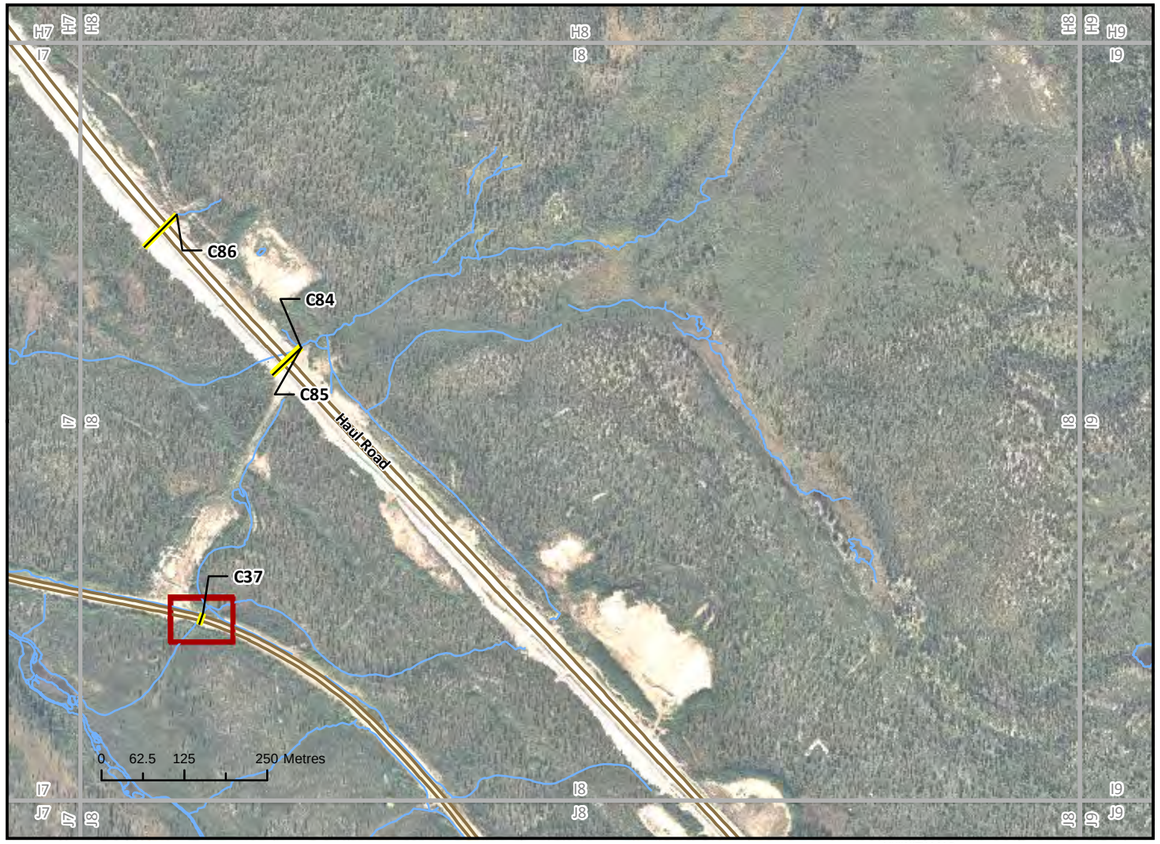
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:36 Culvert: C36 Map Grid: I7
Faro Mine Interim Works

CH2MHILL





CULVERT C37 INLET

UPSTREAM (C37.IU)



DOWNSTREAM (C37.ID)



Northing: 6908915.44
Easting: 588076.66

Invert Elevation: 1185.13
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C37 OUTLET

UPSTREAM (C37.OU)



DOWNSTREAM (C37.OD)

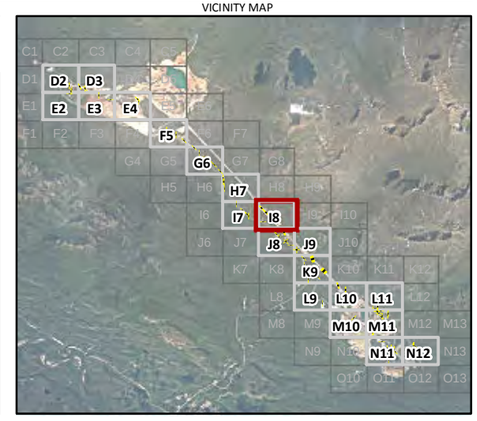


Northing: 6908898.36
Easting: 588070.19

Invert Elevation: 1184.83
Survey Date: 10/4/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

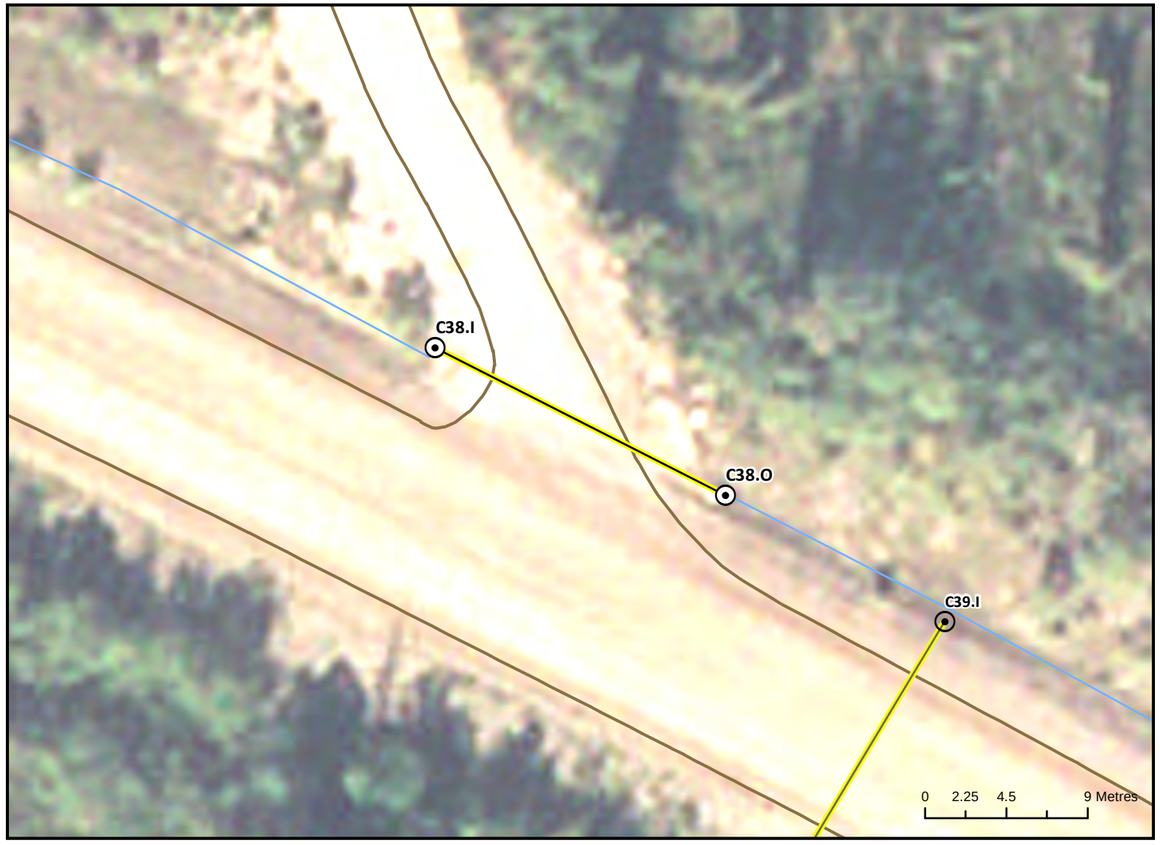
Culvert
Roads Unpaved
Culvert Grid

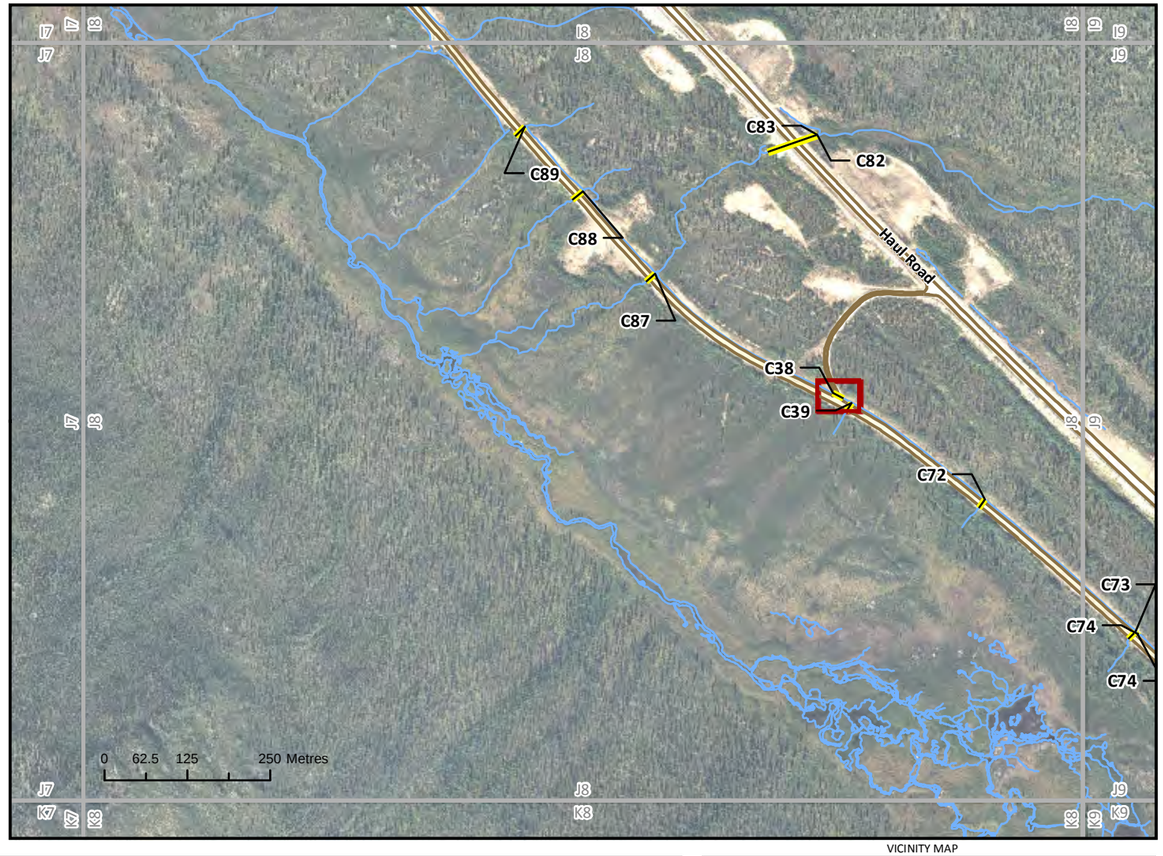
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:37 Culvert: C37 Map Grid: I8
Faro Mine Interim Works

CH2MHILL





CULVERT C38 INLET

UPSTREAM (C38.IU)



DOWNSTREAM (C38.ID)



Northing: 6908104.84
Easting: 589021.80

Invert Elevation: 1203.92
Survey Date: 10/5/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C38 OUTLET

UPSTREAM (C38.OU)



DOWNSTREAM (C38.OD)

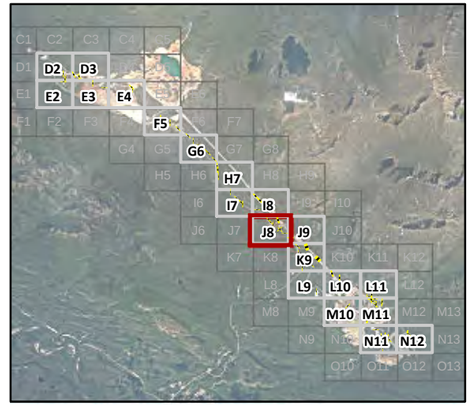


Northing: 6908096.67
Easting: 589037.85

Invert Elevation: 1204.44
Survey Date: 10/5/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

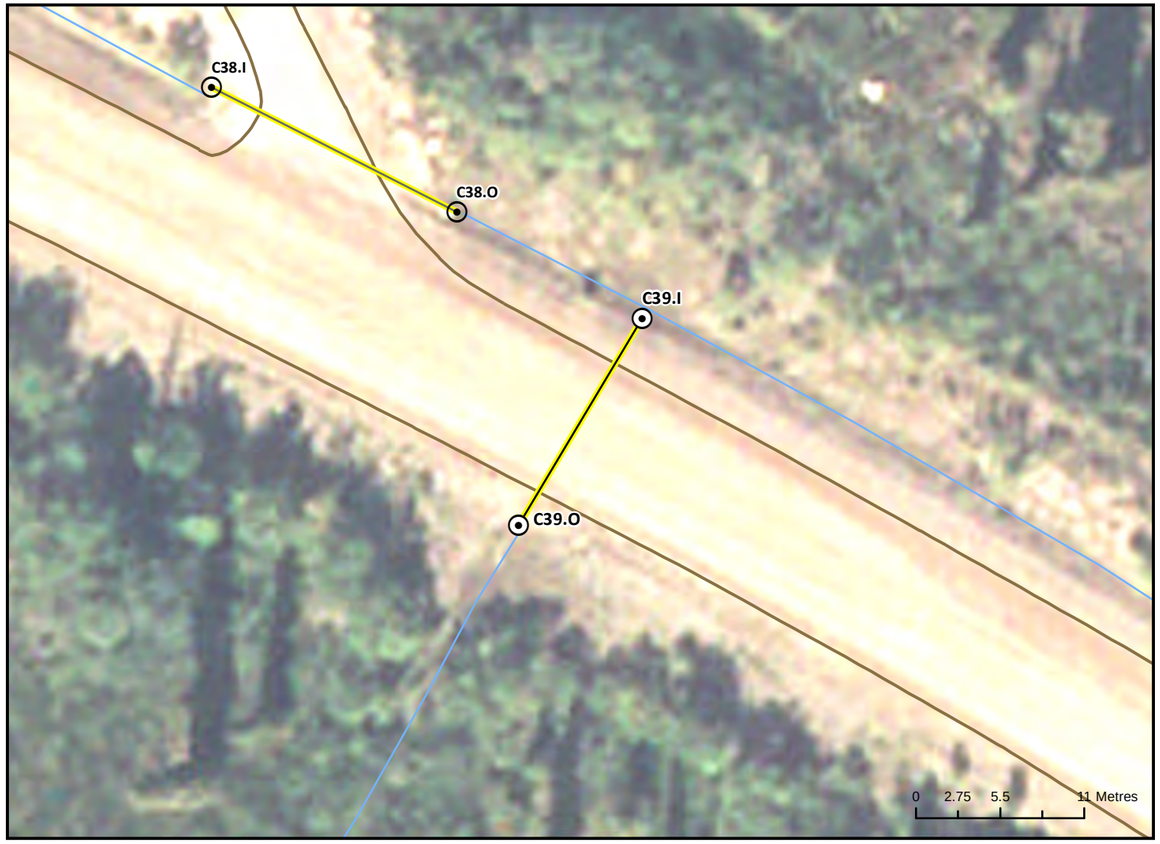
LEGEND

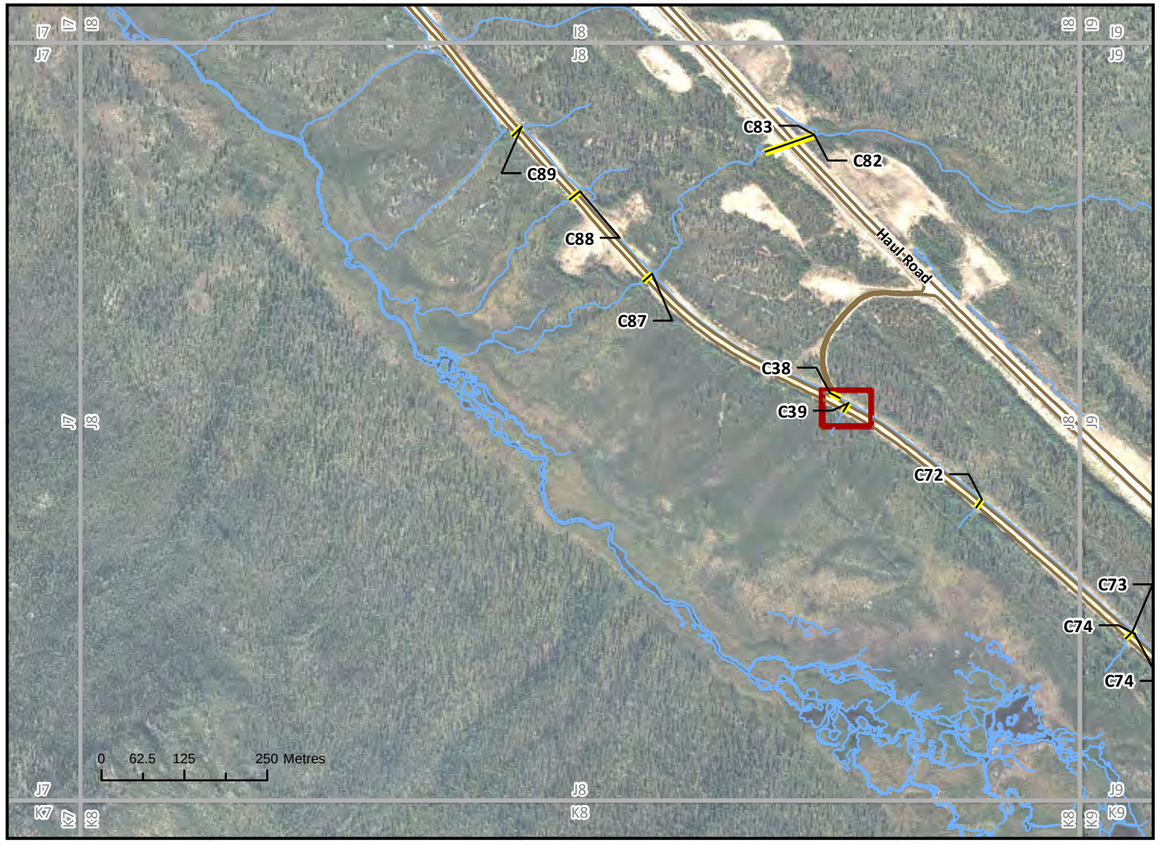
Culvert
Roads Unpaved
Culvert Grid

N

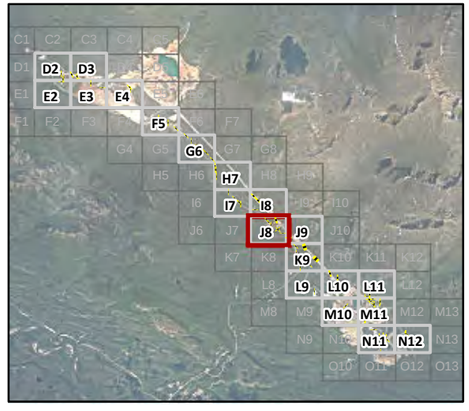
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:38 Culvert: C38 Map Grid: J8
Faro Mine Interim Works





VICINITY MAP



CULVERT C39 INLET

UPSTREAM (C39.IU)



DOWNSTREAM (C39.ID)



Northing: 6908089.73 ***Easting:*** 589049.98 ***Invert Elevation:*** 1204.07 ***Survey Date:*** 10/5/2012 ***Diameter (mm):*** 300 ***Material Type:*** CMP: Corrugated

CULVERT C39 OUTLET

UPSTREAM (C39.OU)



DOWNSTREAM (C39.OD)



Northing: 6908076.22 ***Easting:*** 589041.89 ***Invert Elevation:*** 1203.33 ***Survey Date:*** 10/5/2012 ***Diameter (mm):*** 300 ***Material Type:*** CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert

Roads Unpaved

Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:39 Culvert: C39 Map Grid: J8
Faro Mine Interim Works

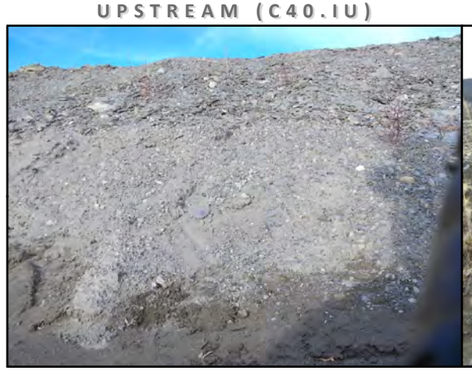




VICINITY MAP

CULVERT C40 INLET

UPSTREAM (C40.IU)



DOWNSTREAM (C40.ID)



Northing: 6914513.92
Easting: 580610.21

Invert Elevation: 1047.35
Survey Date: 10/5/2012

Diameter (mm): 600
Material Type: RCP: Smooth

CULVERT C40 OUTLET

UPSTREAM (C40.OU)



DOWNSTREAM (C40.OD)



Northing: 6914498.45
Easting: 580608.94

Invert Elevation: 1045.96
Survey Date: 10/5/2012

Diameter (mm): 600
Material Type: RCP: Smooth

Created by: CRITIGEN

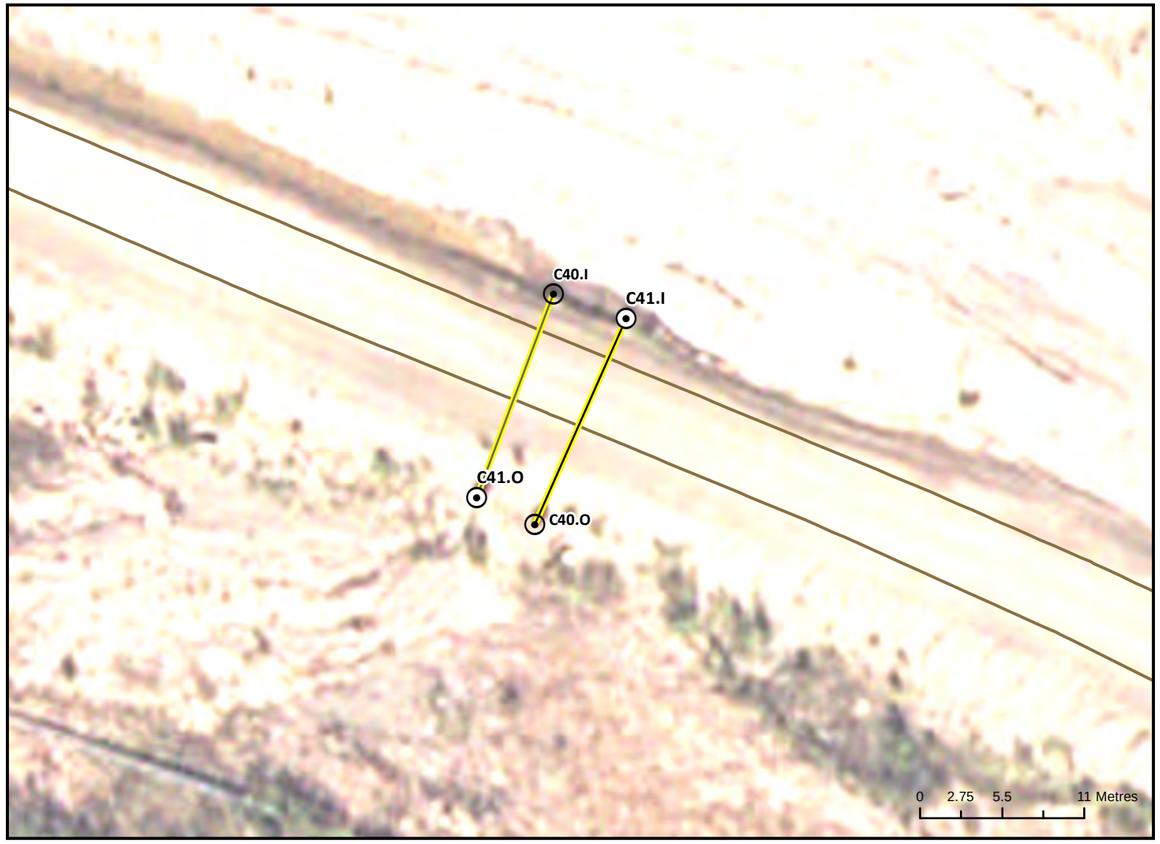
LEGEND

Culvert — Roads Unpaved — Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Citigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:40 Culvert: C40 Map Grid: D3
Faro Mine Interim Works





CULVERT C41 INLET

UPSTREAM (C41.IU)



DOWNSTREAM (C41.ID)



Northing: 6914512.24
Easting: 580615.07

Invert Elevation: 1047.43
Survey Date: 10/5/2012

Diameter (mm): 450
Material Type: RCP: Smooth

CULVERT C41 OUTLET

UPSTREAM (C41.OU)



DOWNSTREAM (C41.OD)

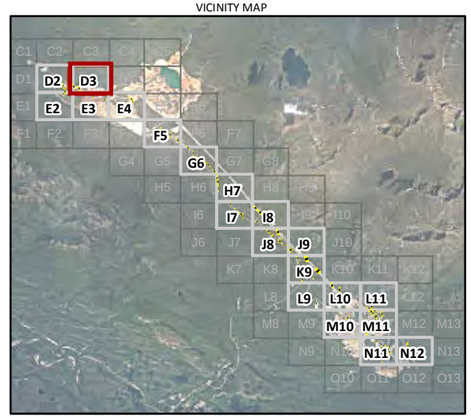


Northing: 6914500.25
Easting: 580605.04

Invert Elevation: 1046.29
Survey Date: 10/5/2012

Diameter (mm): 450
Material Type: RCP: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

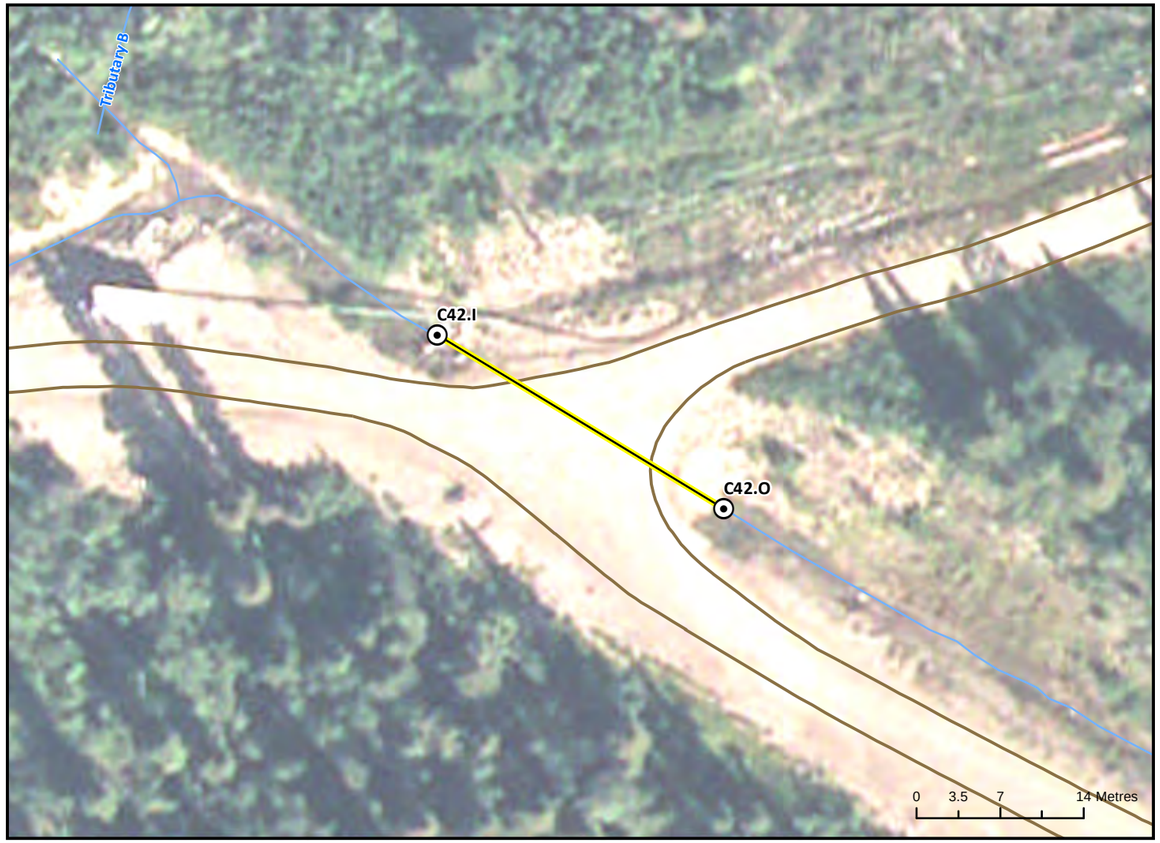
Culvert
Roads Unpaved
Culvert Grid

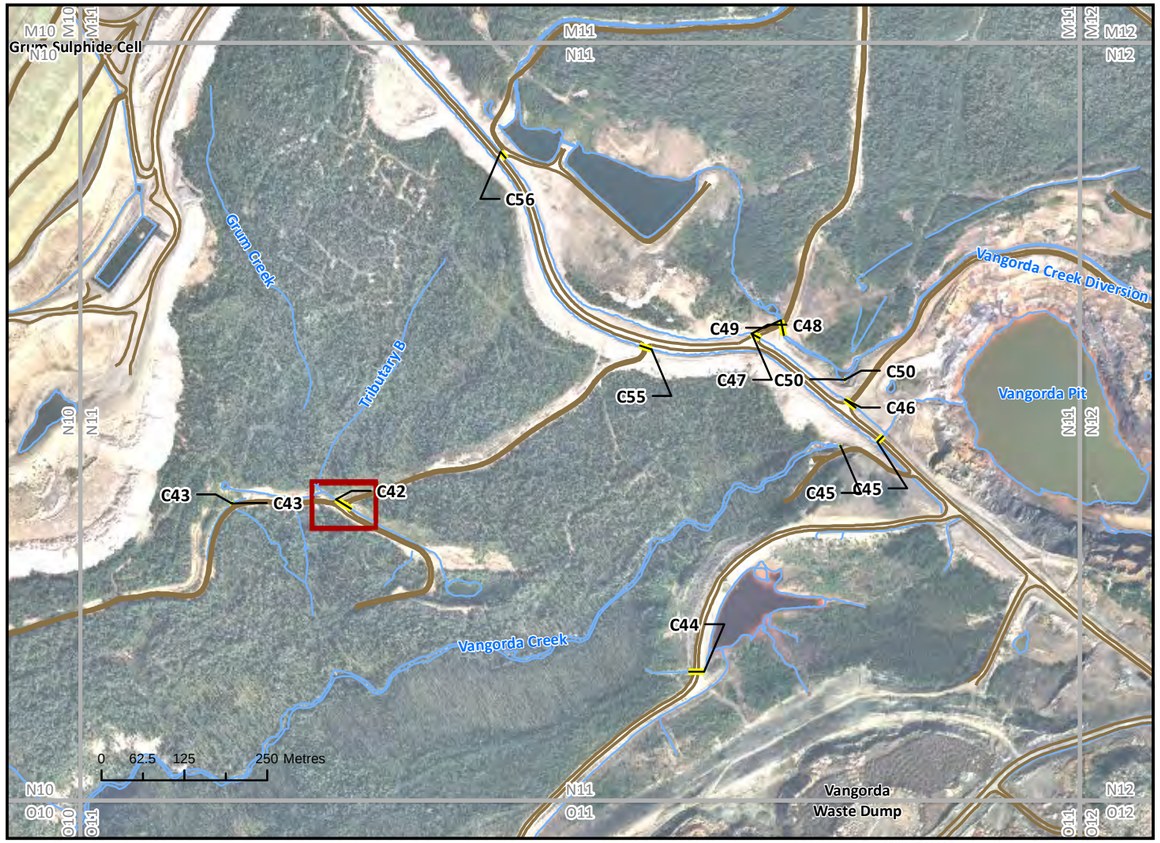
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

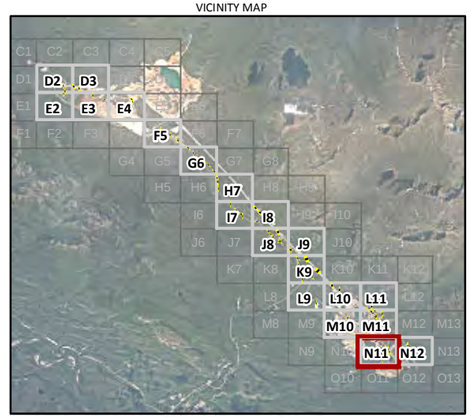
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:41 Culvert: C41 Map Grid: D3
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C42 INLET

UPSTREAM (C42.IU)



DOWNSTREAM (C42.ID)



Northing: 6903371.89
Easting: 592801.03

Invert Elevation: 1101.41
Survey Date: 10/6/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

CULVERT C42 OUTLET

UPSTREAM (C42.OU)



DOWNSTREAM (C42.OD)



Northing: 6903357.35
Easting: 592825.06

Invert Elevation: 1101.17
Survey Date: 10/6/2012

Diameter (mm): 550
Material Type: CMP: Corrugated

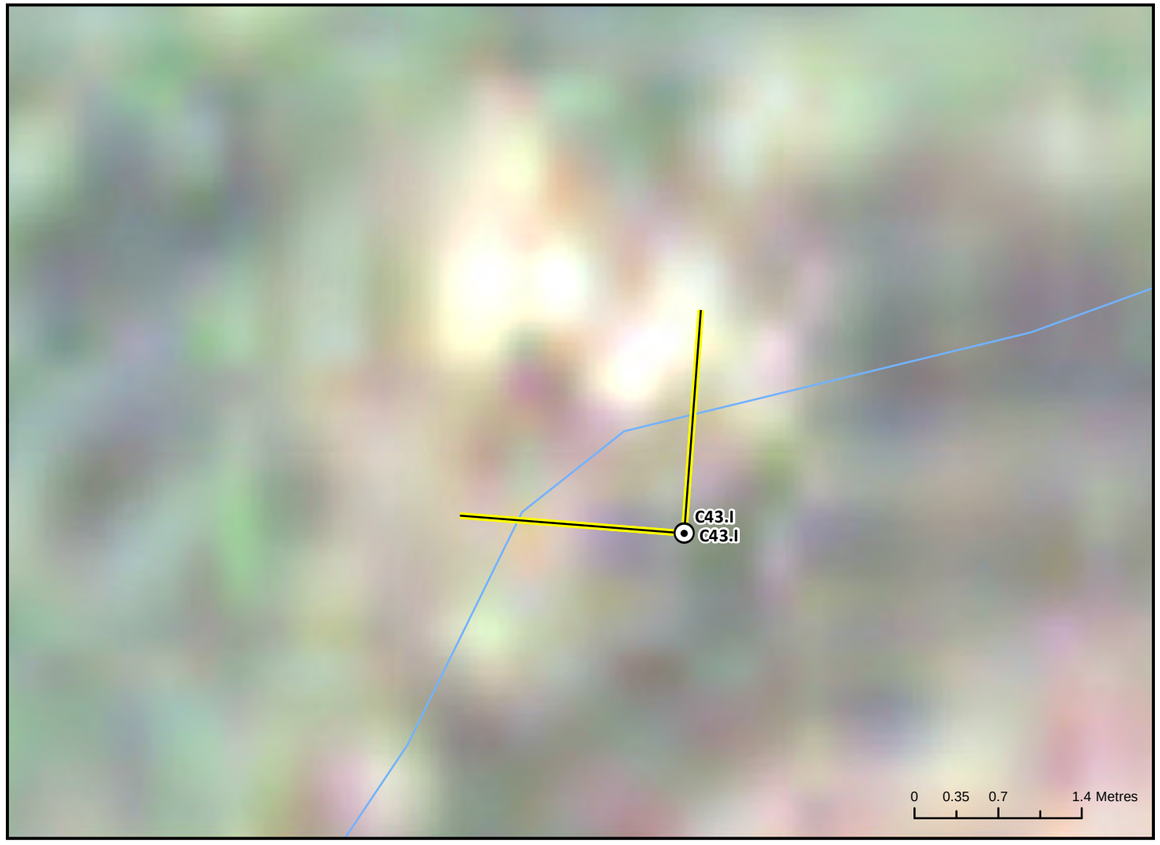
Created by: CRITIGEN

LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:42 Culvert: C42 Map Grid: N11
Faro Mine Interim Works





CULVERT C43 INLET

UPSTREAM (C43.IU)



DOWNSTREAM (C43.ID)



Northing: 6903366.21
Easting: 592644.32

Invert Elevation: 1098.90
Survey Date: 10/6/2012

Diameter (mm): 450
Material Type: RCA: Smooth

CULVERT C43 OUTLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (N/A)

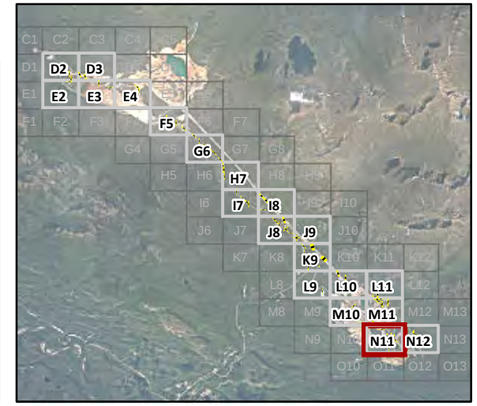
Photo Not Available

Northing:
Easting:

Invert Elevation:
Survey Date:

Diameter (mm): 450
Material Type: N/A

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

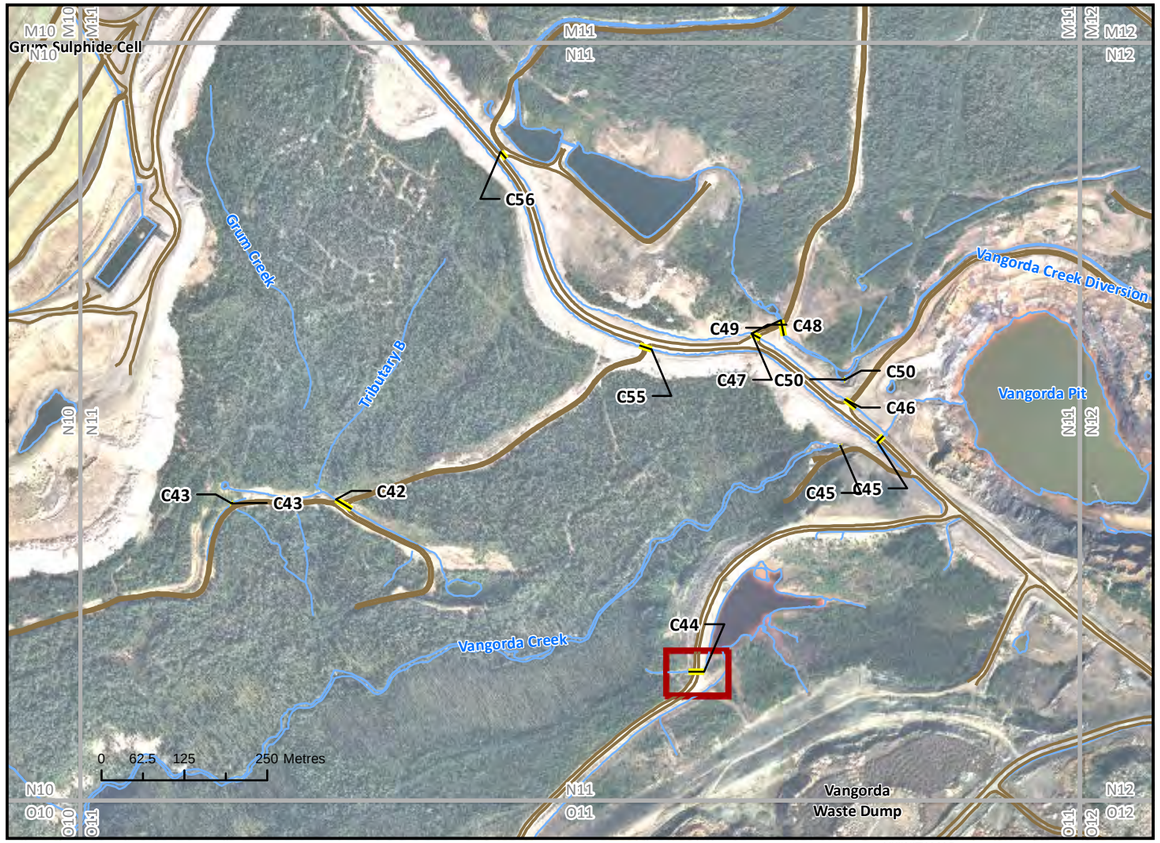
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

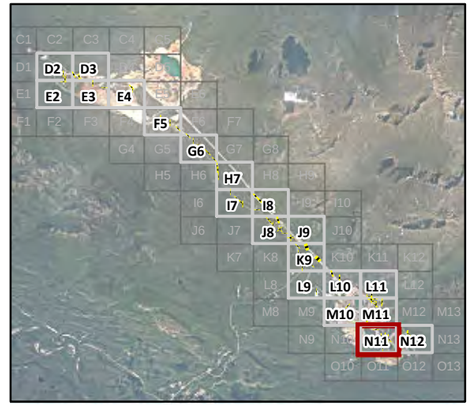
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:43 Culvert: C43 Map Grid: N11
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C44 INLET

UPSTREAM (C44.IU)



DOWNSTREAM (C44.ID)



Northing: 6903111.85
Easting: 593356.68

Invert Elevation: 1112.57
Survey Date: 10/6/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C44 OUTLET

UPSTREAM (C44.OU)



DOWNSTREAM (C44.OD)



Northing: 6903111.90
Easting: 593332.93

Invert Elevation: 1111.72
Survey Date: 10/6/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

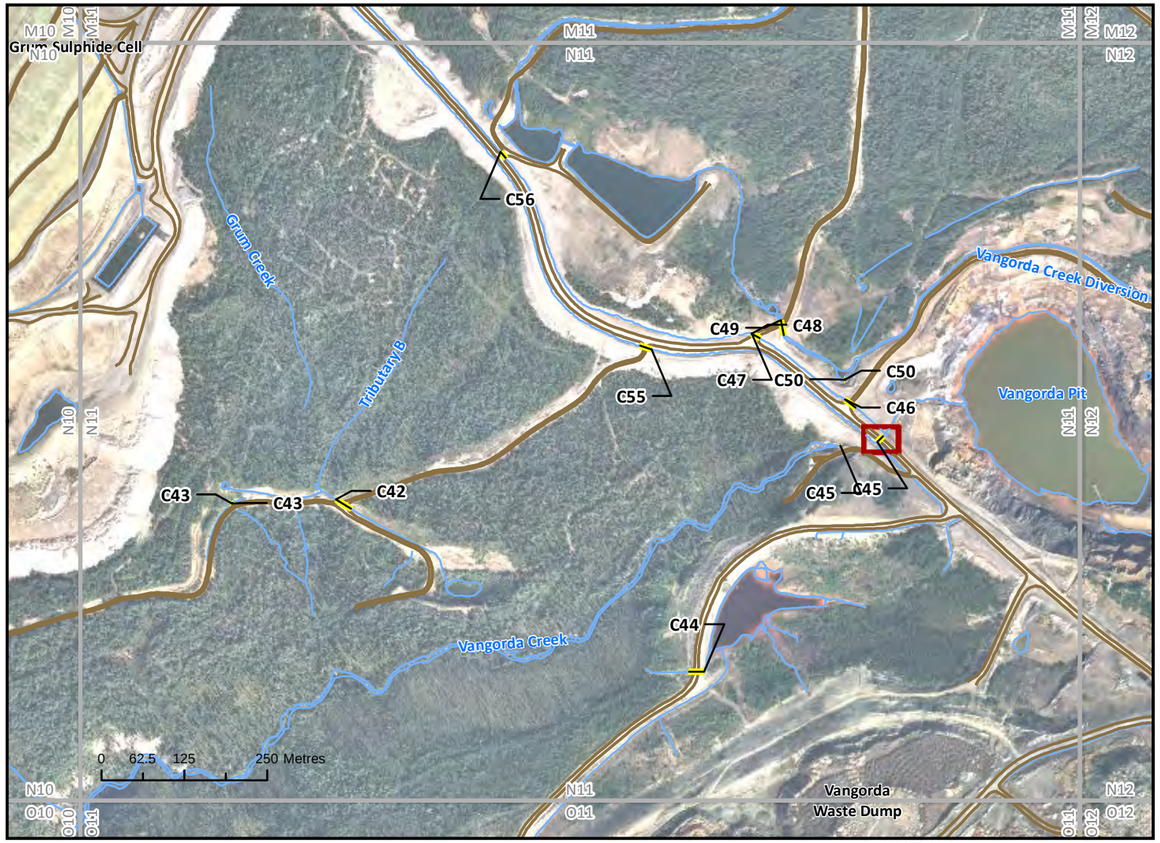
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:44 Culvert: C44 Map Grid: N11
Faro Mine Interim Works

CH2MHILL





CULVERT C45 INLET

UPSTREAM (C45.IU)



DOWNSTREAM (C45.ID)



Northing: 6903458.86
Easting: 593618.01

Invert Elevation: 1128.83
Survey Date: 10/6/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C45 OUTLET

UPSTREAM (C45.OU)



DOWNSTREAM (C45.OD)

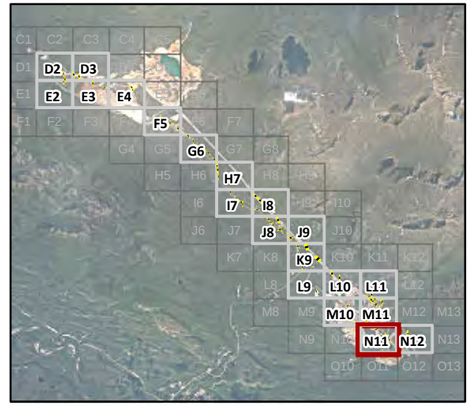


Northing: 6903468.22
Easting: 593627.02

Invert Elevation: 1128.49
Survey Date: 10/6/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

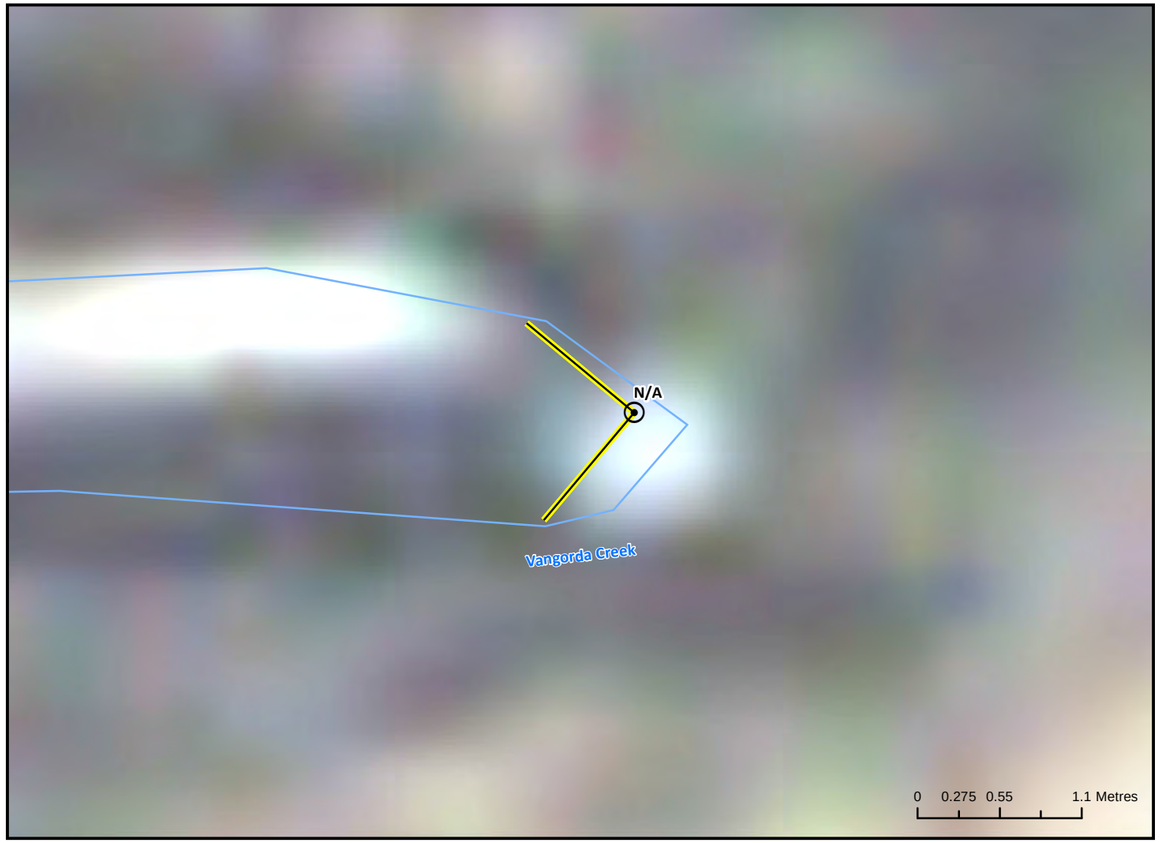
Culvert
Roads Unpaved
Culvert Grid

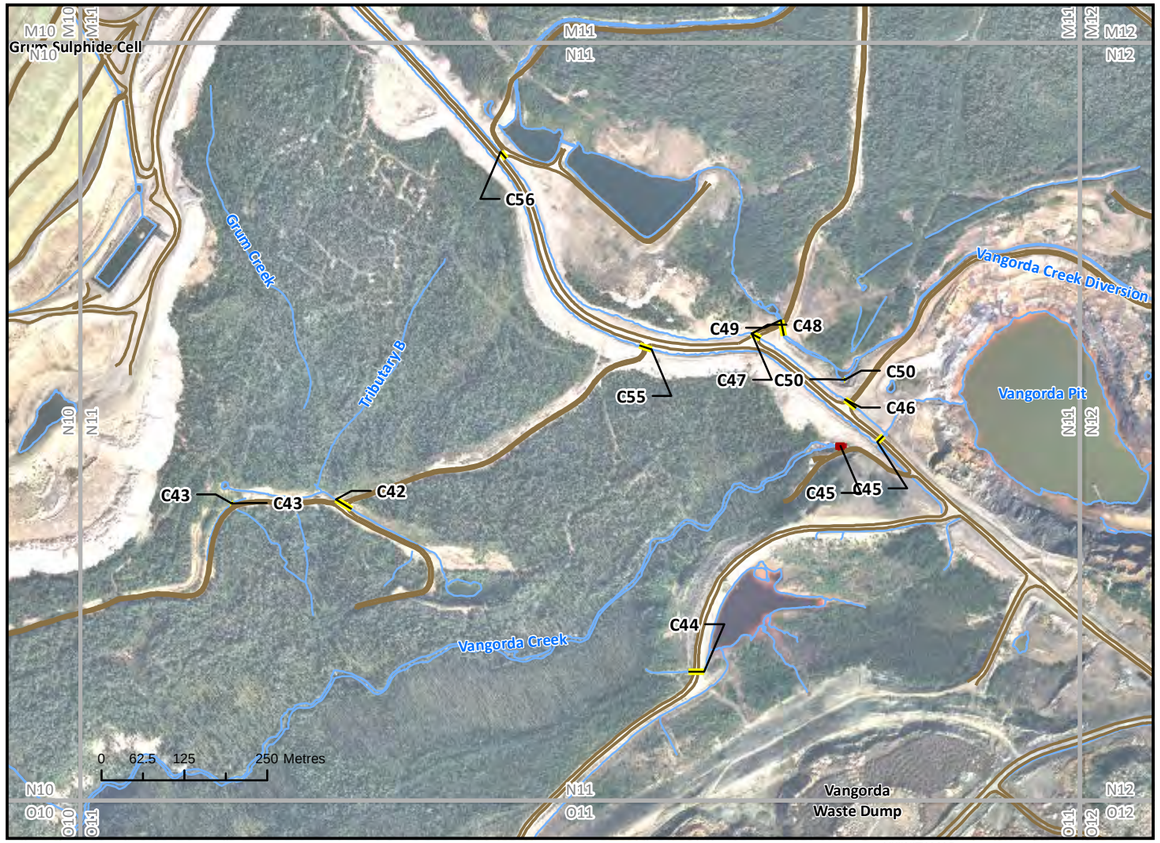
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

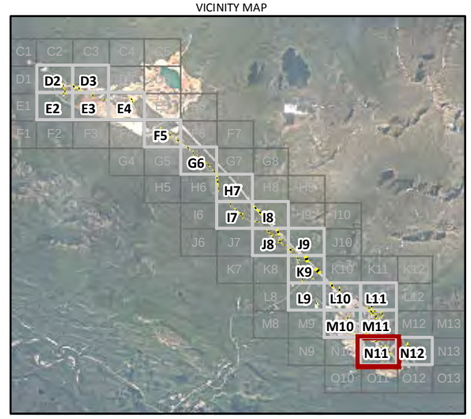
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:45 Culvert: C45 Map Grid: N11
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C45A INLET

UPSTREAM (C45A.IU)

Photo Not Available

Northing: 6903458.86
Easting: 593618.01
Invert Elevation: 1128.83
Survey Date: 10/6/2012
Diameter (mm): 900
Material Type: CMP: Corrugated

DOWNSTREAM (C45A.ID)

Photo Not Available

CULVERT C45A OUTLET

UPSTREAM (C45A.OU)

Photo Not Available

Northing: 6903468.22
Easting: 593627.02
Invert Elevation: 1128.49
Survey Date: 10/6/2012
Diameter (mm): 900
Material Type: CMP: Corrugated

DOWNSTREAM (C45A.OD)

Photo Not Available

Created by: CRITIGEN

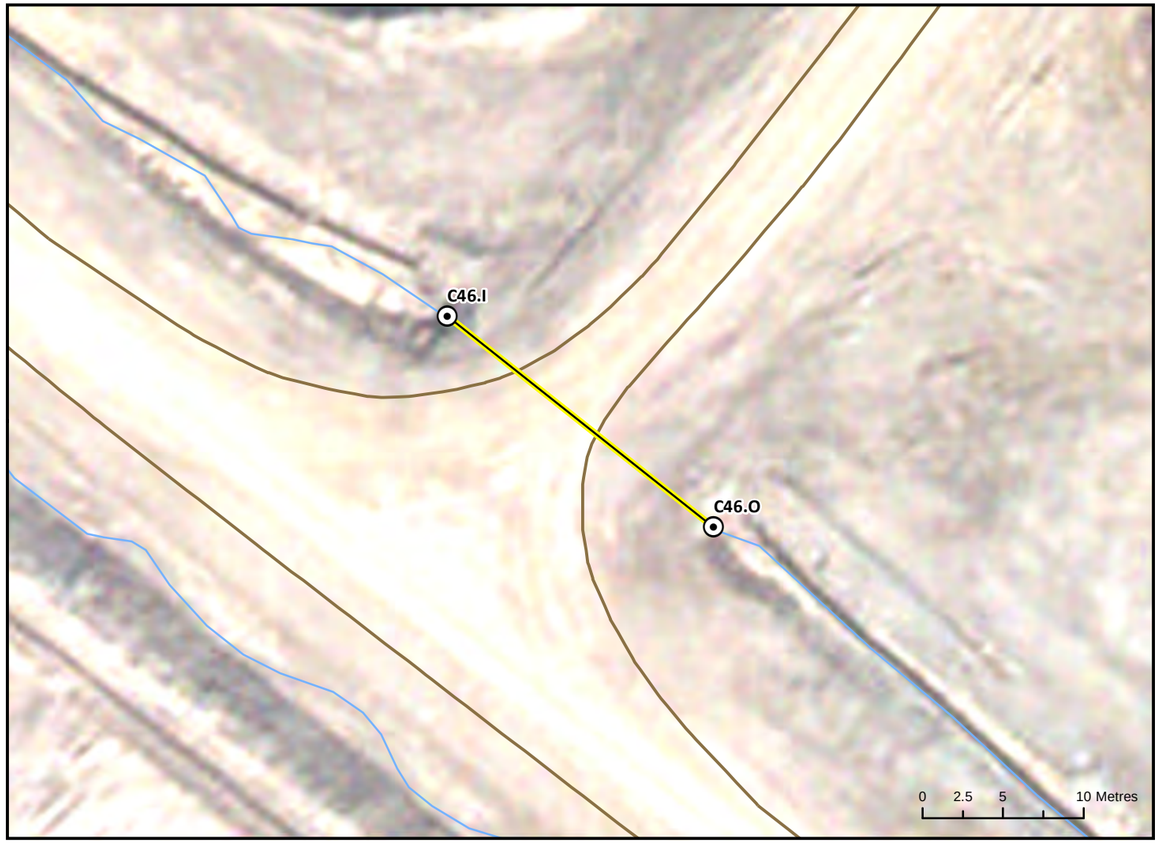
LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:46 Culvert: C45A Map Grid: N11
Faro Mine Interim Works





CULVERT C46 INLET

UPSTREAM (C46.IU)



DOWNSTREAM (C46.ID)



Northing: 6903522.87
Easting: 593569.52

Invert Elevation: 1132.31
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C46 OUTLET

UPSTREAM (C46.OU)



DOWNSTREAM (C46.OD)

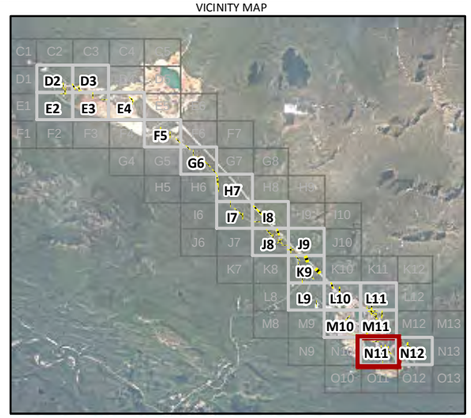


Northing: 6903509.79
Easting: 593586.03

Invert Elevation: 1131.75
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



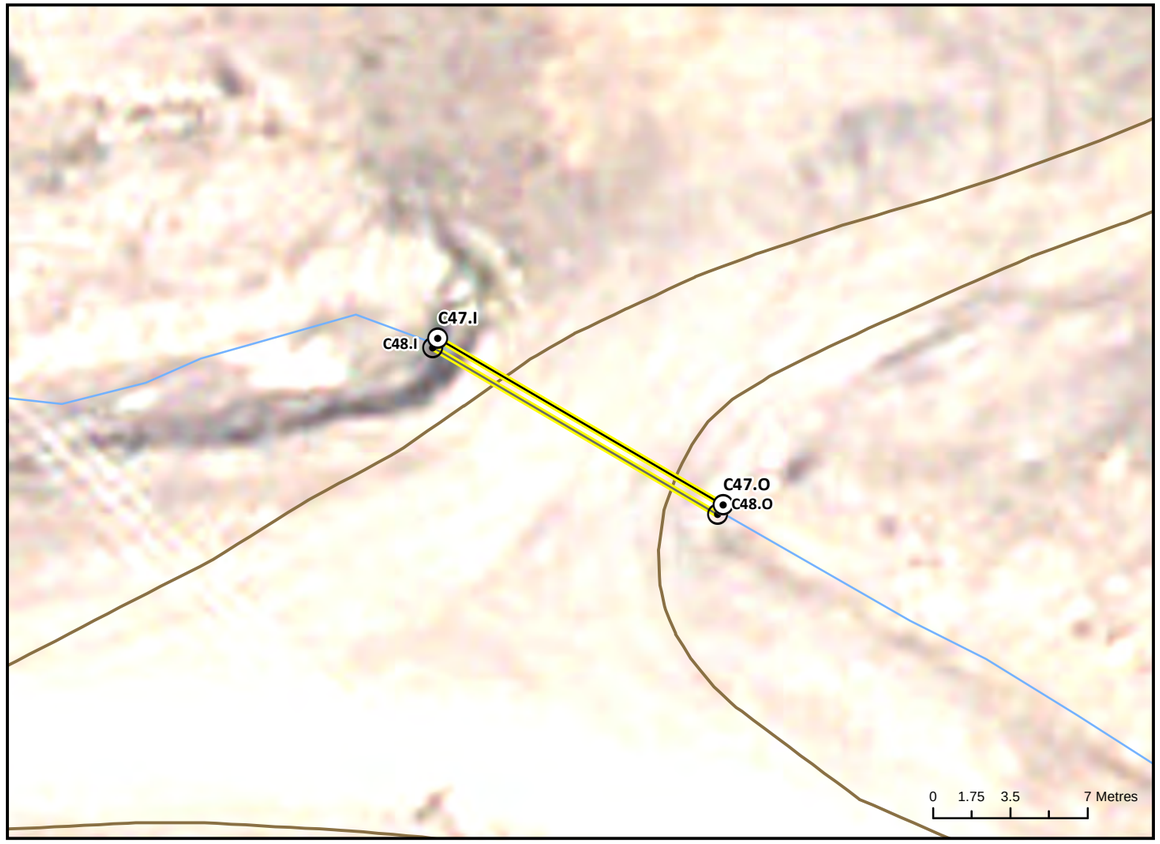
Created by: CRITIGEN

LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:47 Culvert: C46 Map Grid: N11
Faro Mine Interim Works





CULVERT C47 INLET

UPSTREAM (C47.IU)



DOWNSTREAM (C47.ID)



Northing: 6903622.73
Easting: 593428.62

Invert Elevation: 1148.14
Survey Date: 10/6/2012

Diameter (mm): 450
Material Type: RCA: Smooth

CULVERT C47 OUTLET

UPSTREAM (C47.OU)



DOWNSTREAM (C47.OD)

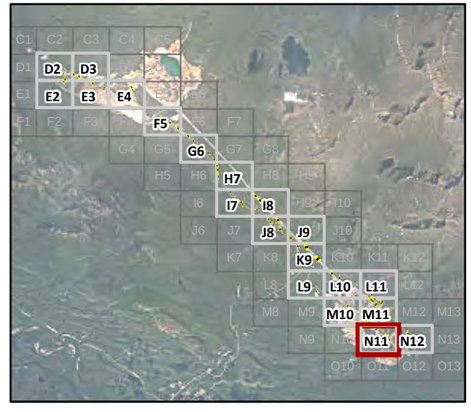


Northing: 6903615.20
Easting: 593441.52

Invert Elevation: 1146.96
Survey Date: 10/6/2012

Diameter (mm): 450
Material Type: RCA: Smooth

VICINITY MAP



Created by:
CRITIGEN

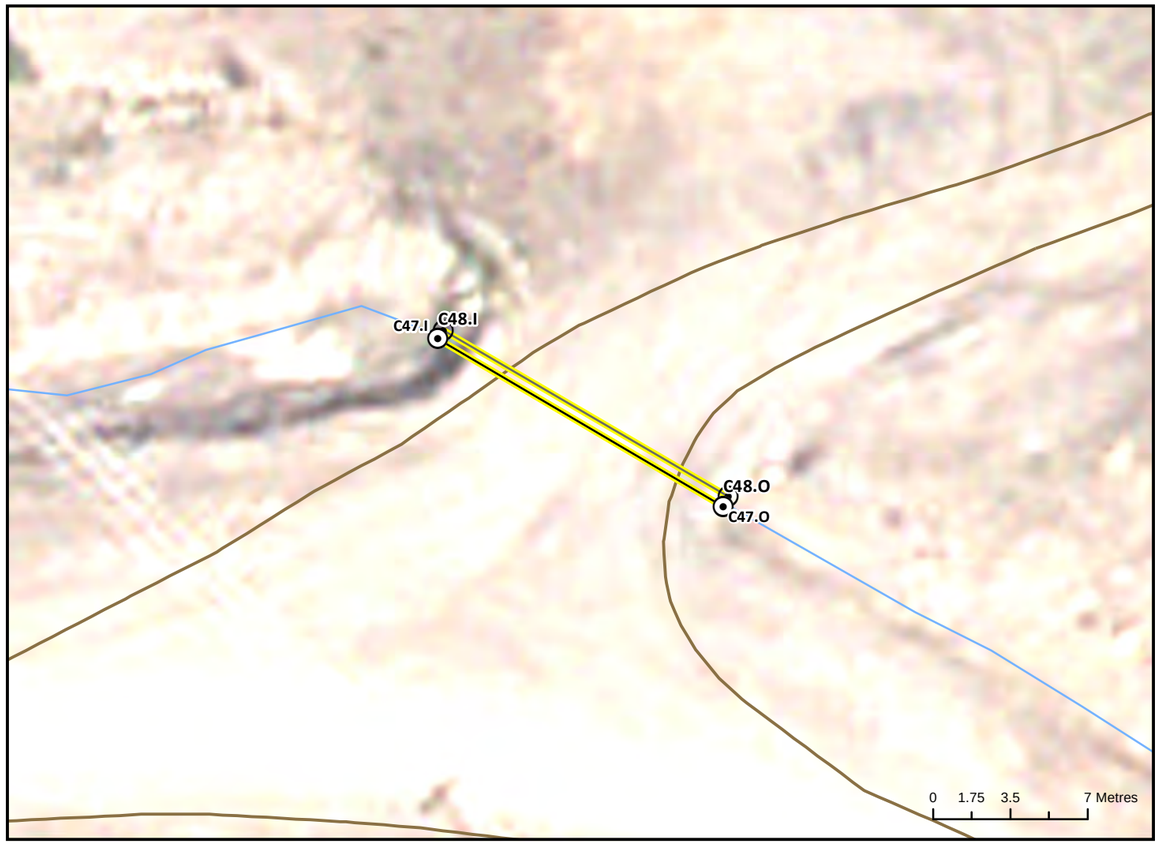
LEGEND
Culvert
Roads Unpaved
Culvert Grid

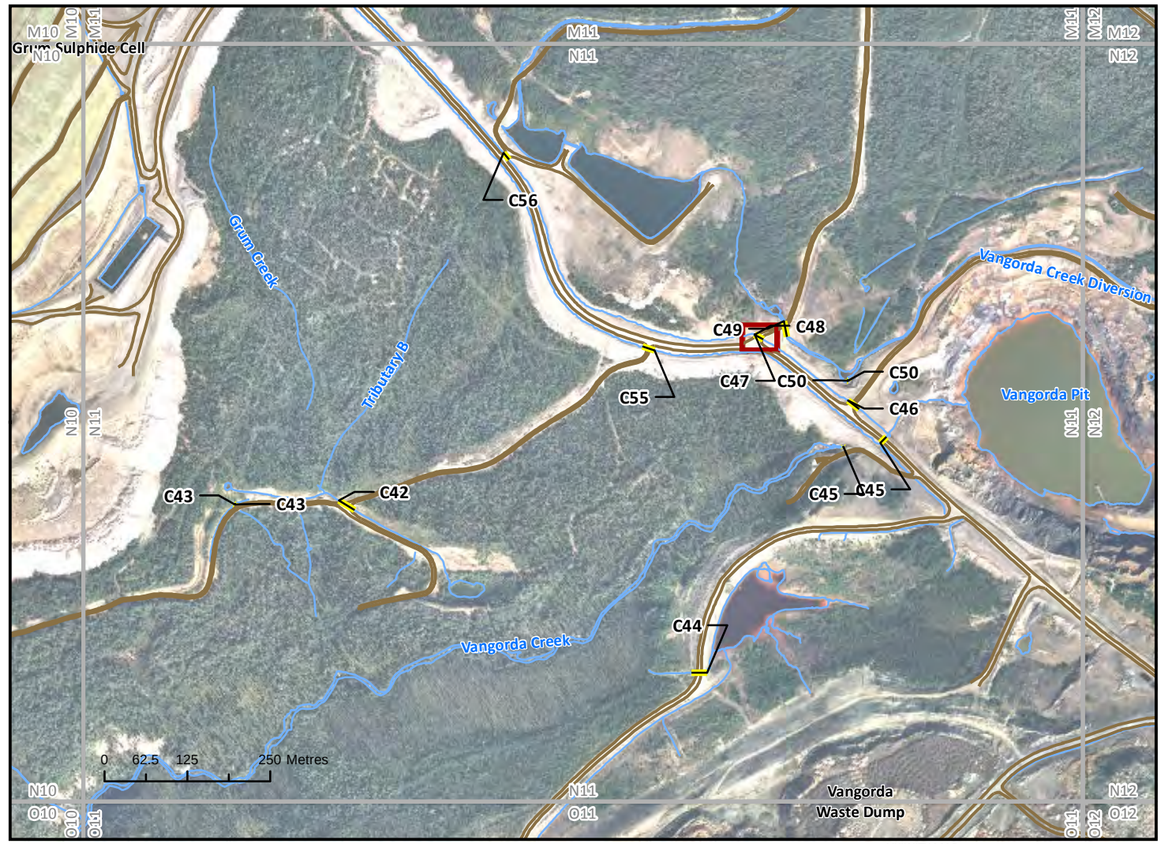
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:48 Culvert: C47 Map Grid: N11
Faro Mine Interim Works

CH2MHILL





CULVERT C48 INLET

UPSTREAM (C48.IU)



DOWNSTREAM (C48.ID)



Northing: 6903622.32
Easting: 593428.38

Invert Elevation: 1148.13
Survey Date: 10/6/2012

Diameter (mm): 450
Material Type: RCA: Smooth

CULVERT C48 OUTLET

UPSTREAM (C48.OU)



DOWNSTREAM (C48.OD)

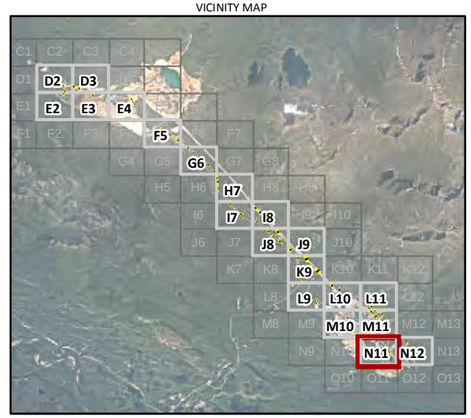


Northing: 6903614.75
Easting: 593441.28

Invert Elevation: 1147
Survey Date: 10/6/2012

Diameter (mm): 450
Material Type: RCA: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

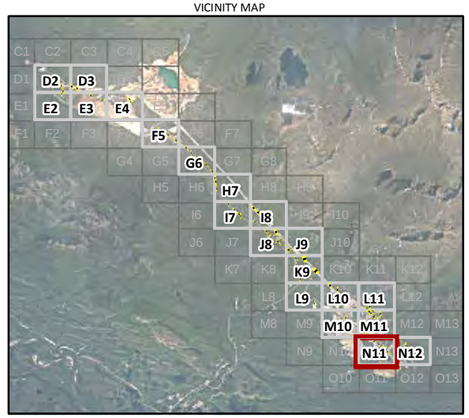
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:49 Culvert: C48 Map Grid: N11
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C49 INLET

UPSTREAM (C49.IU)



DOWNSTREAM (C49.ID)



Northing: 6903642.92
Easting: 593472.48
Invert Elevation: 1145.90
Survey Date: 10/6/2012
Diameter (mm): 1200
Material Type: CMP: Corrugated

CULVERT C49 OUTLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (C49.OD)



Northing: 6903618.96
Easting: 593477.33
Invert Elevation: 1144.82
Survey Date: 10/6/2012
Diameter (mm): 1200
Material Type: CMP: Corrugated

Created by: CRITIGEN

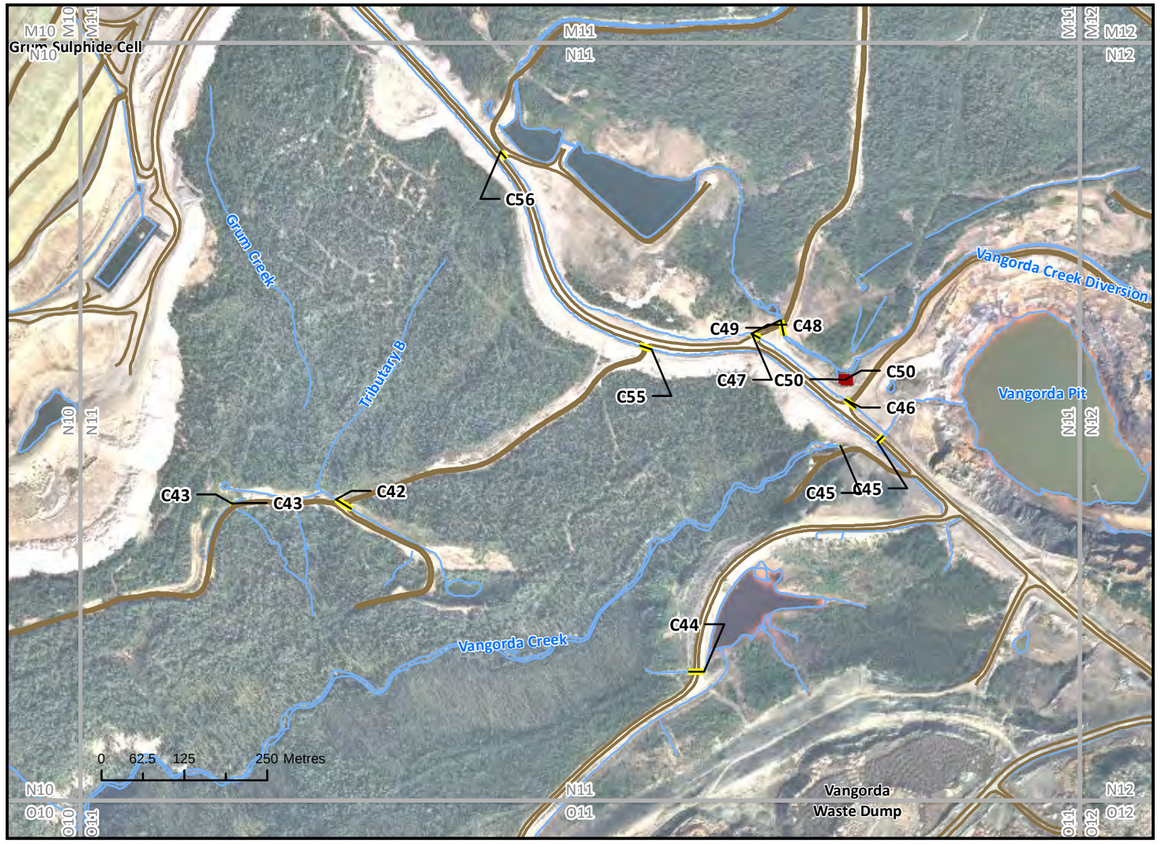
LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:50 Culvert: C49 Map Grid: N11
Faro Mine Interim Works





CULVERT C50 INLET

UPSTREAM (C50.IU)



DOWNSTREAM (C50.ID)



Northing: 6903552.75
Easting: 593569.32
Invert Elevation: 1128.22
Survey Date: 10/6/2012
Diameter (mm): 2000
Material Type: CMP: Corrugated

CULVERT C50 OUTLET

UPSTREAM (N/A)

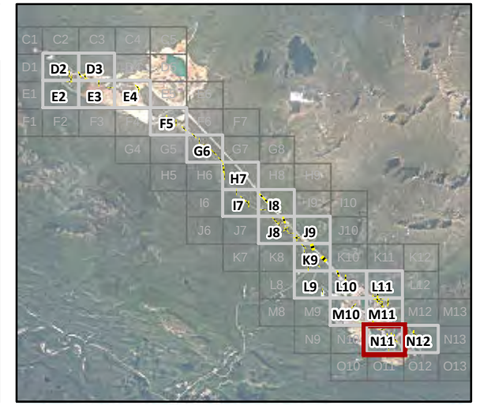
Photo Not Available

DOWNSTREAM (N/A)

Photo Not Available

Northing:
Easting:
Invert Elevation:
Survey Date:
Diameter (mm): 2000
Material Type: N/A

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:51 Culvert: C50 Map Grid: N11
Faro Mine Interim Works

CH2MHILL





CULVERT C51 INLET

UPSTREAM (C51.IU)



DOWNSTREAM (C51.ID)



Northing: 6903737.90
Easting: 594394.64

Invert Elevation: 1167.82
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C51 OUTLET

UPSTREAM (C51.OU)



DOWNSTREAM (C51.OD)

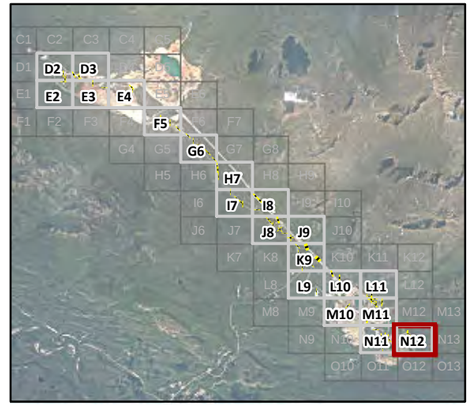


Northing: 6903728.98
Easting: 594386.30

Invert Elevation: 1166.8
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

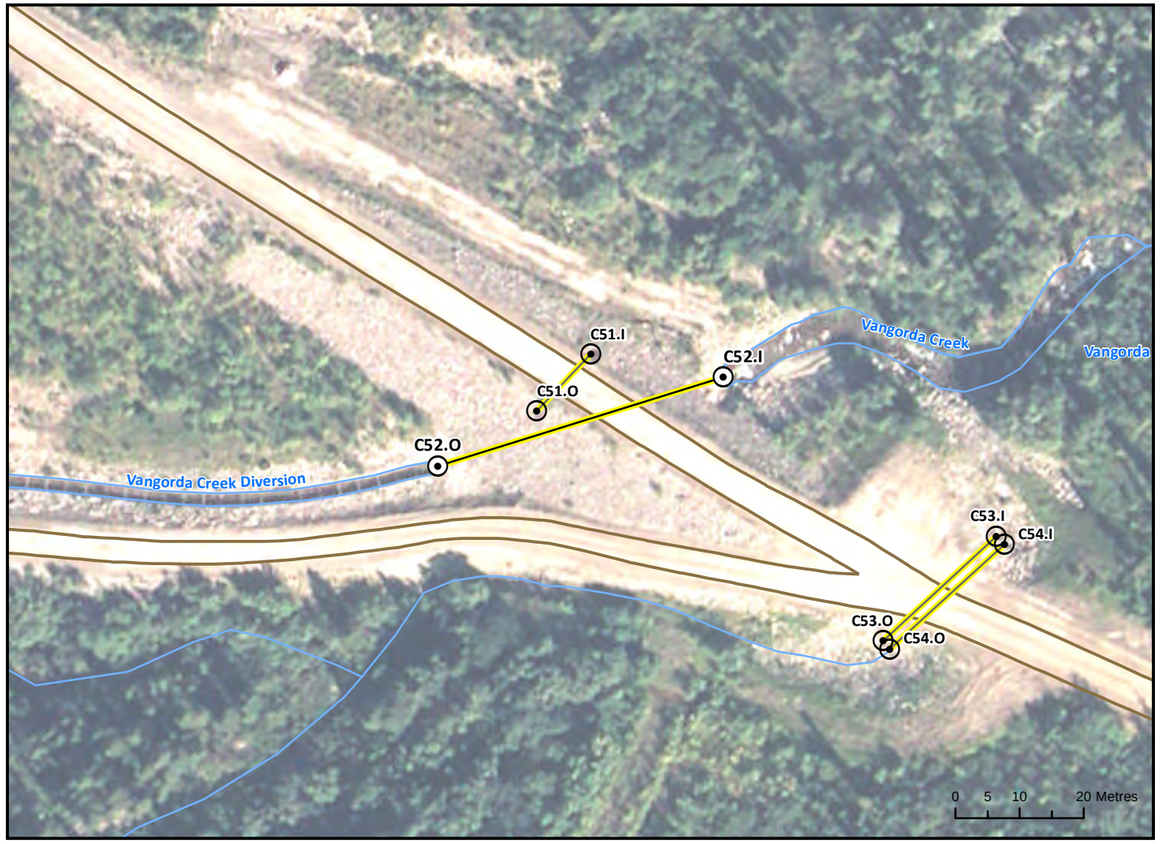
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:52 Culvert: C51 Map Grid: N12
Faro Mine Interim Works

CH2MHILL





CULVERT C52 INLET

UPSTREAM (C52.IU)



DOWNSTREAM (C52.ID)



Northing: 6903734.25
Easting: 594415.33

Invert Elevation: 1161.15
Survey Date: 10/6/2012

Diameter (mm): 1800
Material Type: CMP: Corrugated

CULVERT C52 OUTLET

UPSTREAM (C52.OU)



DOWNSTREAM (C52.OD)

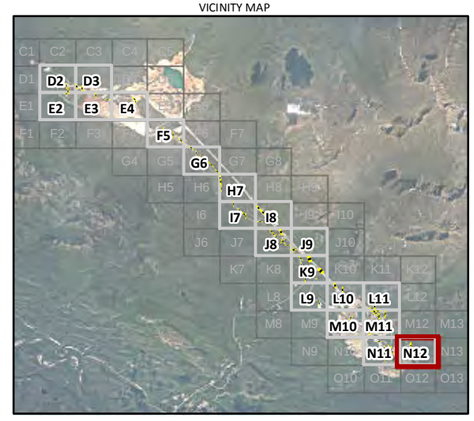


Northing: 6903720.43
Easting: 594370.80

Invert Elevation: 1159.35
Survey Date: 10/6/2012

Diameter (mm): 1800
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

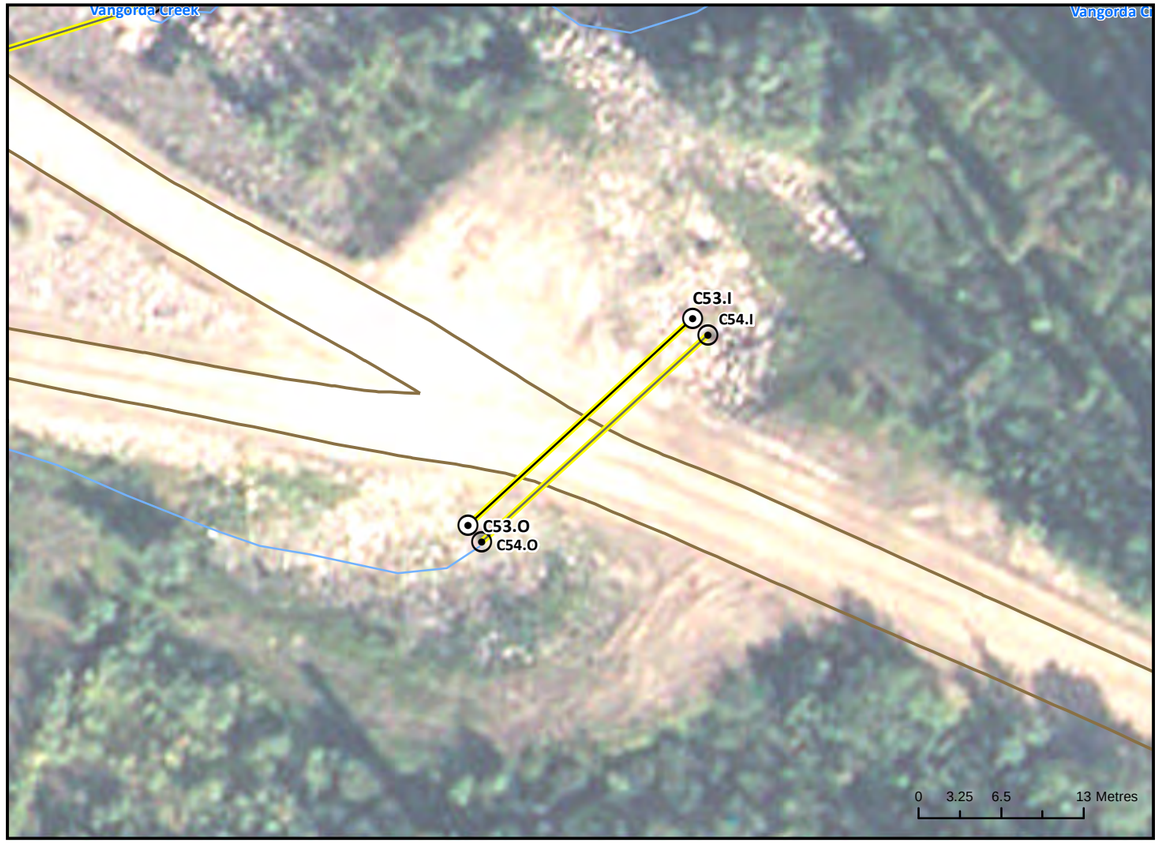
Culvert
Roads Unpaved
Culvert Grid

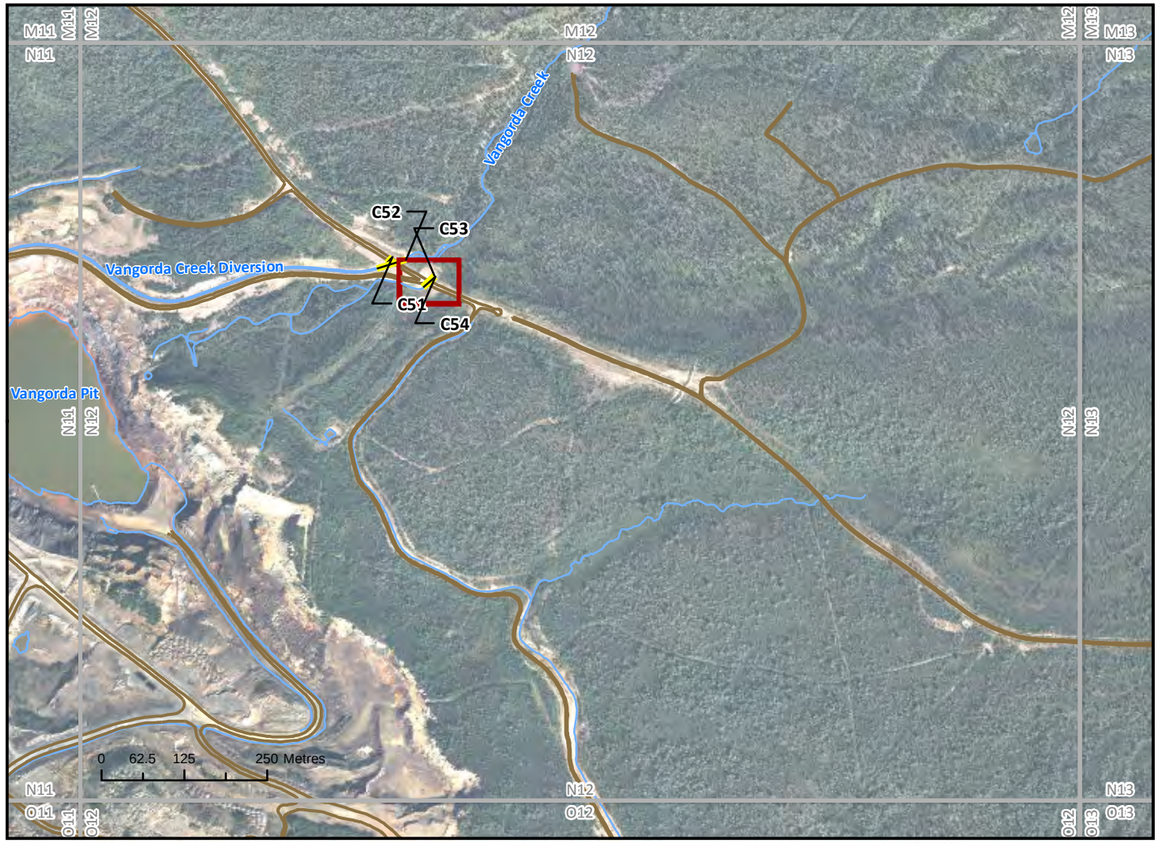
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:53 Culvert: C52 Map Grid: N12
Faro Mine Interim Works

CH2MHILL





CULVERT C53 INLET

UPSTREAM (C53.IU)



DOWNSTREAM (C53.ID)



Northing: 6903709.49
Easting: 594457.93

Invert Elevation: 1166.74
Survey Date: 10/6/2012

Diameter (mm): 1050
Material Type: CMP: Corrugated

CULVERT C53 OUTLET

UPSTREAM (C53.OU)



DOWNSTREAM (C53.OD)

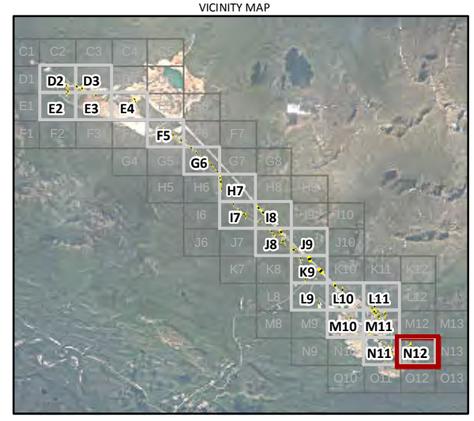


Northing: 6903693.20
Easting: 594440.24

Invert Elevation: 1166.21
Survey Date: 10/6/2012

Diameter (mm): 1050
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

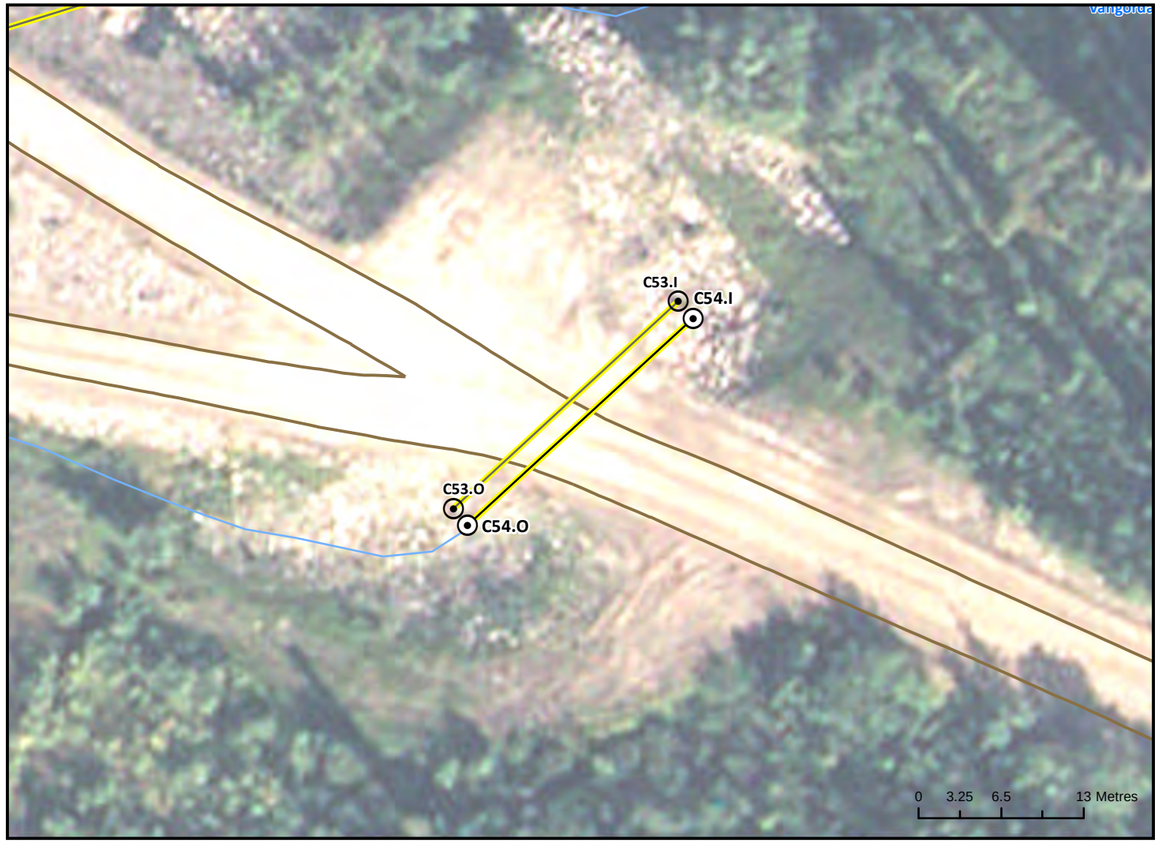
Culvert
Roads Unpaved
Culvert Grid

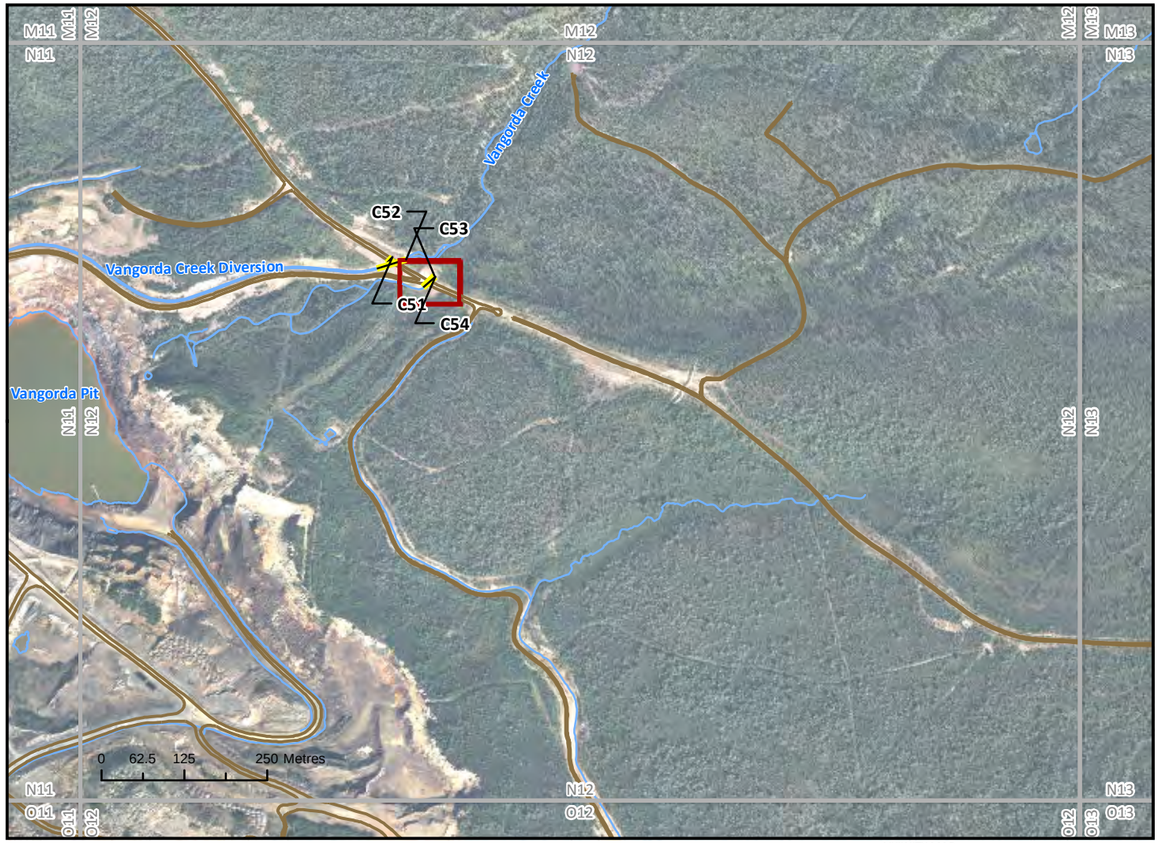
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:54 Culvert: C53 Map Grid: N12
Faro Mine Interim Works

CH2MHILL





CULVERT C54 INLET

UPSTREAM (C54.IU)



DOWNSTREAM (C54.ID)



Northing: 6903708.18
Easting: 594459.14

Invert Elevation: 1166.70
Survey Date: 10/6/2012

Diameter (mm): 1050
Material Type: CMP: Corrugated

CULVERT C54 OUTLET

UPSTREAM (C54.OU)



DOWNSTREAM (C54.OD)

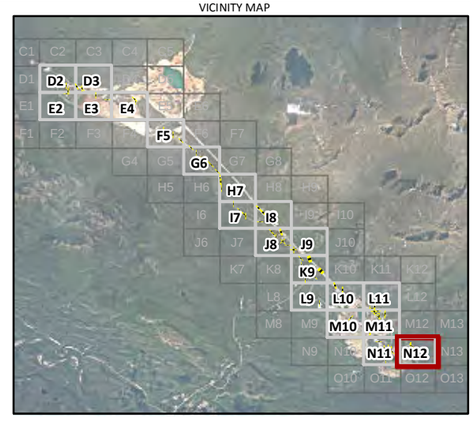


Northing: 6903691.89
Easting: 594441.32

Invert Elevation: 1166.04
Survey Date: 10/6/2012

Diameter (mm): 1050
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

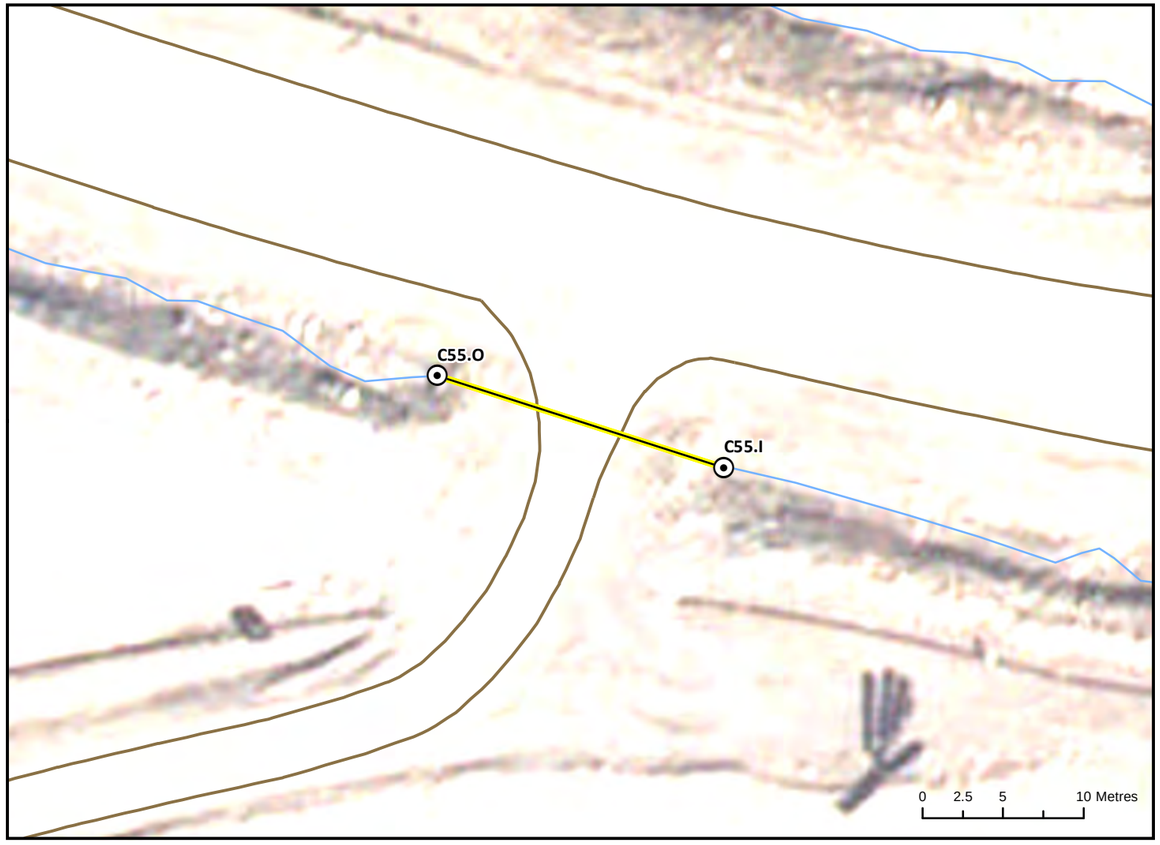
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:55 Culvert: C54 Map Grid: N12
Faro Mine Interim Works

CH2MHILL





CULVERT C55 INLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (N/A)

Photo Not Available

Northing: 6903598.73
Easting: 593277.17
Invert Elevation: 1158.30
Survey Date: 10/6/2012
Diameter (mm): 600
Material Type: RCA: Smooth

CULVERT C55 OUTLET

UPSTREAM (C55.OU)

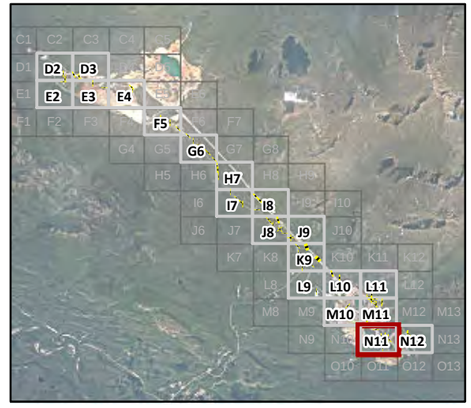


DOWNSTREAM (C55.OD)



Northing: 6903604.40
Easting: 593259.39
Invert Elevation: 1159.89
Survey Date: 10/6/2012
Diameter (mm): 600
Material Type: RCA: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

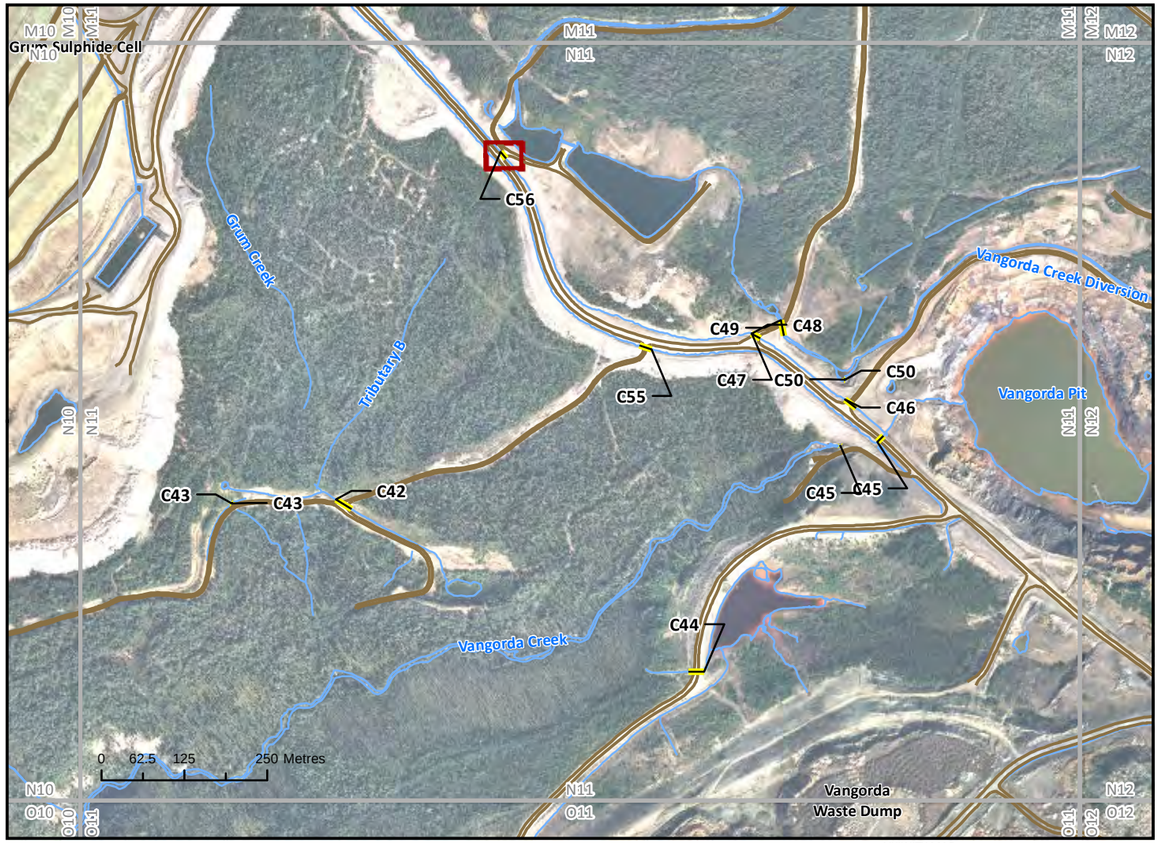
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:56 Culvert: C55 Map Grid: N11
Faro Mine Interim Works

CH2MHILL





CULVERT C56 INLET

UPSTREAM (C56.IU)



DOWNSTREAM (C56.ID)



Northing: 6903896.14
Easting: 593049.53

Invert Elevation: 1186.46
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C56 OUTLET

UPSTREAM (C56.OU)



DOWNSTREAM (C56.OD)

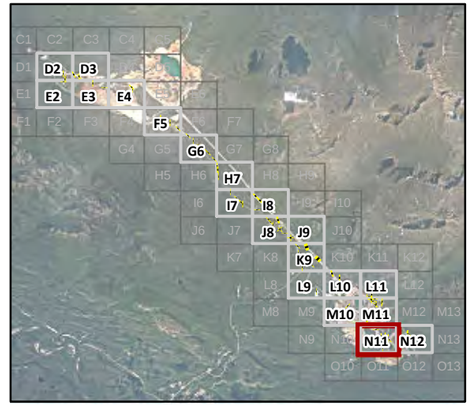


Northing: 6903886.21
Easting: 593058.01

Invert Elevation: 1186.21
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:57 Culvert: C56 Map Grid: N11
Faro Mine Interim Works

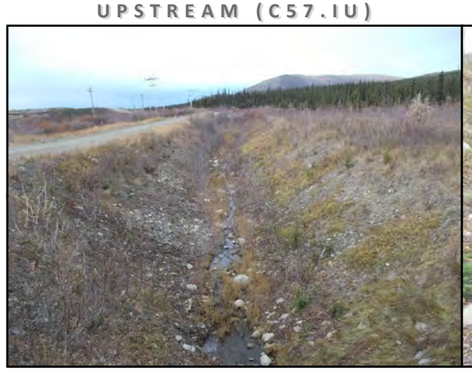
CH2MHILL





CULVERT C57 INLET

UPSTREAM (C57.IU)



DOWNSTREAM (C57.ID)



Northing: 6905431.45
Easting: 592682.61

Invert Elevation: 1299.70
Survey Date: 10/6/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

CULVERT C57 OUTLET

UPSTREAM (C57.OU)



DOWNSTREAM (C57.OD)

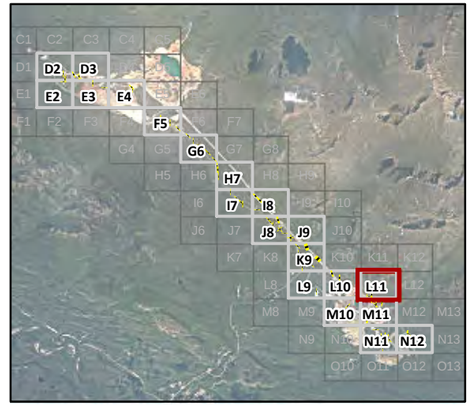


Northing: 6905414.79
Easting: 592691.43

Invert Elevation: 1299.51
Survey Date: 10/6/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

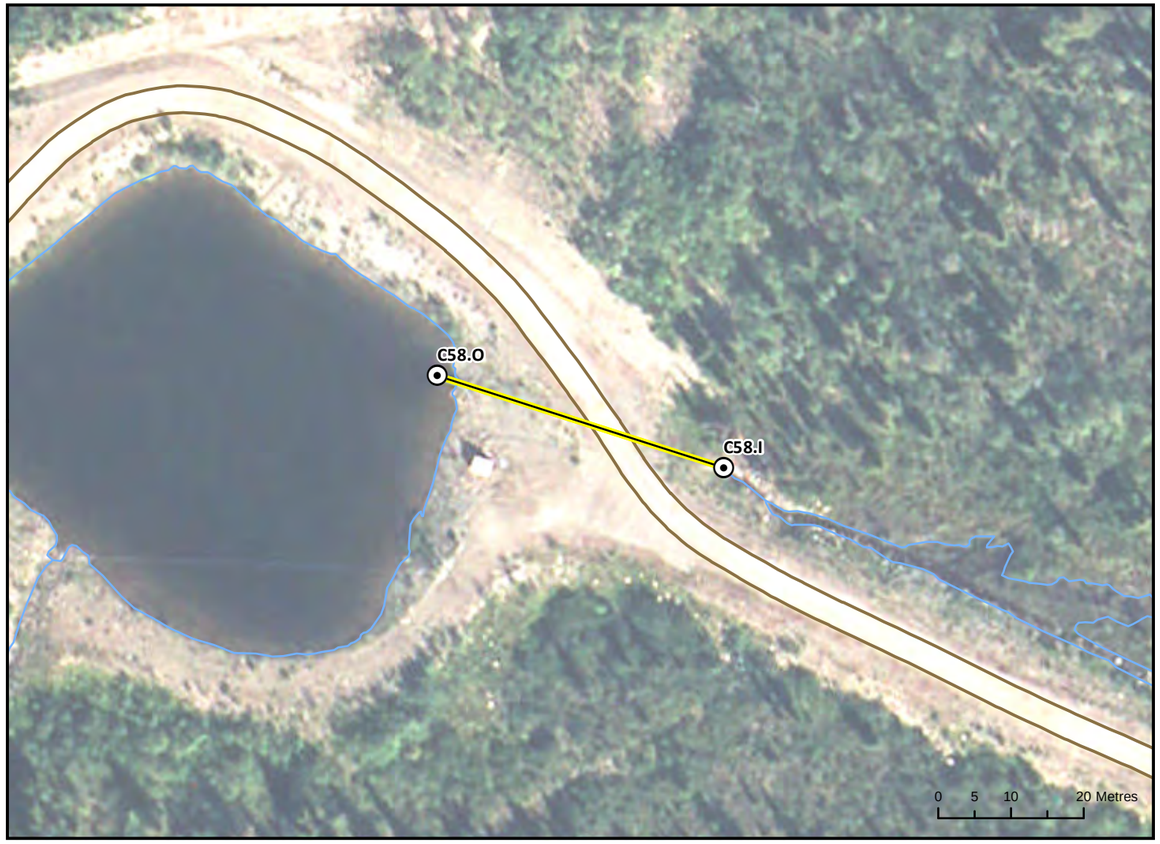
Culvert
Roads Unpaved
Culvert Grid

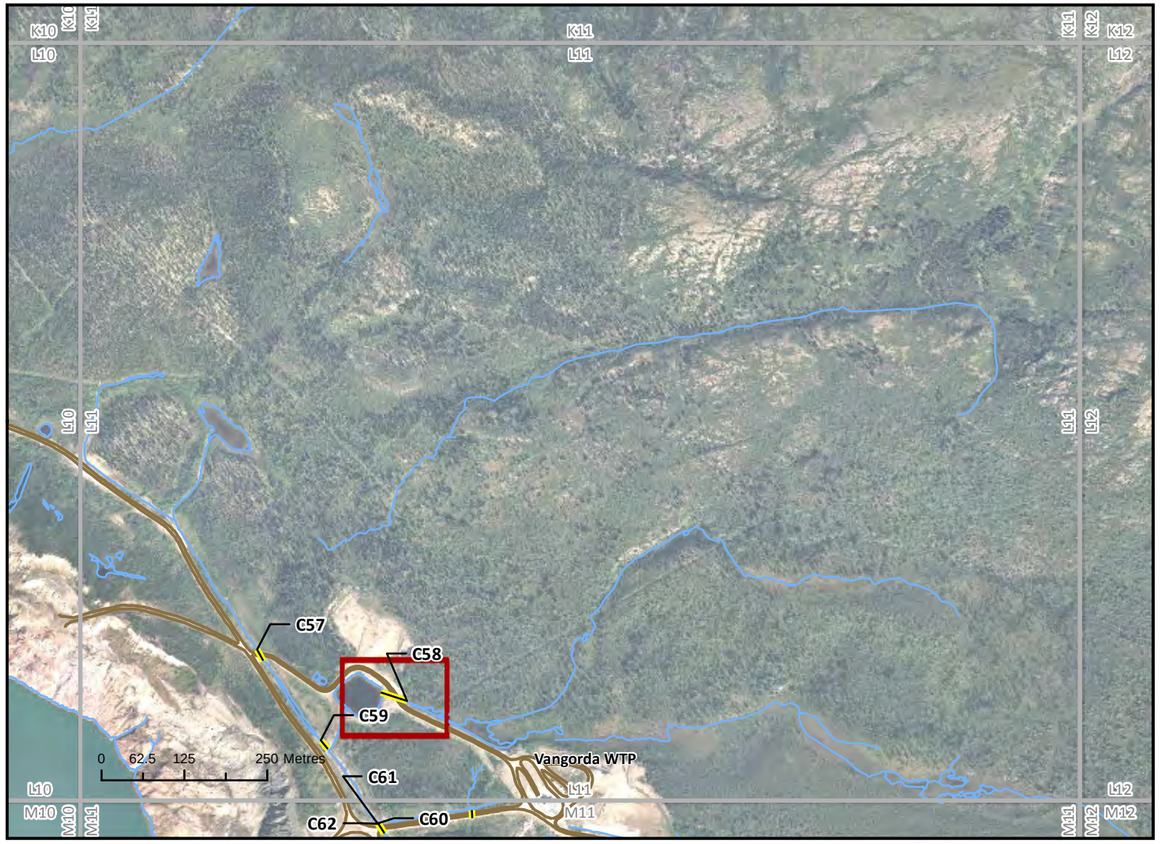
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:58 Culvert: C57 Map Grid: L11
Faro Mine Interim Works

CH2MHILL





CULVERT C58 INLET

UPSTREAM (C58.IU)



DOWNSTREAM (C58.ID)



Northing: 6905354.09
Easting: 592908.76

Invert Elevation: 1304.85
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C58 OUTLET

UPSTREAM (C58.OU)



DOWNSTREAM (C58.OD)

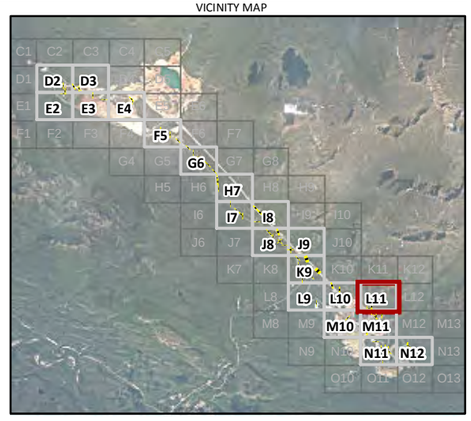


Northing: 6905366.70
Easting: 592869.41

Invert Elevation: 1304.49
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by:
CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:59 Culvert: C58 Map Grid: L11
Faro Mine Interim Works

CH2MHILL





CULVERT C59 INLET

UPSTREAM (C59.IU)



DOWNSTREAM (C59.ID)



CULVERT C59 OUTLET

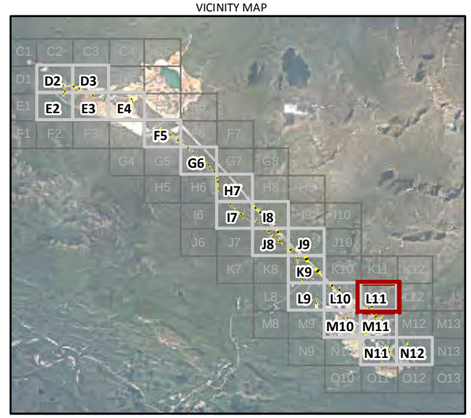
UPSTREAM (C59.OU)



DOWNSTREAM (C59.OD)



VICINITY MAP



Northing: 6905294.55
Easting: 592778.45
Invert Elevation: 1298.90
Survey Date: 10/6/2012
Diameter (mm): 1500
Material Type: CMP: Corrugated

Northing: 6905281.28
Easting: 592789.15
Invert Elevation: 1299.17
Survey Date: 10/6/2012
Diameter (mm): 1500
Material Type: CMP: Corrugated

Created by: CRITIGEN

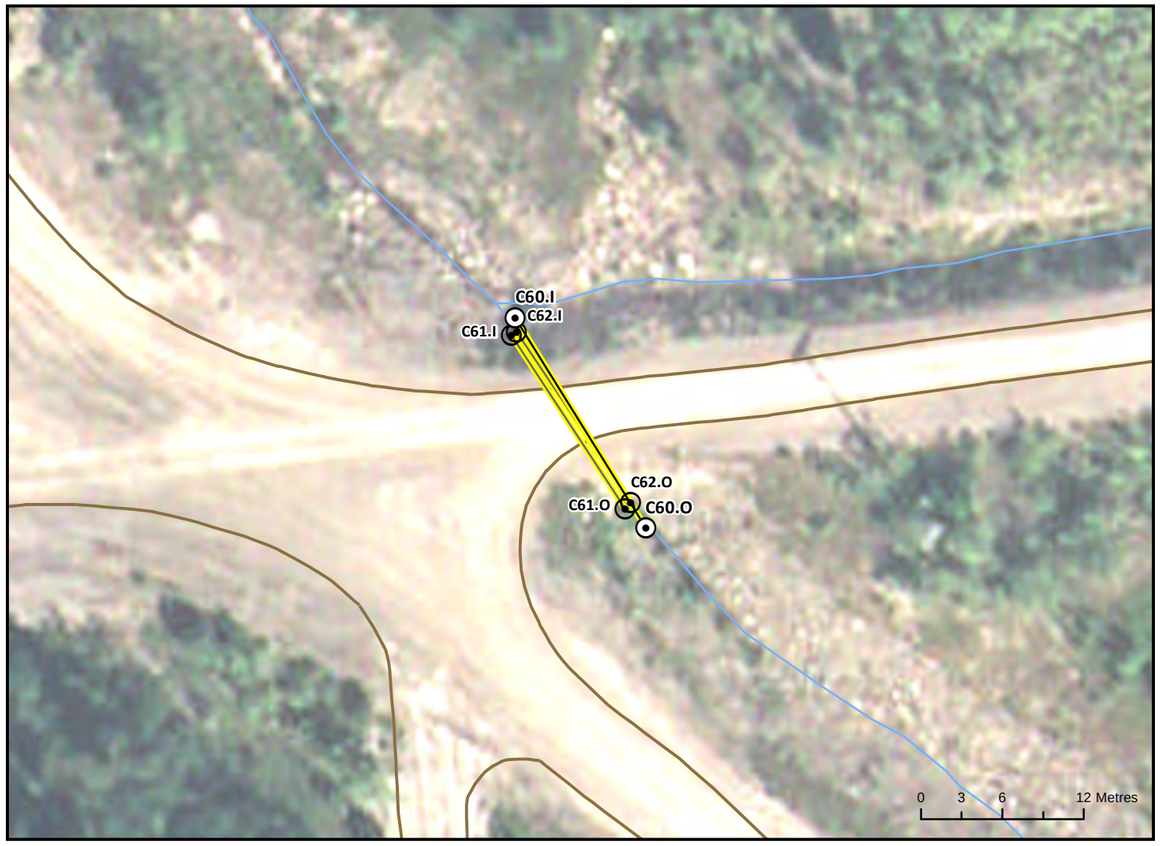
LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:60 Culvert: C59 Map Grid: L11
Faro Mine Interim Works





CULVERT C60 INLET

UPSTREAM (C60.IU)



DOWNSTREAM (C60.ID)



Northing: 6905169.87
Easting: 592864.94

Invert Elevation: 1297.08
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C60 OUTLET

UPSTREAM (C60.OU)



DOWNSTREAM (C60.OD)

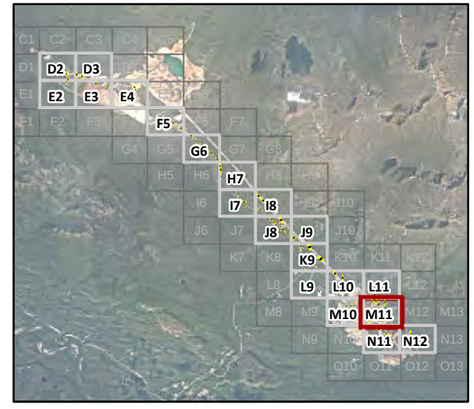


Northing: 6905154.34
Easting: 592874.56

Invert Elevation: 1296.21
Survey Date: 10/6/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:61 Culvert: C60 Map Grid: M11
Faro Mine Interim Works

CH2MHILL





CULVERT C61 INLET

UPSTREAM (C61.IU)



DOWNSTREAM (C61.ID)



Northing: 6905168.54
Easting: 592864.66

Invert Elevation: 1297.87
Survey Date: 10/6/2012

Diameter (mm): 450
Material Type: RCA: Smooth

CULVERT C61 OUTLET

UPSTREAM (C61.OU)



DOWNSTREAM (C61.OD)

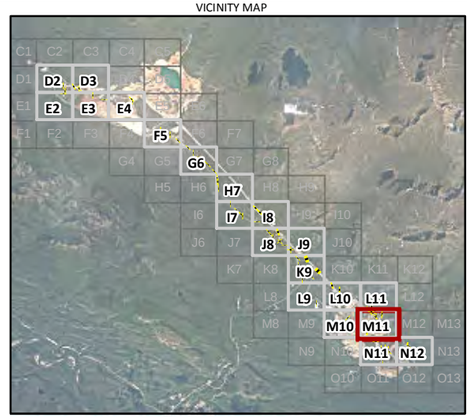
Photo Not Available

Northing: 6905155.77
Easting: 592873.06

Invert Elevation: 1297.08
Survey Date: 10/6/2012

Diameter (mm): 450
Material Type: RCA: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

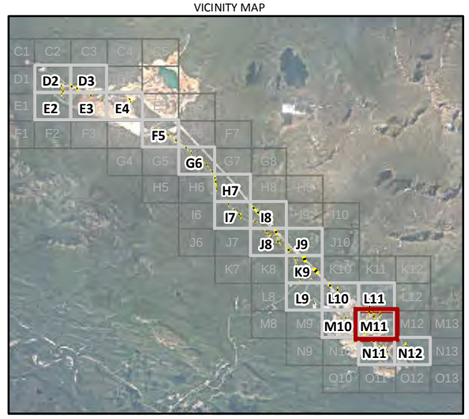
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:62 Culvert: C61 Map Grid: M11
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C62 INLET

UPSTREAM (C62.IU)



DOWNSTREAM (C62.ID)



Northing: 6905168.83
Easting: 592865.05
Invert Elevation: 1297.99
Survey Date: 10/6/2012
Diameter (mm): 450
Material Type: RCA: Smooth

CULVERT C62 OUTLET

UPSTREAM (C62.OU)

Photo Not Available

DOWNSTREAM (C62.OD)



Northing: 6905156.23
Easting: 592873.47
Invert Elevation: 1297.17
Survey Date: 10/6/2012
Diameter (mm): 450
Material Type: RCA: Smooth

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:63 Culvert: C62 Map Grid: M11
Faro Mine Interim Works

CH2MHILL





CULVERT C63 INLET

UPSTREAM (C63.IU)



DOWNSTREAM (C63.ID)



Northing: 6904287.75
Easting: 592661.73

Invert Elevation: 1230.34
Survey Date: 10/7/2012

Diameter (mm): 300
Material Type: RCA: Smooth

CULVERT C63 OUTLET

UPSTREAM (C63.OU)



DOWNSTREAM (C63.OD)

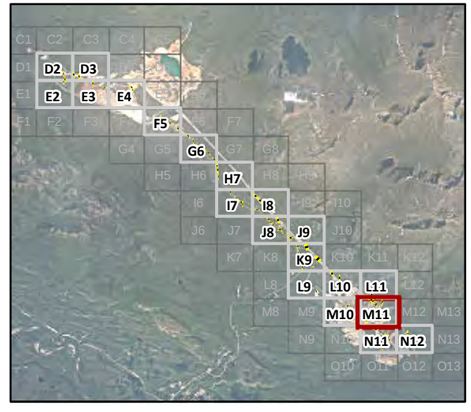


Northing: 6904275.21
Easting: 592669.22

Invert Elevation: 1229.48
Survey Date: 10/7/2012

Diameter (mm): 300
Material Type: RCA: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:64 Culvert: C63 Map Grid: M11
Faro Mine Interim Works

CH2MHILL





CULVERT C63A INLET

UPSTREAM (C63A.IU)

Photo Not Available

DOWNSTREAM (C63A.ID)

Photo Not Available

Northing: 6904287.75
Easting: 592661.73
Invert Elevation: 1230.34
Survey Date: 10/7/2012
Diameter (mm): 300
Material Type: RCA: Smooth

CULVERT C63A OUTLET

UPSTREAM (C63A.OU)

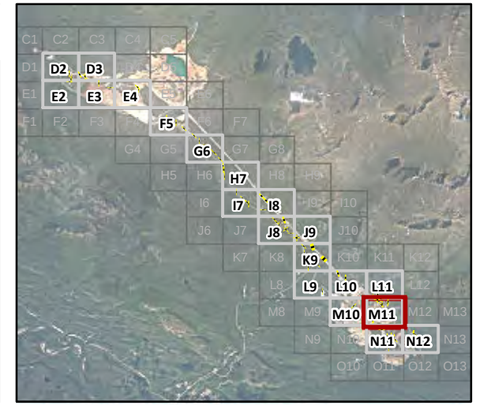
Photo Not Available

DOWNSTREAM (C63A.OD)

Photo Not Available

Northing: 6904275.21
Easting: 592669.22
Invert Elevation: 1229.48
Survey Date: 10/7/2012
Diameter (mm): 300
Material Type: RCA: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:65 Culvert: C63A Map Grid: M11
Faro Mine Interim Works

CH2MHILL





CULVERT C63B INLET

UPSTREAM (C63B.IU)

Photo Not Available

DOWNSTREAM (C63B.ID)

Photo Not Available

Northing: 6904287.75
Easting: 592661.73
Invert Elevation: 1230.34
Survey Date: 10/7/2012
Diameter (mm): 300
Material Type: RCA: Smooth

CULVERT C63B OUTLET

UPSTREAM (C63B.OU)

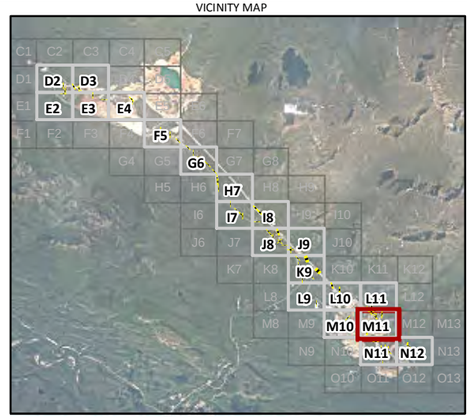
Photo Not Available

DOWNSTREAM (C63B.OD)

Photo Not Available

Northing: 6904275.21
Easting: 592669.22
Invert Elevation: 1229.48
Survey Date: 10/7/2012
Diameter (mm): 300
Material Type: RCA: Smooth

VICINITY MAP



Created by: CRITIGEN

LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

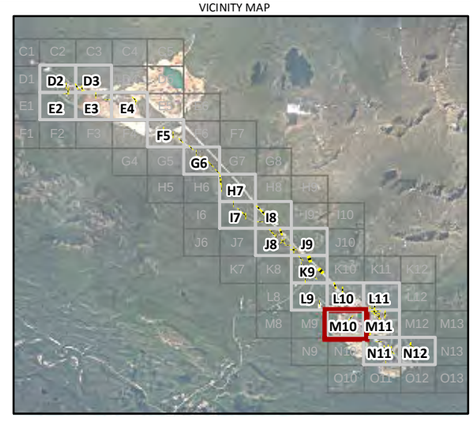
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:66 Culvert: C63B Map Grid: M11
Faro Mine Interim Works





VICINITY MAP



CULVERT C64 INLET

UPSTREAM (C64.IU)



DOWNSTREAM (C64.ID)



Northing: 6904886.50
Easting: 591874.22
Invert Elevation: 1294.81
Survey Date: 10/7/2012
Diameter (mm): 450
Material Type: RCA: Smooth

CULVERT C64 OUTLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (N/A)

Photo Not Available

Northing: 6904877.99
Easting: 591882.68
Invert Elevation: 1294.11
Survey Date: 10/7/2012
Diameter (mm): 450
Material Type: RCA: Smooth

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:67 Culvert: C64 Map Grid: M10
Faro Mine Interim Works





CULVERT C65 INLET

UPSTREAM (C65.IU)



DOWNSTREAM (C65.ID)



CULVERT C65 OUTLET

UPSTREAM (C65.OU)



DOWNSTREAM (C65.OD)



Northing: 6905081.98
Easting: 592935.31

Invert Elevation: 1290.84
Survey Date: 10/7/2012

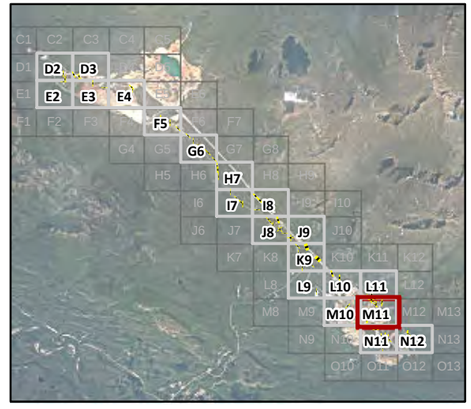
Diameter (mm): 1500
Material Type: CMP: Corrugated

Northing: 6905068.57
Easting: 592922.73

Invert Elevation: 1290.03
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

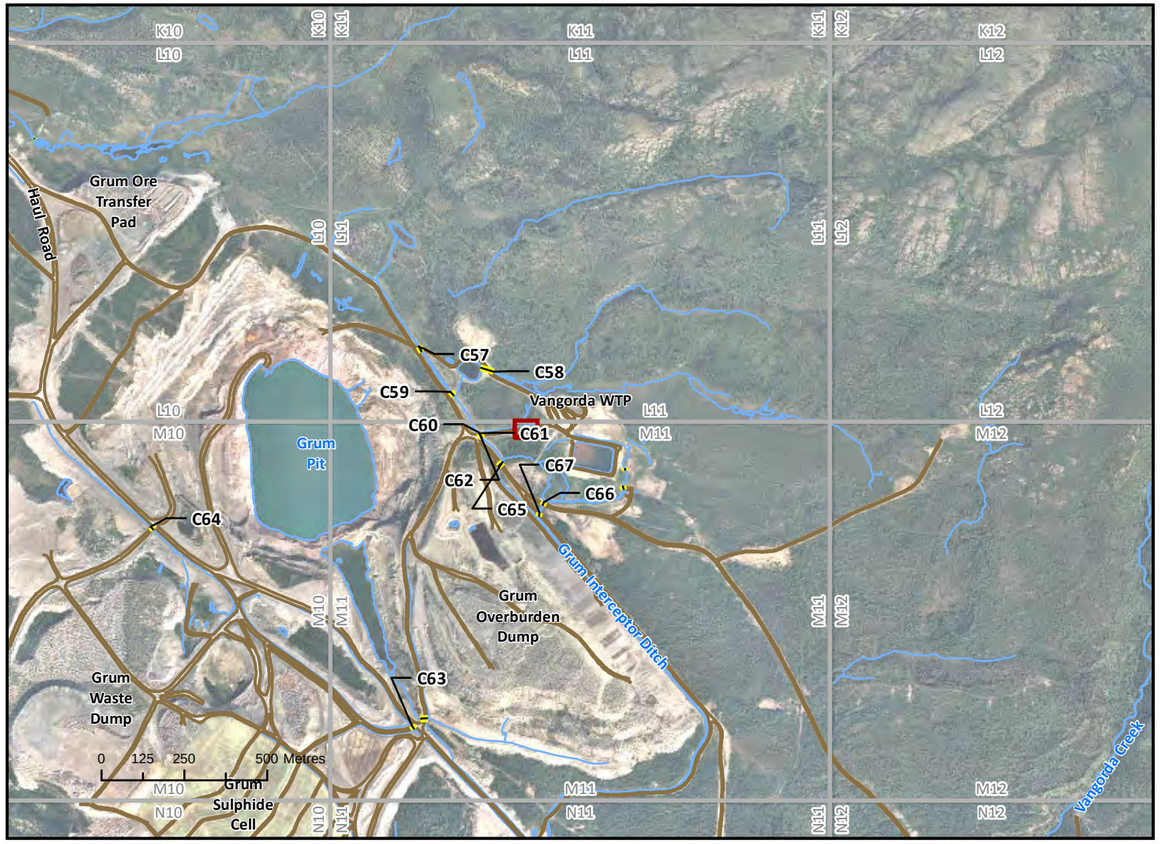
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

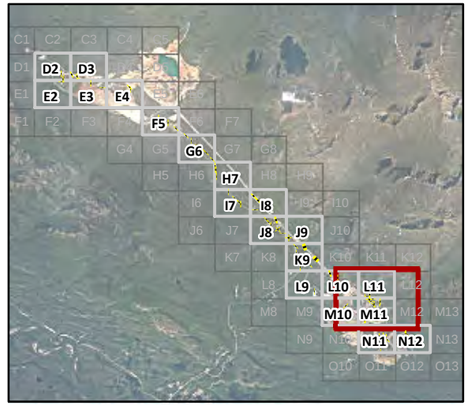
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:68 Culvert: C65 Map Grid: M11
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C65 INLET

UPSTREAM (C65.IU)



DOWNSTREAM (C65.ID)



Northing: 6905081.98
Easting: 592935.31

Invert Elevation: 1290.84
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

CULVERT C65 OUTLET

UPSTREAM (C65.OU)



DOWNSTREAM (C65.OD)



Northing: 6905068.57
Easting: 592922.73

Invert Elevation: 1290.03
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:69 Culvert: C65 Map Grid: M11
Faro Mine Interim Works

CH2MHILL





CULVERT C66 INLET

UPSTREAM (C66.IU)



DOWNSTREAM (C66.ID)



Northing: 6904962.04
Easting: 593061.43
Invert Elevation: 1286.54
Survey Date: 10/7/2012
Diameter (mm): 1500
Material Type: CMP: Corrugated

CULVERT C66 OUTLET

UPSTREAM (C66.OU)

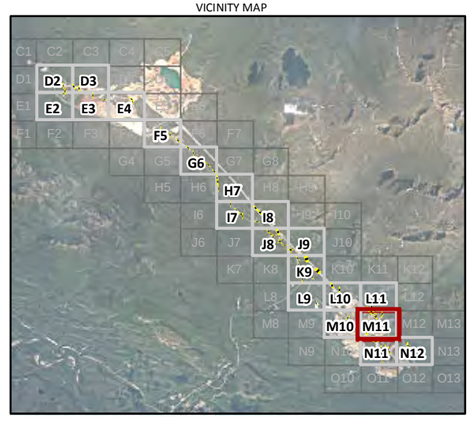


DOWNSTREAM (C66.OD)



Northing: 6904951.23
Easting: 593055.41
Invert Elevation: 1285.87
Survey Date: 10/7/2012
Diameter (mm): 1500
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:70 Culvert: C66 Map Grid: M11
Faro Mine Interim Works

CH2MHILL





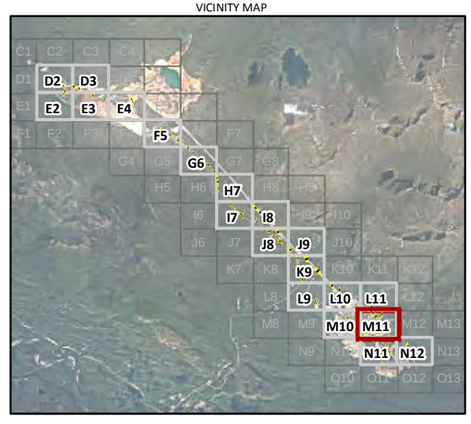
CULVERT C66A INLET

UPSTREAM (C66A.IU)	DOWNSTREAM (C66A.ID)
Photo Not Available	Photo Not Available

CULVERT C66A OUTLET

UPSTREAM (C66A.OU)	DOWNSTREAM (C66A.OD)
Photo Not Available	Photo Not Available

VICINITY MAP



Northing: 6904962.04 ***Easting:*** 593061.43 ***Invert Elevation:*** 1286.54 ***Survey Date:*** 10/7/2012 ***Diameter (mm):*** 1500 ***Material Type:*** CMP: Corrugated

Northing: 6904951.23 ***Easting:*** 593055.41 ***Invert Elevation:*** 1285.87 ***Survey Date:*** 10/7/2012 ***Diameter (mm):*** 1500 ***Material Type:*** CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert | Roads Unpaved | Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:71 Culvert: C66A Map Grid: M11
Faro Mine Interim Works

CH2MHILL





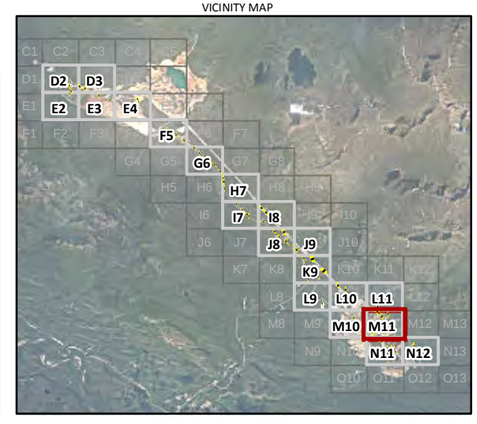
CULVERT C66B INLET

UPSTREAM (C66B.IU)	DOWNSTREAM (C66B.ID)
Photo Not Available	Photo Not Available

CULVERT C66B OUTLET

UPSTREAM (C66B.OU)	DOWNSTREAM (C66B.OD)
Photo Not Available	Photo Not Available

VICINITY MAP



Northing: 6904962.04	***Invert Elevation:*** 1286.54	***Diameter (mm):*** 1500	***Northing:*** 6904951.23	***Invert Elevation:*** 1285.87	***Diameter (mm):*** 1500
Easting: 593061.43	***Survey Date:*** 10/7/2012	***Material Type:*** CMP: Corrugated	***Easting:*** 593055.41	***Survey Date:*** 10/7/2012	***Material Type:*** CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert — Roads Unpaved — Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:72 Culvert: C66B Map Grid: M11
Faro Mine Interim Works

CH2MHILL





CULVERT C67 INLET

UPSTREAM (C67.IU)



DOWNSTREAM (C67.ID)



Northing: 6904929.93
Easting: 593047.70

Invert Elevation: 1283.54
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

CULVERT C67 OUTLET

UPSTREAM (C67.OU)



DOWNSTREAM (C67.OD)

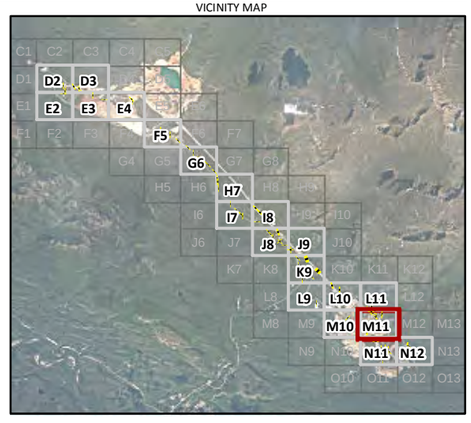


Northing: 6904916.63
Easting: 593045.58

Invert Elevation: 1282.61
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

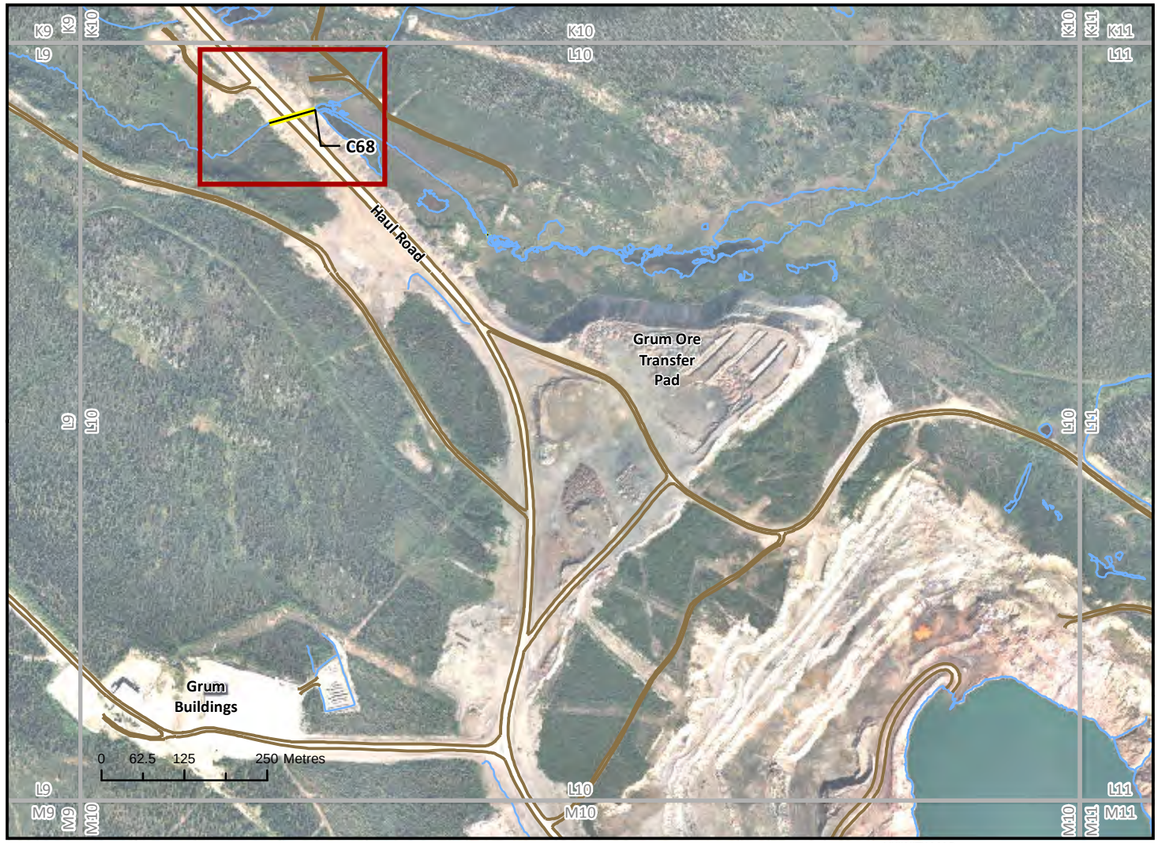
Culvert
Roads Unpaved
Culvert Grid

N

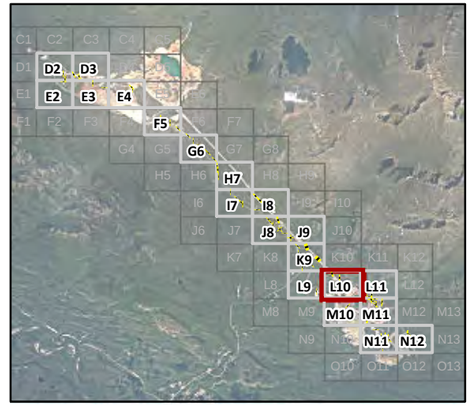
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:73 Culvert: C67 Map Grid: M11
Faro Mine Interim Works





VICINITY MAP



CULVERT C68 INLET

UPSTREAM (C68.IU)



DOWNSTREAM (C68.ID)



Northing: 6906245.78
Easting: 591261.82

Invert Elevation: 1285.64
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C68 OUTLET

UPSTREAM (C68.OU)



DOWNSTREAM (C68.OD)



Northing: 6906226.12
Easting: 591192.20

Invert Elevation: 1283.76
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

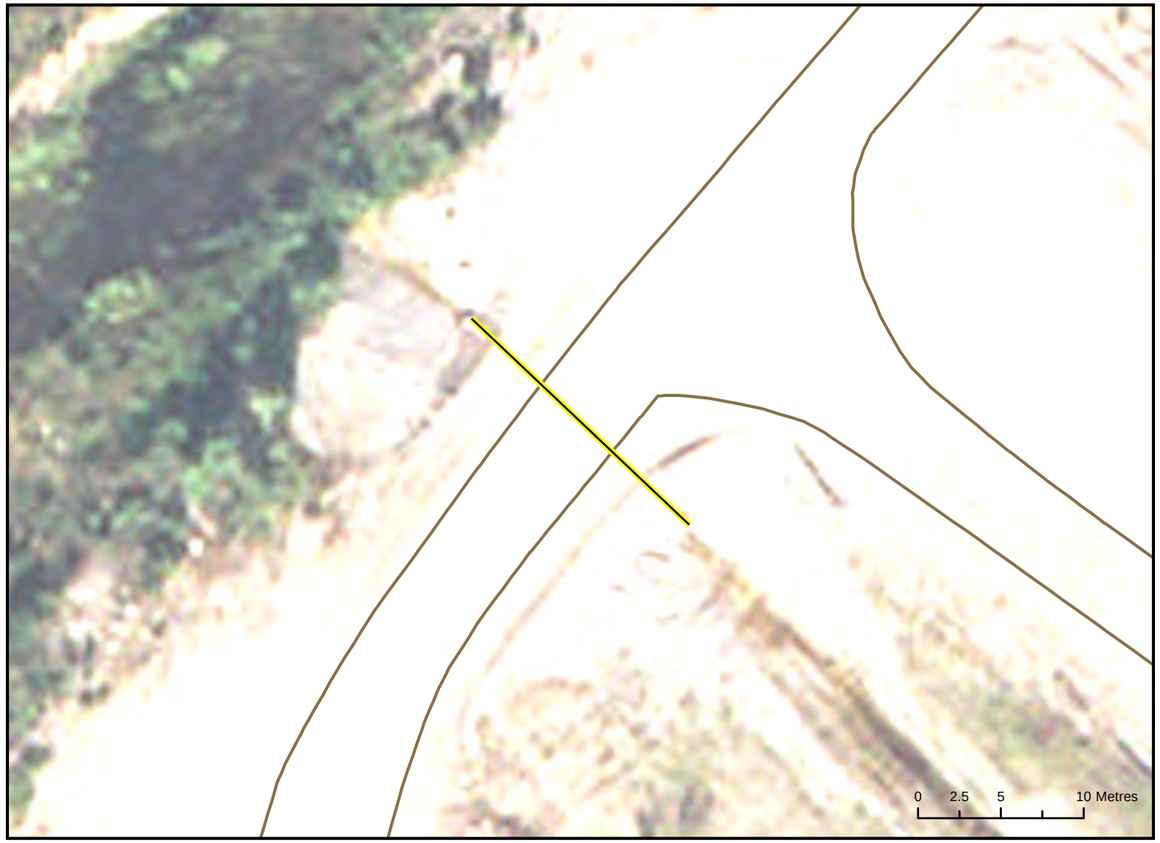
Culvert
Roads Unpaved
Culvert Grid

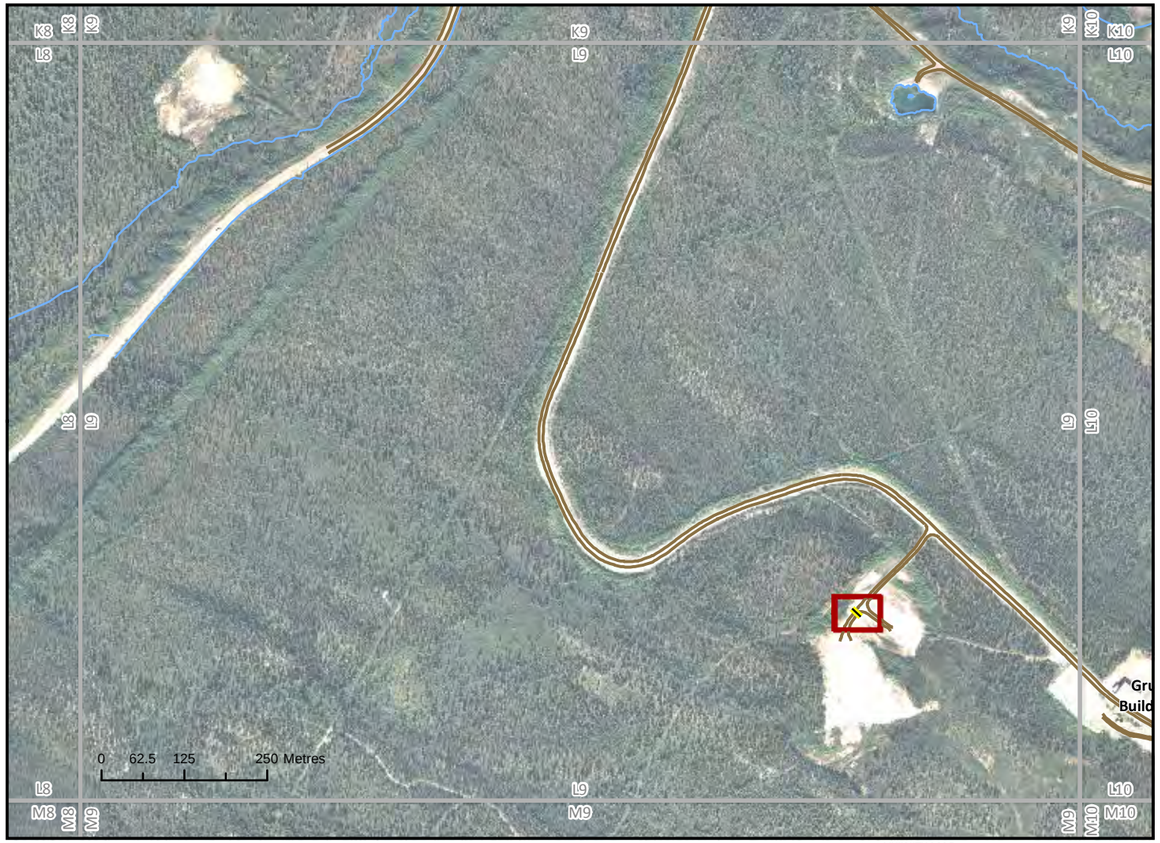
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:74 Culvert: C68 Map Grid: L10
Faro Mine Interim Works

CH2MHILL





CULVERT C68A INLET

UPSTREAM (C68A.IU)

Photo Not Available

DOWNSTREAM (C68A.ID)

Photo Not Available

CULVERT C68A OUTLET

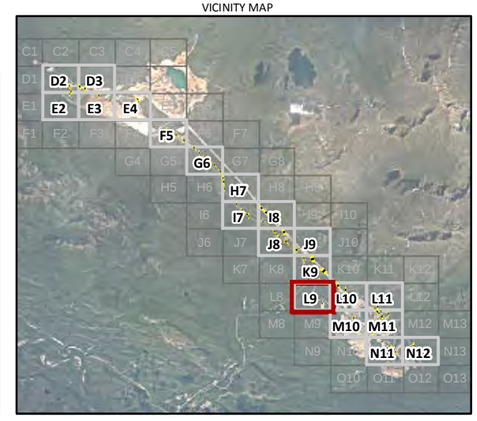
UPSTREAM (C68A.OU)

Photo Not Available

DOWNSTREAM (C68A.OD)

Photo Not Available

VICINITY MAP



Northing: 6906245.78
Easting: 591261.82
Invert Elevation: 1285.64
Survey Date: 10/7/2012
Diameter (mm): 900
Material Type: CMP: Corrugated

Northing: 6906226.12
Easting: 591192.20
Invert Elevation: 1283.76
Survey Date: 10/7/2012
Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

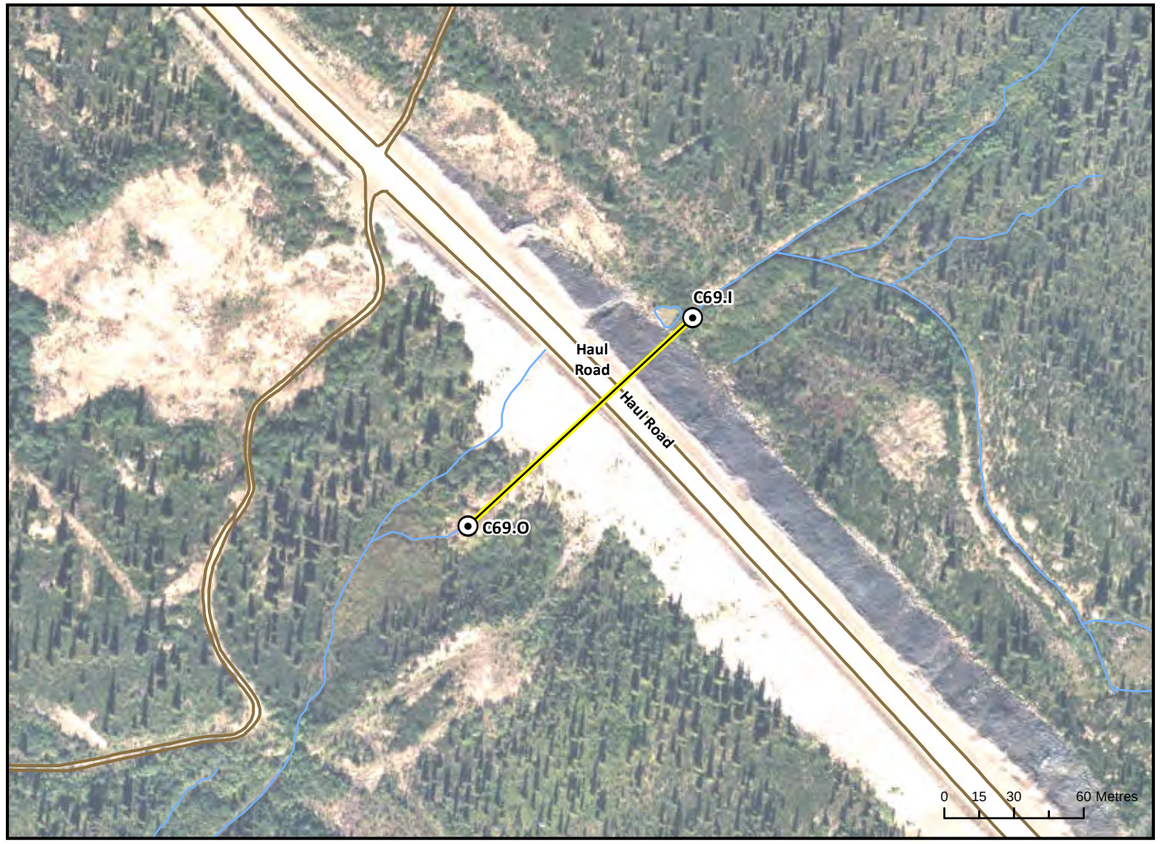
Culvert
Roads Unpaved
Culvert Grid

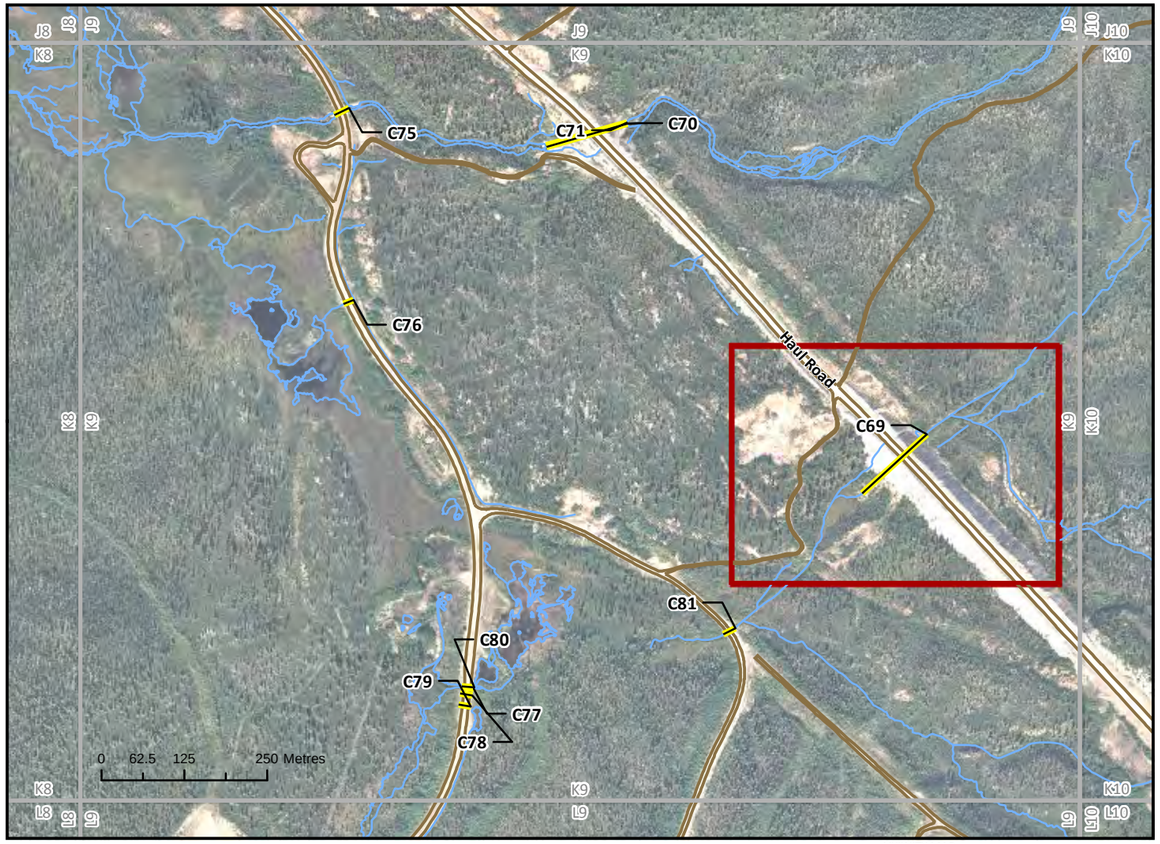
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

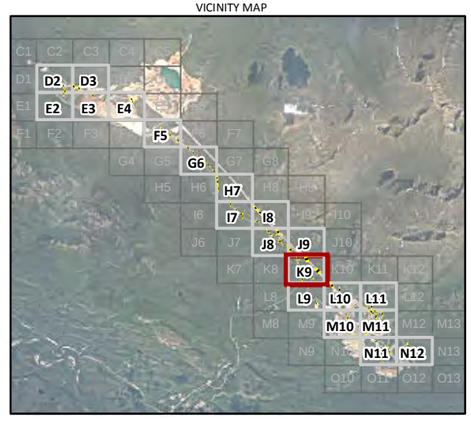
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:75 Culvert: C68A Map Grid: L9
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C69 INLET

UPSTREAM (C69.IU)



DOWNSTREAM (C69.ID)



Northing: 6906899.56
Easting: 590676.19

Invert Elevation: 1244.52
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C69 OUTLET

UPSTREAM (C69.OU)



DOWNSTREAM (C69.OD)



Northing: 6906809.93
Easting: 590579.16

Invert Elevation: 1230.64
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

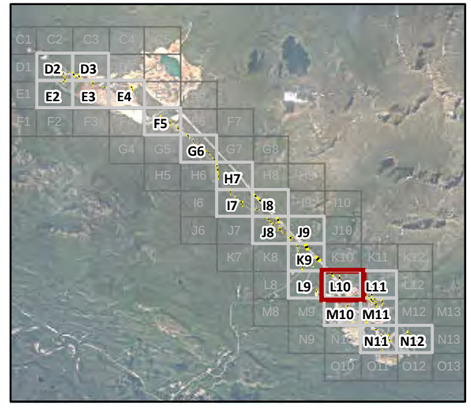
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:76 Culvert: C69 Map Grid: K9
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C68B INLET

UPSTREAM (C68B.IU)

Photo Not Available

DOWNSTREAM (C68B.ID)

Photo Not Available

Northing: 6906245.78
Easting: 591261.82
Invert Elevation: 1285.64
Survey Date: 10/7/2012
Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C68B OUTLET

UPSTREAM (C68B.OU)

Photo Not Available

DOWNSTREAM (C68B.OD)

Photo Not Available

Northing: 6906226.12
Easting: 591192.20
Invert Elevation: 1283.76
Survey Date: 10/7/2012
Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

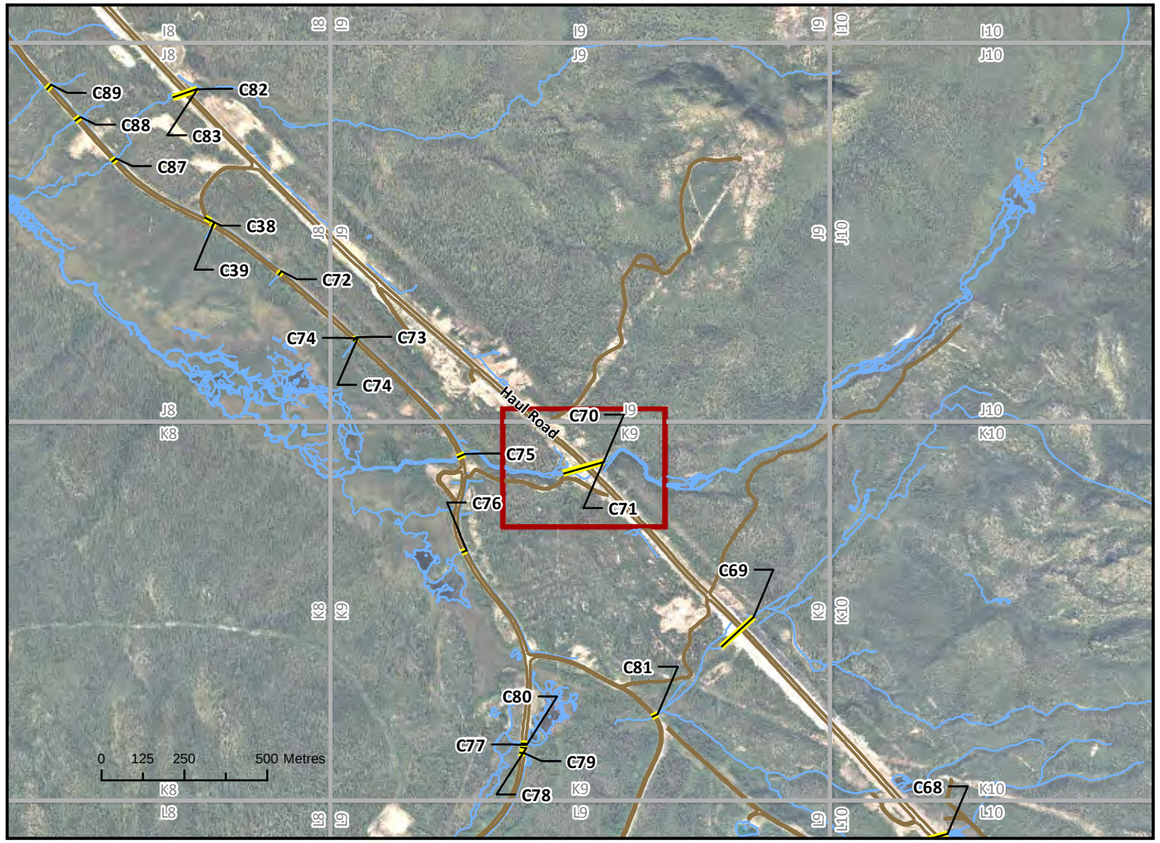
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

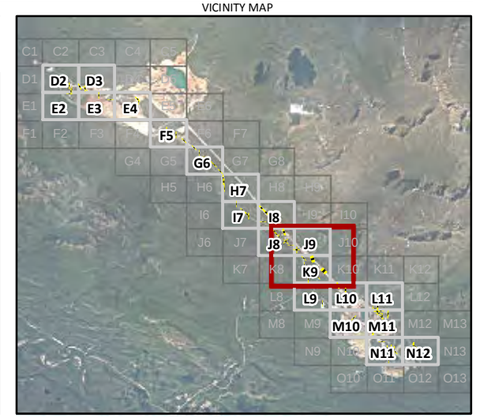
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:77 Culvert: C68B Map Grid: L10
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C70 INLET

UPSTREAM (C71.IU)



DOWNSTREAM (C71.ID)



Northing: 6907369.86
Easting: 590223.69

Invert Elevation: 1234.40
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

CULVERT C70 OUTLET

UPSTREAM (C71.OU)



DOWNSTREAM (C71.OD)



Northing: 6907333.10
Easting: 590102.89

Invert Elevation: 1229.26
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

Created by:
CRITIGEN

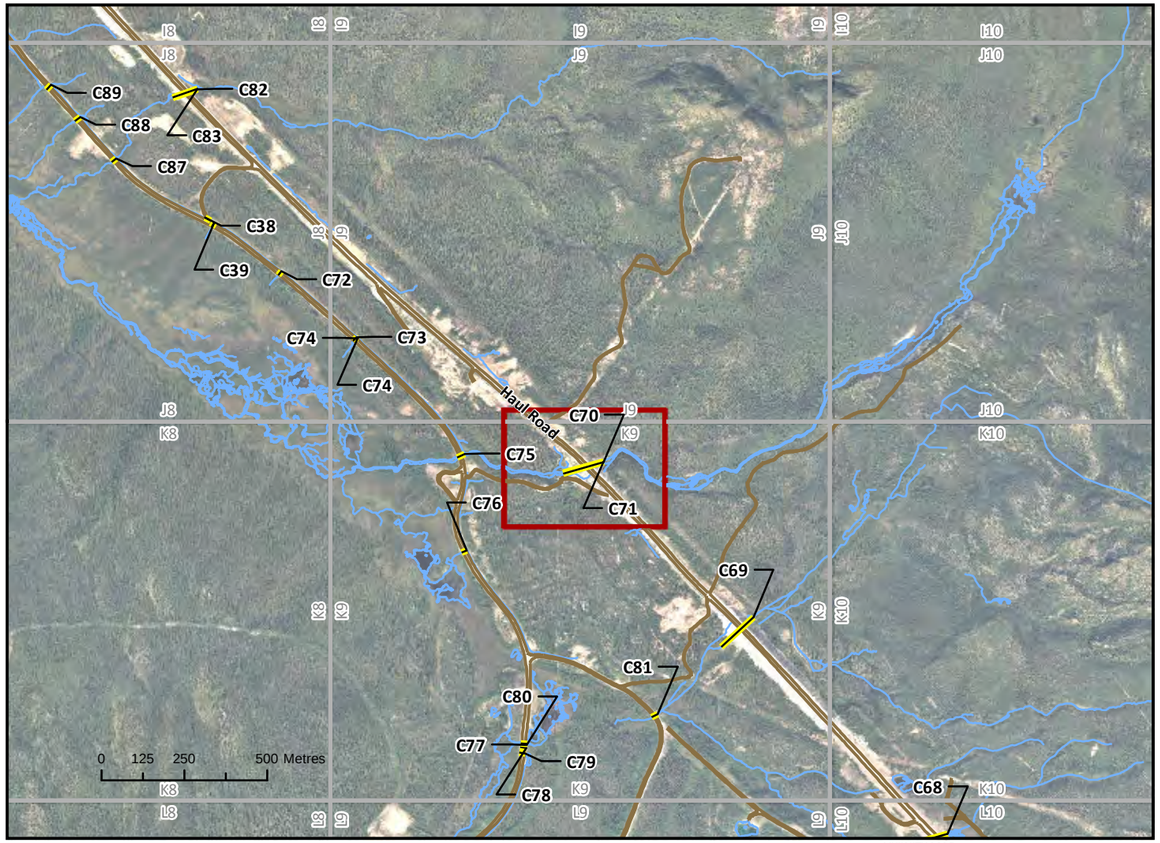
LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

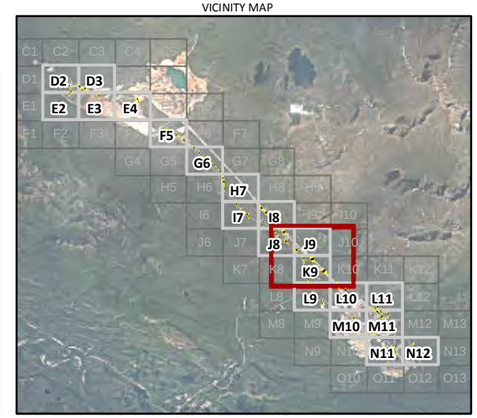
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:78 Culvert: C70 Map Grid: K9
Faro Mine Interim Works





VICINITY MAP



CULVERT C71 INLET

UPSTREAM (C71.IU)



DOWNSTREAM (C71.ID)



Northing: 6907369.86
Easting: 590223.69
Invert Elevation: 1234.40
Survey Date: 10/7/2012
Diameter (mm): 1500
Material Type: CMP: Corrugated

CULVERT C71 OUTLET

UPSTREAM (C71.OU)



DOWNSTREAM (C71.OD)



Northing: 6907333.10
Easting: 590102.89
Invert Elevation: 1229.26
Survey Date: 10/7/2012
Diameter (mm): 1500
Material Type: CMP: Corrugated

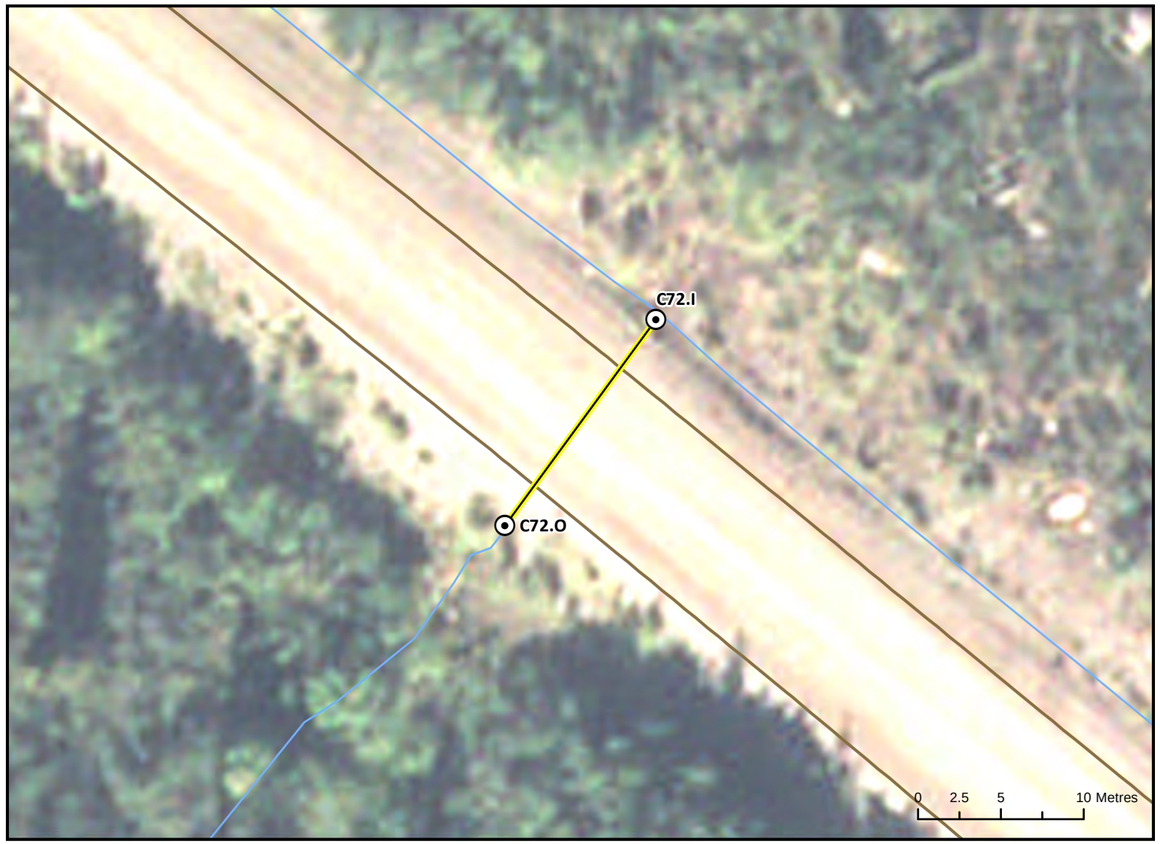
Created by: CRITIGEN

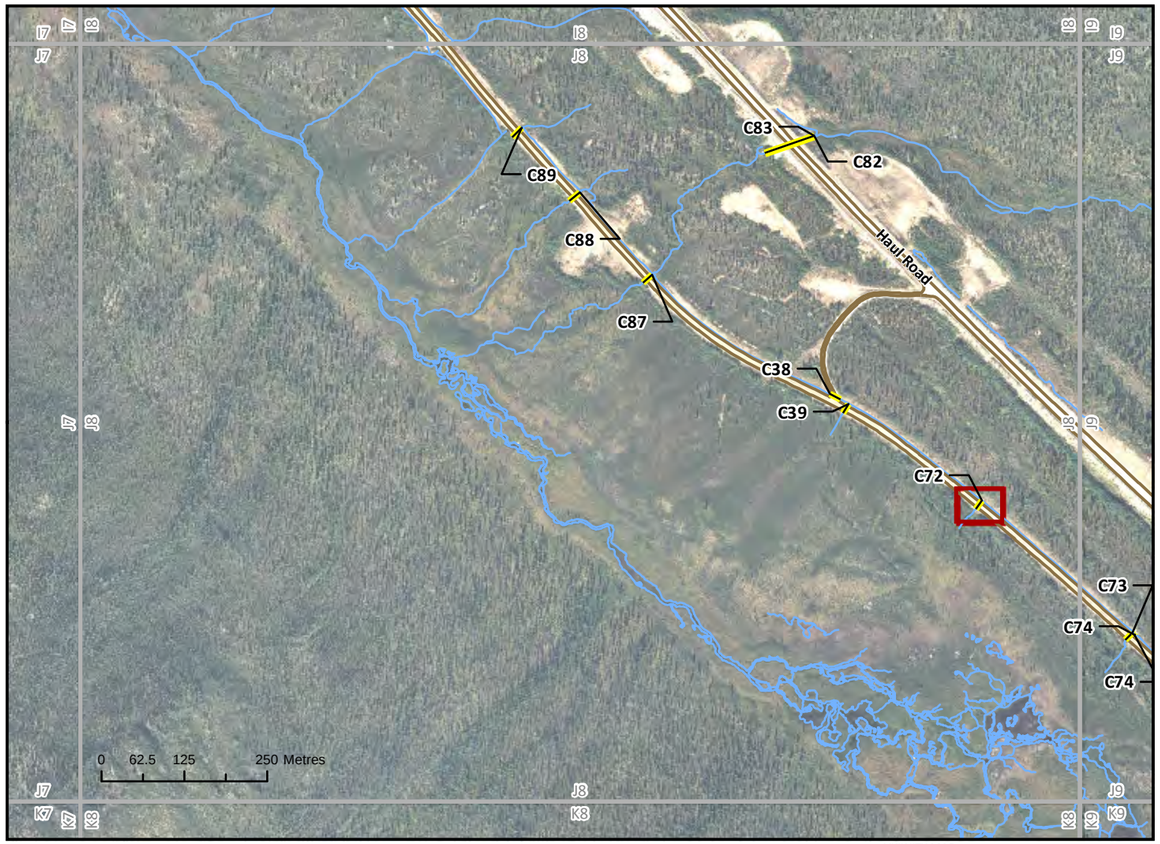
LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:79 Culvert: C71 Map Grid: K9
Faro Mine Interim Works





CULVERT C72 INLET

UPSTREAM (C72.IU)



DOWNSTREAM (C72.ID)



Northing: 6907943.74
Easting: 589251.55

Invert Elevation: 1201.20
Survey Date: 10/7/2012

Diameter (mm): 400
Material Type: CMP: Corrugated

CULVERT C72 OUTLET

UPSTREAM (C72.OU)



DOWNSTREAM (C72.OD)

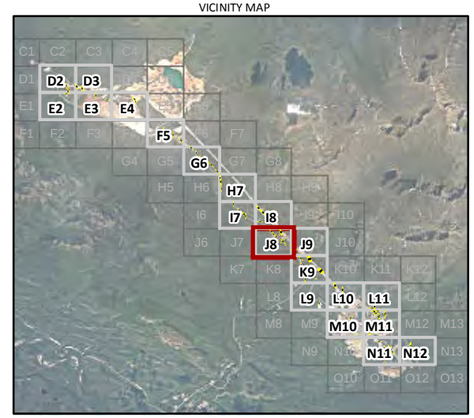


Northing: 6907931.33
Easting: 589242.41

Invert Elevation: 1200.42
Survey Date: 10/7/2012

Diameter (mm): 400
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

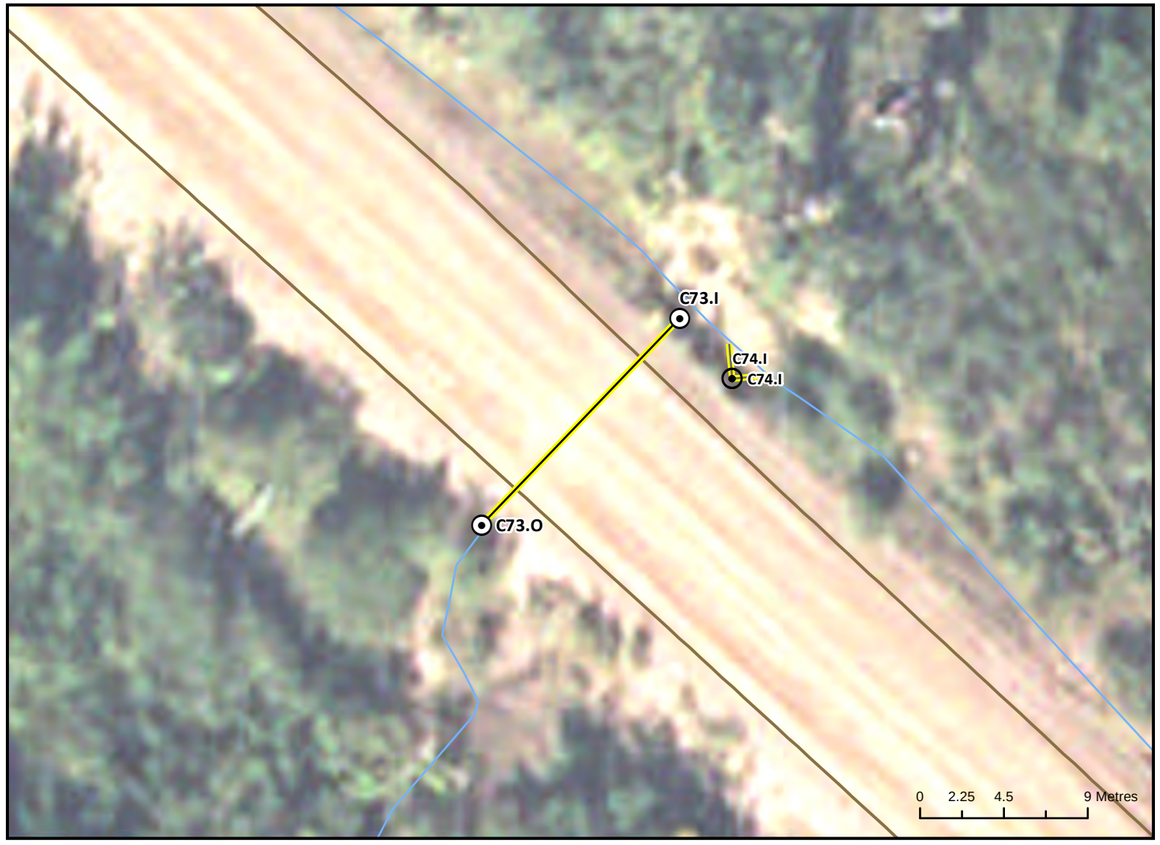
LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:80 Culvert: C72 Map Grid: J8
Faro Mine Interim Works





CULVERT C73 INLET

UPSTREAM (C73.IU)



DOWNSTREAM (C73.ID)



Northing: 6907744.48
Easting: 589478.68

Invert Elevation: 1203.71
Survey Date: 10/7/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C73 OUTLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (N/A)

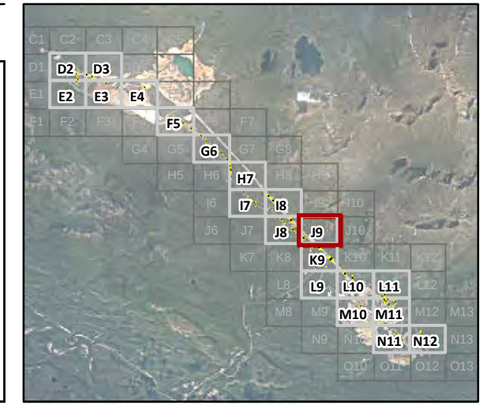
Photo Not Available

Northing: 6907733.39
Easting: 589468.06

Invert Elevation: 1203.32
Survey Date: 10/7/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

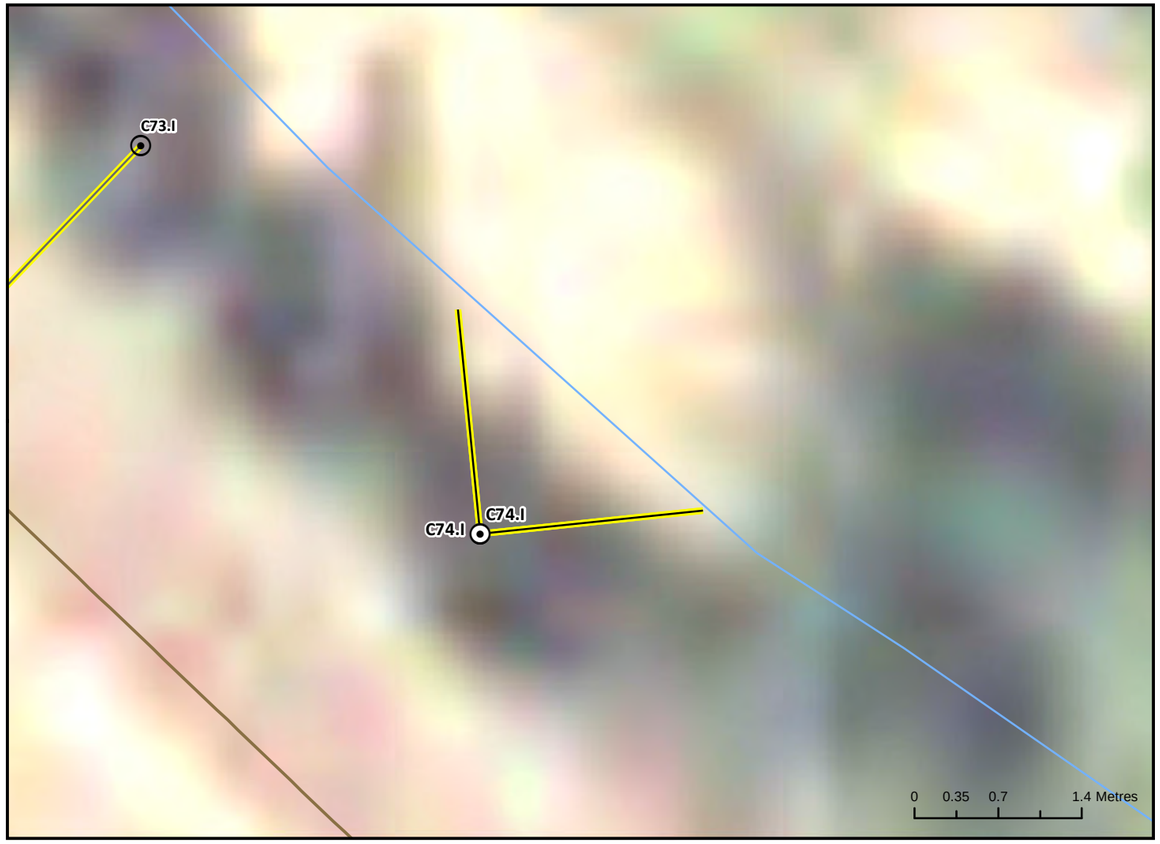
LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:81 Culvert: C73 Map Grid: J9
Faro Mine Interim Works





CULVERT C74 INLET

UPSTREAM (C74.IU)



DOWNSTREAM (C74.ID)



Northing: 6907741.23
Easting: 589481.52
Invert Elevation: 1203.81
Survey Date: 10/7/2012
Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C74 OUTLET

UPSTREAM (N/A)

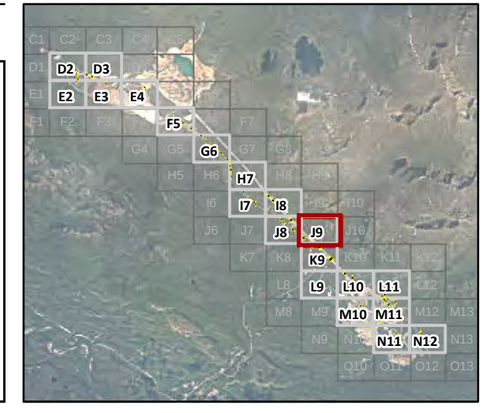
Photo Not Available

DOWNSTREAM (N/A)

Photo Not Available

Northing:
Easting:
Invert Elevation:
Survey Date:
Diameter (mm): 450
Material Type: N/A

VICINITY MAP



Created by: CRITIGEN

LEGEND

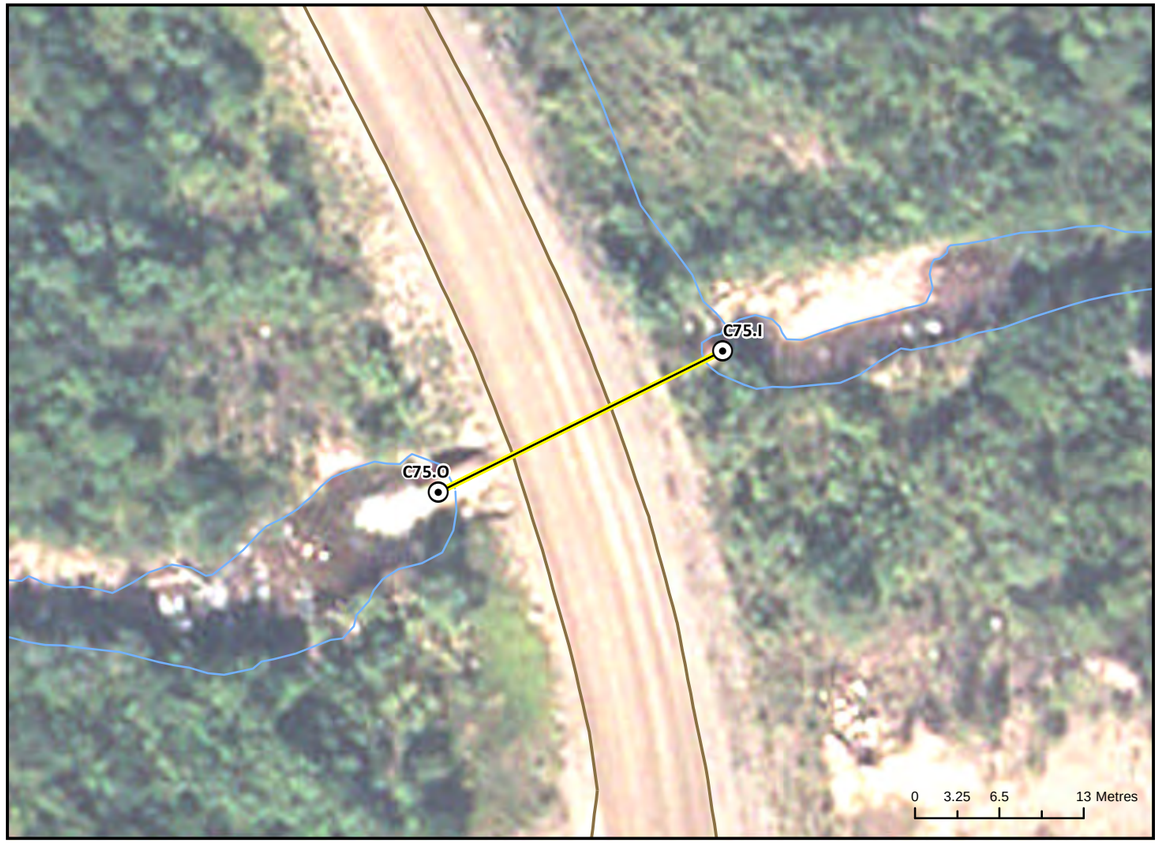
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:82 Culvert: C74 Map Grid: J9
Faro Mine Interim Works

CH2MHILL





CULVERT C75 INLET

UPSTREAM (C75.IU)



DOWNSTREAM (C75.ID)



Northing: 6907391.92
Easting: 589804.98

Invert Elevation: 1206.59
Survey Date: 10/7/2012

Diameter (mm): 2400
Material Type: CMP: Corrugated

CULVERT C75 OUTLET

UPSTREAM (C75.OU)



DOWNSTREAM (C75.OD)

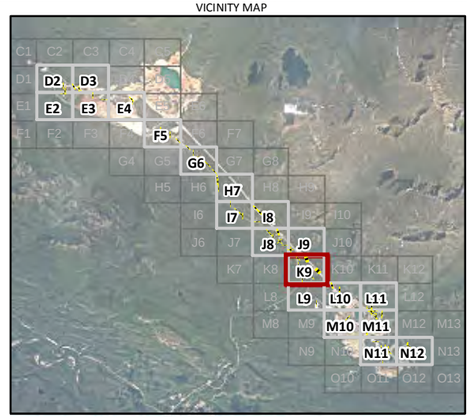


Northing: 6907381.05
Easting: 589783.02

Invert Elevation: 1208.16
Survey Date: 10/7/2012

Diameter (mm): 2400
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

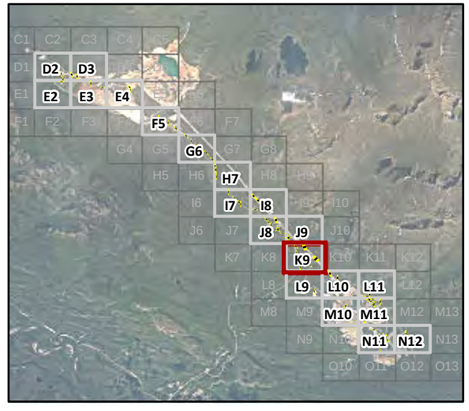
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:83 Culvert: C75 Map Grid: K9
Faro Mine Interim Works





VICINITY MAP



CULVERT C76 INLET

UPSTREAM (C76.IU)



DOWNSTREAM (C76.ID)



Northing: 6907101.84
Easting: 589811.99

Invert Elevation: 1198.68
Survey Date: 10/7/2012

Diameter (mm): 400
Material Type: CMP: Corrugated

CULVERT C76 OUTLET

UPSTREAM (C76.OU)



DOWNSTREAM (C76.OD)



Northing: 6907095.82
Easting: 589796.44

Invert Elevation: 1197.89
Survey Date: 10/7/2012

Diameter (mm): 400
Material Type: RCA: Smooth

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

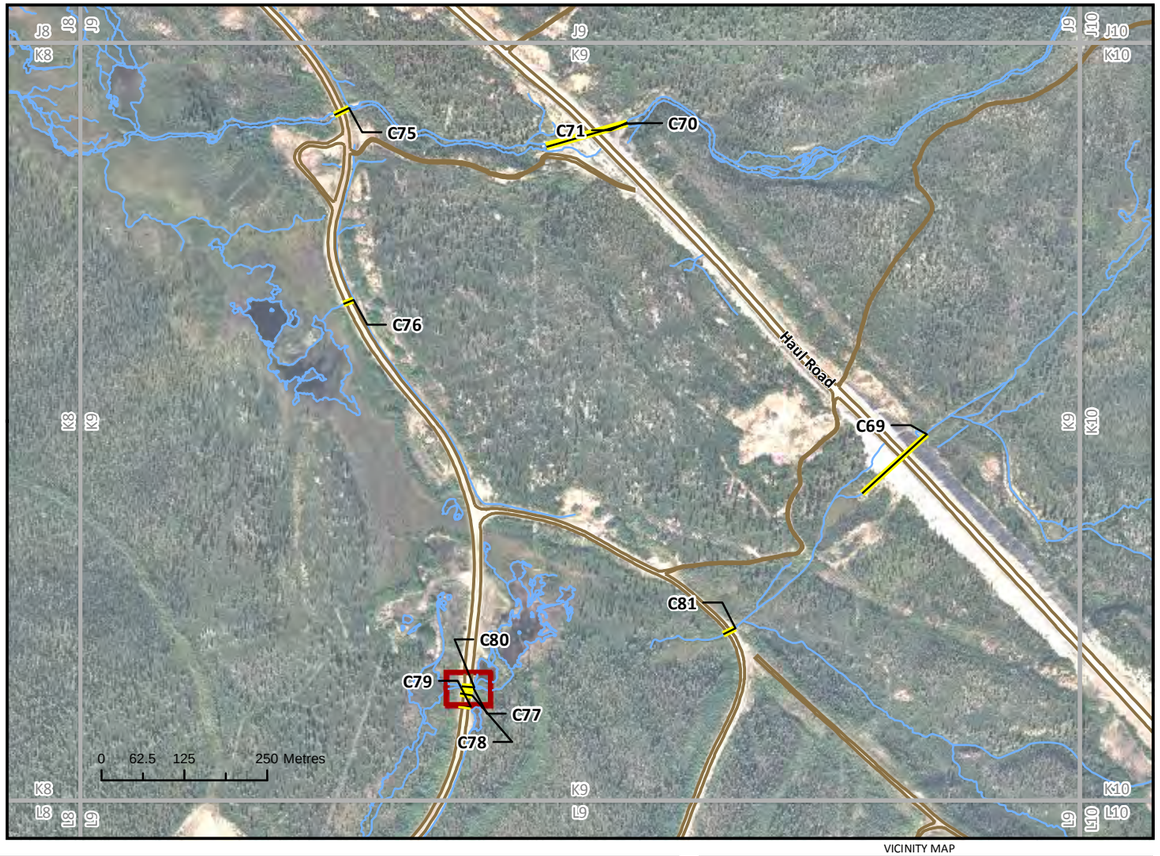
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:84 Culvert: C76 Map Grid: K9
Faro Mine Interim Works

CH2MHILL





CULVERT C77 INLET

UPSTREAM (C77.IU)



DOWNSTREAM (C77.ID)



Northing: 6906515.01
Easting: 589992.66

Invert Elevation: 1196.24
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C77 OUTLET

UPSTREAM (C77.OU)



DOWNSTREAM (C77.OD)

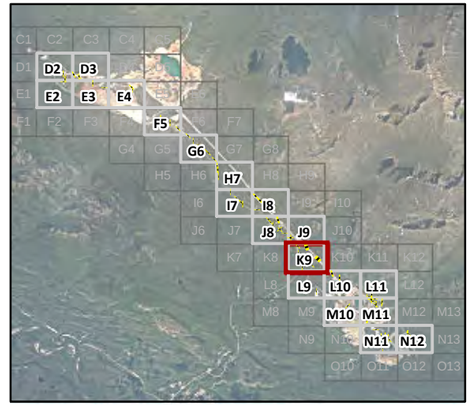


Northing: 6906518.55
Easting: 589975.64

Invert Elevation: 1195.55
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

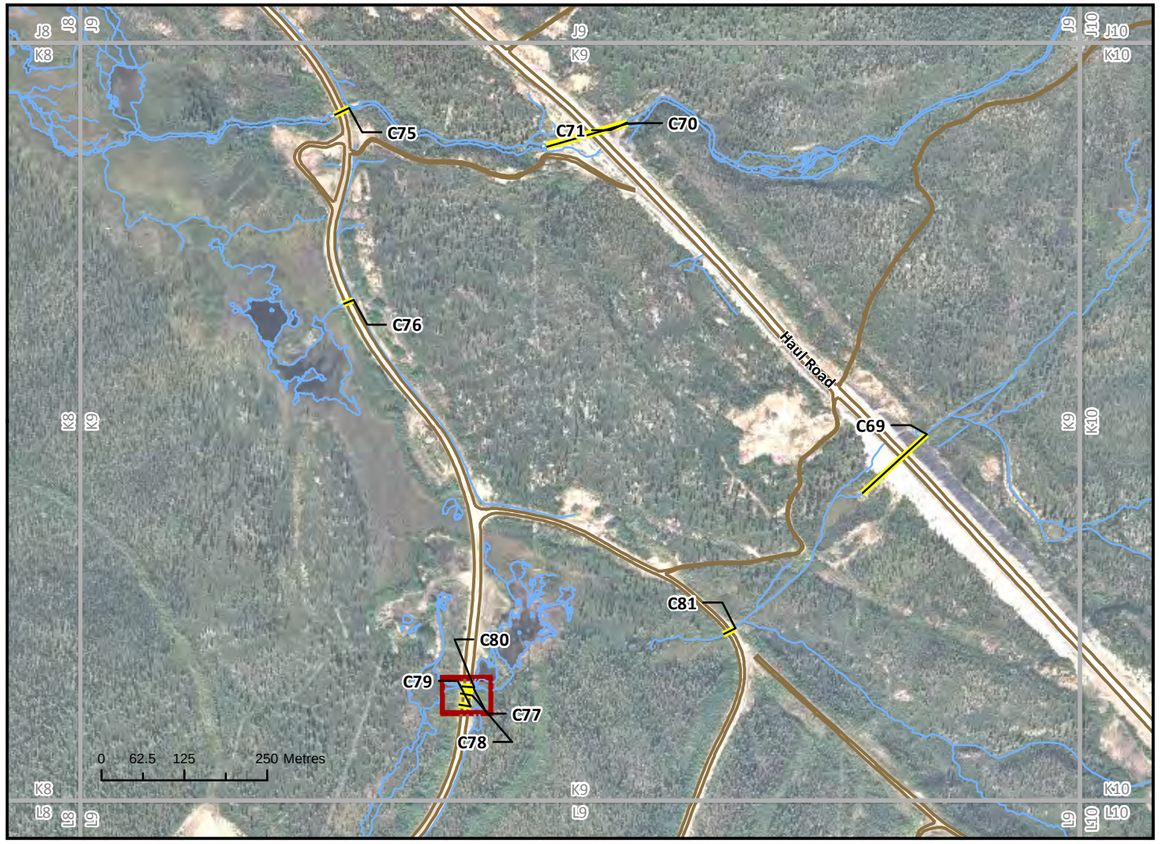
Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:85 Culvert: C77 Map Grid: K9
Faro Mine Interim Works





VICINITY MAP

CULVERT C78 INLET

UPSTREAM (C78.IU)



DOWNSTREAM (C78.ID)



Northing: 6906505.72
Easting: 589991.03

Invert Elevation: 1196.31
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C78 OUTLET

UPSTREAM (C78.OU)



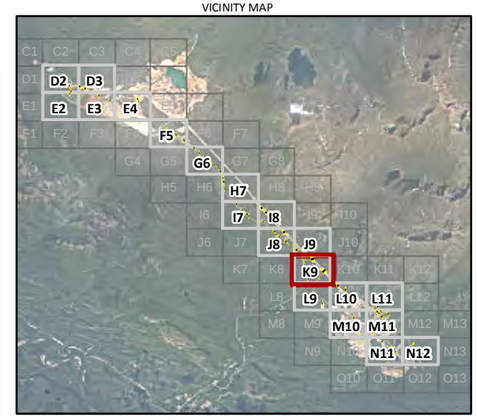
DOWNSTREAM (C78.OD)



Northing: 6906508.54
Easting: 589972.67

Invert Elevation: 1196.05
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated



Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

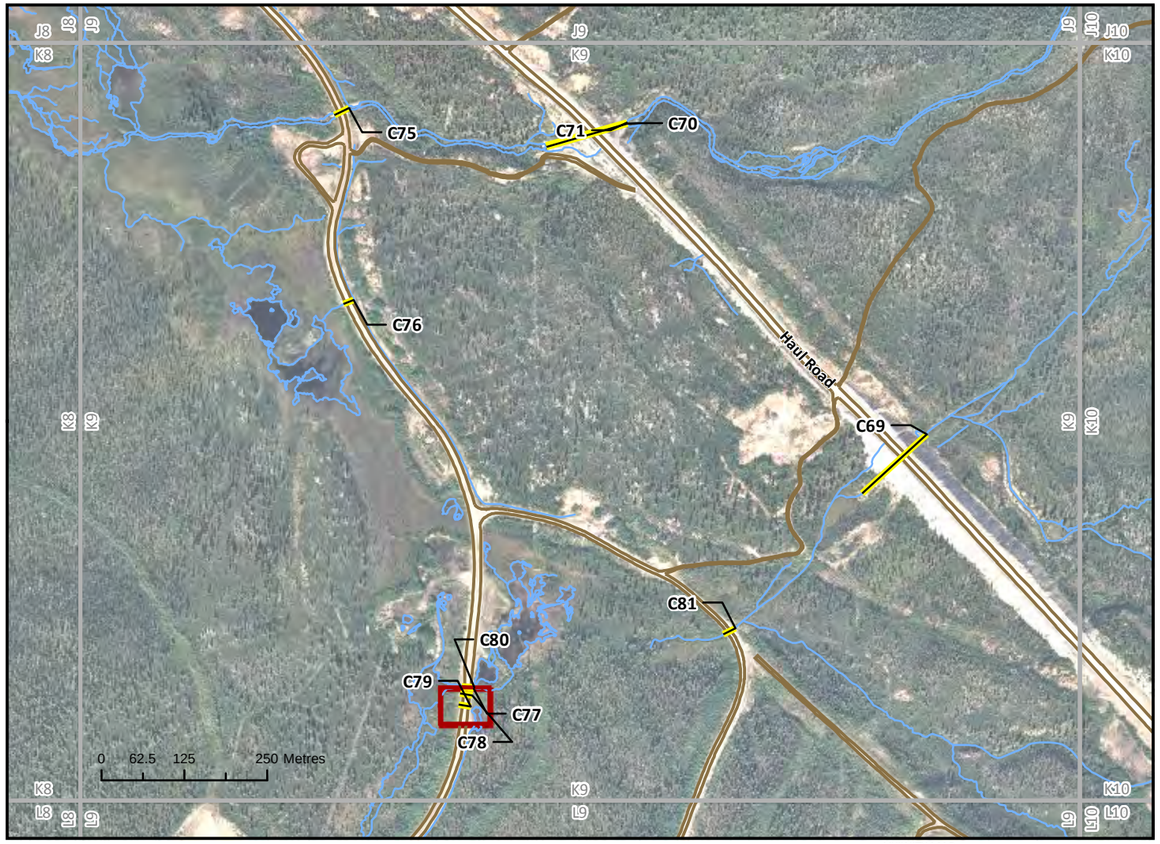
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

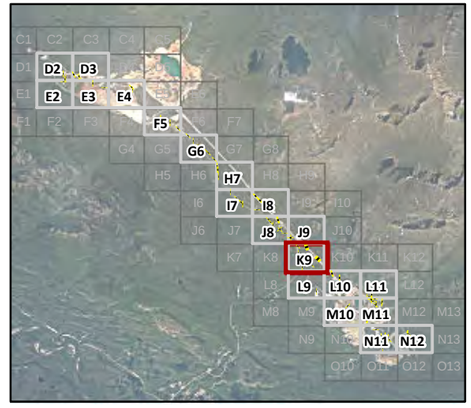
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:86 Culvert: C78 Map Grid: K9
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C79 INLET

UPSTREAM (C79.IU)



DOWNSTREAM (C79.ID)



Northing: 6906488.82
Easting: 589988.72

Invert Elevation: 1195.66
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C79 OUTLET

UPSTREAM (C79.OU)



DOWNSTREAM (C79.OD)



Northing: 6906491.51
Easting: 589970.02

Invert Elevation: 1194.93
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

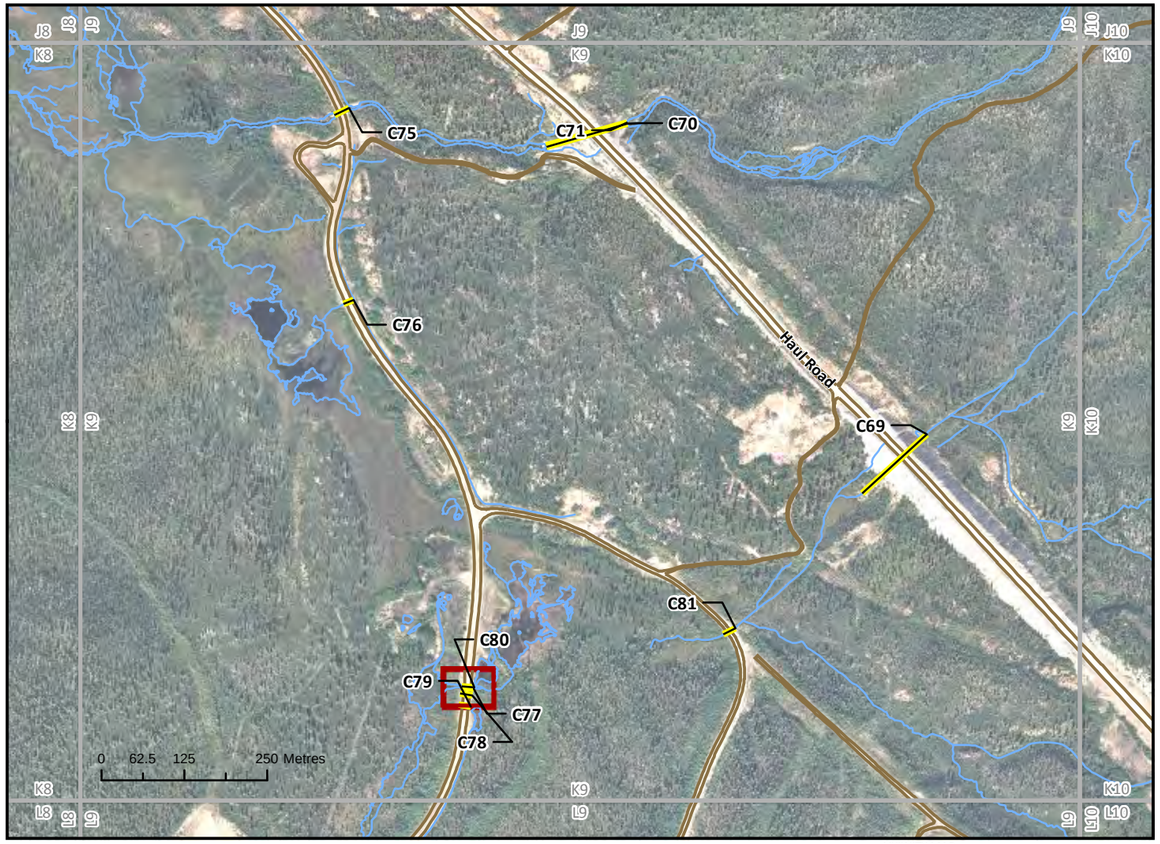
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

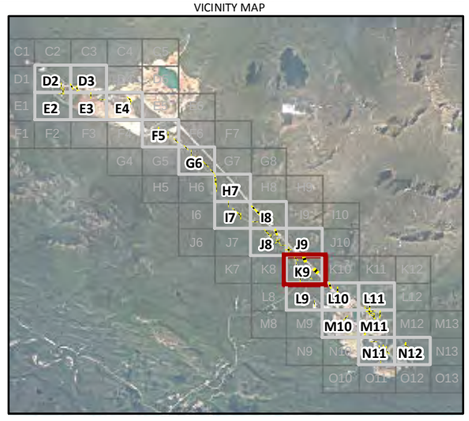
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:87 Culvert: C79 Map Grid: K9
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C80 INLET

UPSTREAM (C80.IU)



DOWNSTREAM (C80.ID)



Northing: 6906517.74
Easting: 589994.05

Invert Elevation: 1195.20
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C80 OUTLET

UPSTREAM (C80.OU)



DOWNSTREAM (C80.OD)



Northing: 6906519.08
Easting: 589974.85

Invert Elevation: 1194.58
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert — Roads Unpaved — Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

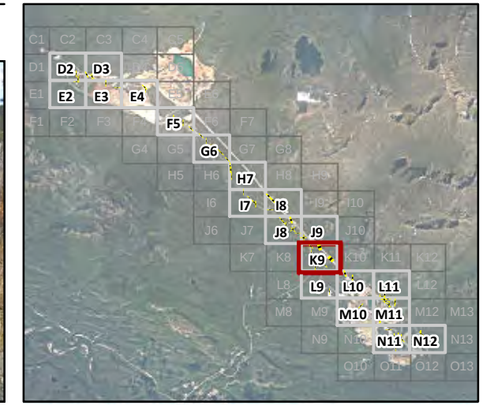
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:88 Culvert: C80 Map Grid: K9
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C81 INLET

UPSTREAM (C81.IU)



DOWNSTREAM (C81.ID)



Northing: 6906607.09
Easting: 590387.62

Invert Elevation: 1211.00
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

CULVERT C81 OUTLET

UPSTREAM (C81.OU)



DOWNSTREAM (C81.OD)



Northing: 6906597.61
Easting: 590369.38

Invert Elevation: 1209.93
Survey Date: 10/7/2012

Diameter (mm): 1500
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

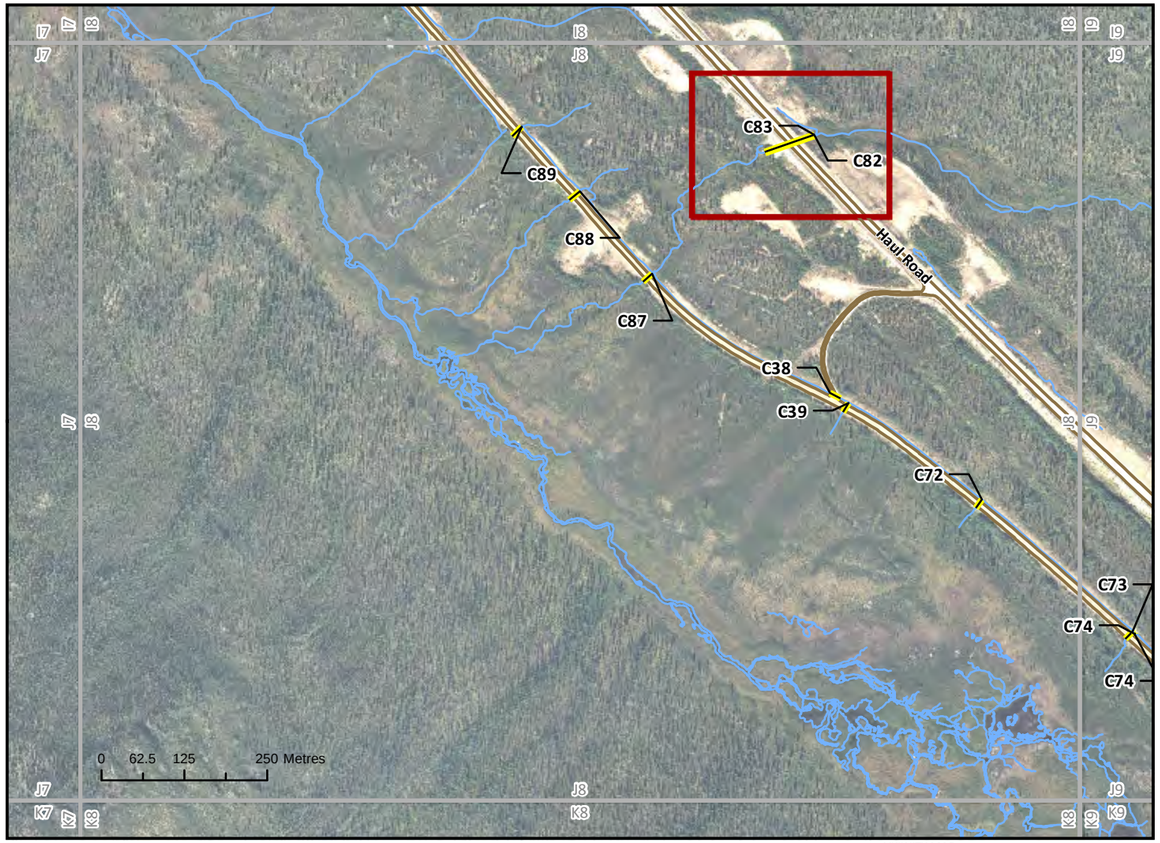
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

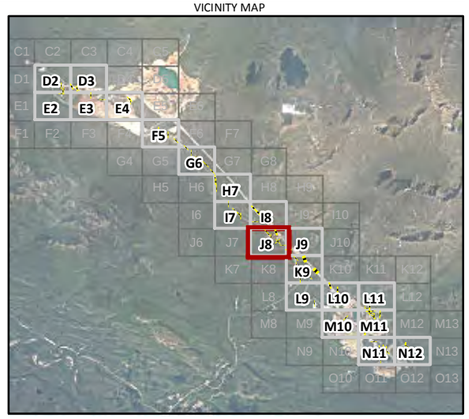
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:89 Culvert: C81 Map Grid: K9
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C82 INLET

UPSTREAM (C82.IU)



DOWNSTREAM (C82.ID)



Northing: 6908492.46
Easting: 588998.95

Invert Elevation: 1219.27
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C82 OUTLET

UPSTREAM (C82.OU)



DOWNSTREAM (C82.OD)



Northing: 6908466.73
Easting: 588924.48

Invert Elevation: 1215.96
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

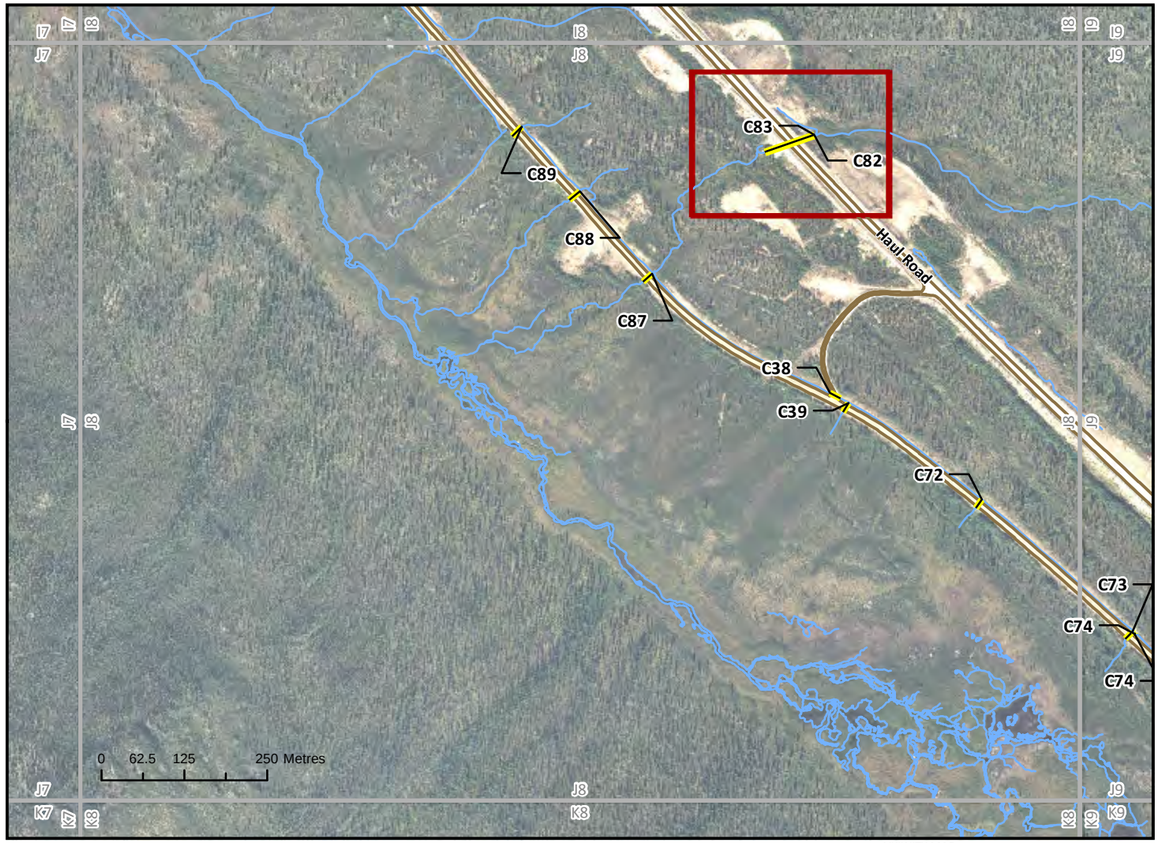
Culvert — Roads Unpaved — Culvert Grid

N

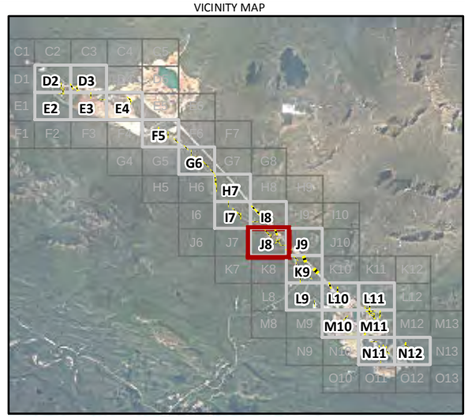
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:90 Culvert: C82 Map Grid: J8
Faro Mine Interim Works





VICINITY MAP



CULVERT C83 INLET

UPSTREAM (C83.IU)



DOWNSTREAM (C83.ID)



Northing: 6908494.42
Easting: 588998.36

Invert Elevation: 1219.08
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C83 OUTLET

UPSTREAM (C83.OU)



DOWNSTREAM (C83.OD)



Northing: 6908468.44
Easting: 588924.04

Invert Elevation: 1215.72
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

Created by: CRITIGEN

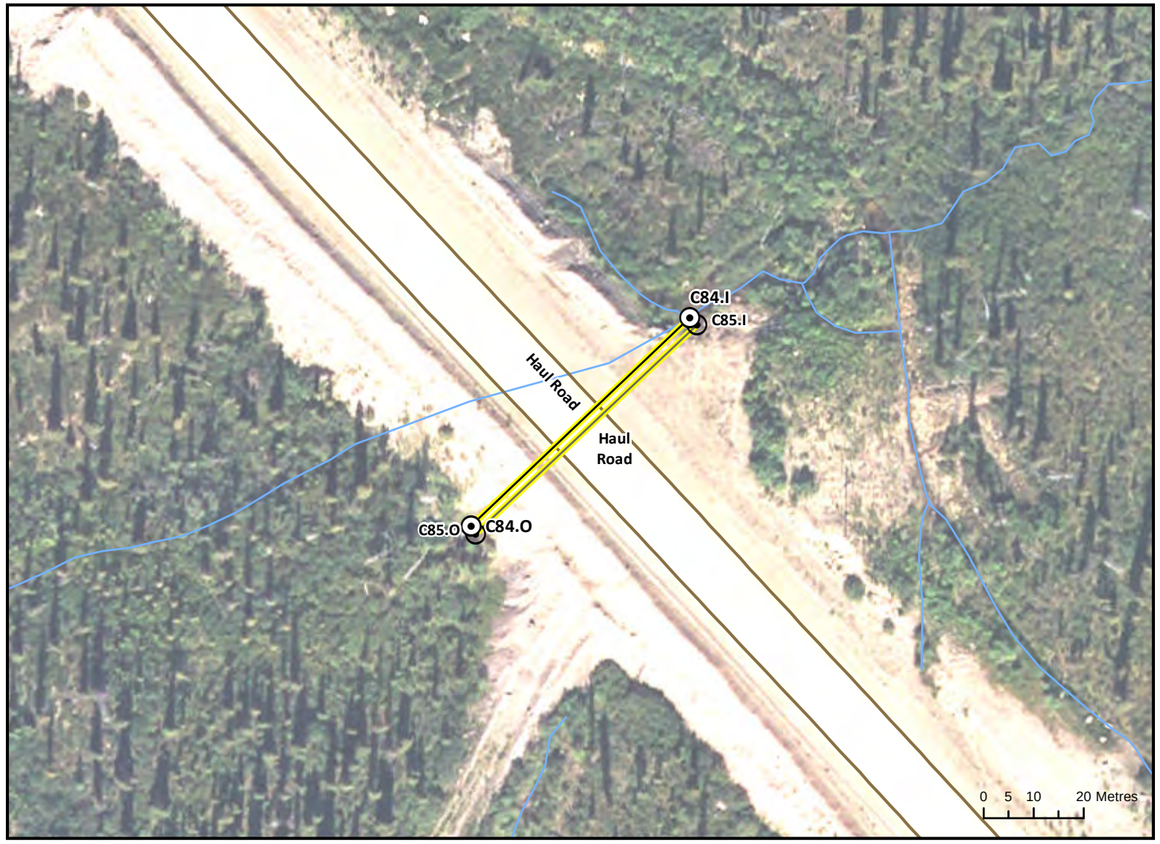
LEGEND

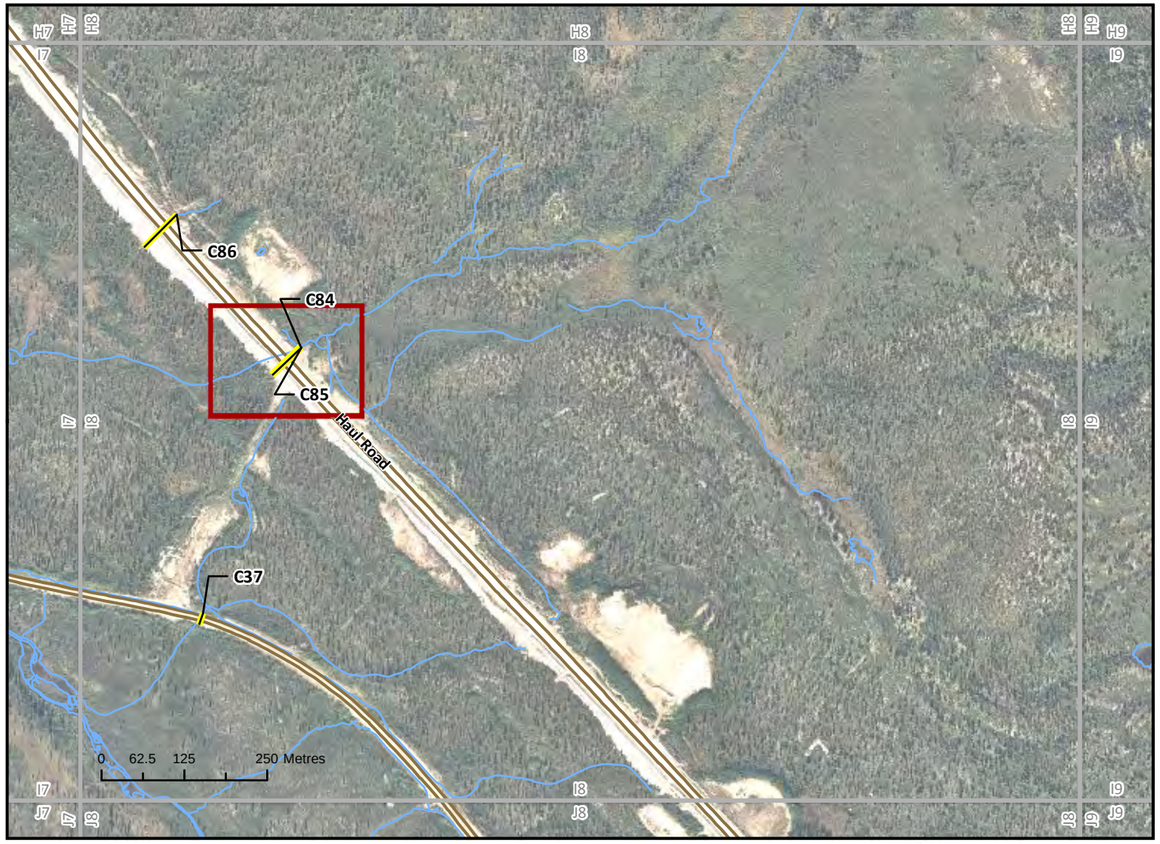
Culvert — Roads Unpaved — Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:91 Culvert: C83 Map Grid: J8
Faro Mine Interim Works





CULVERT C84 INLET

UPSTREAM (C84.IU)



DOWNSTREAM (C84.ID)



Northing: 6909317.75
Easting: 588223.60

Invert Elevation: 1216.05
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

CULVERT C84 OUTLET

UPSTREAM (C84.OU)



DOWNSTREAM (C84.OD)

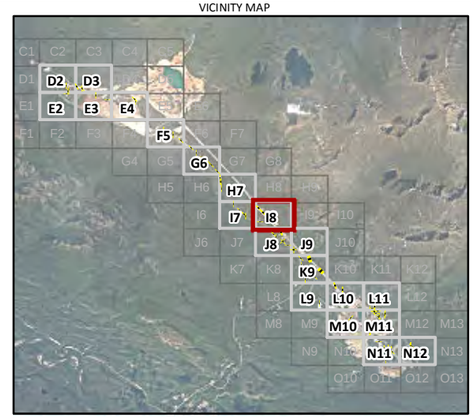


Northing: 6909276.23
Easting: 588179.89

Invert Elevation: 1210.72
Survey Date: 10/7/2012

Diameter (mm): 900
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

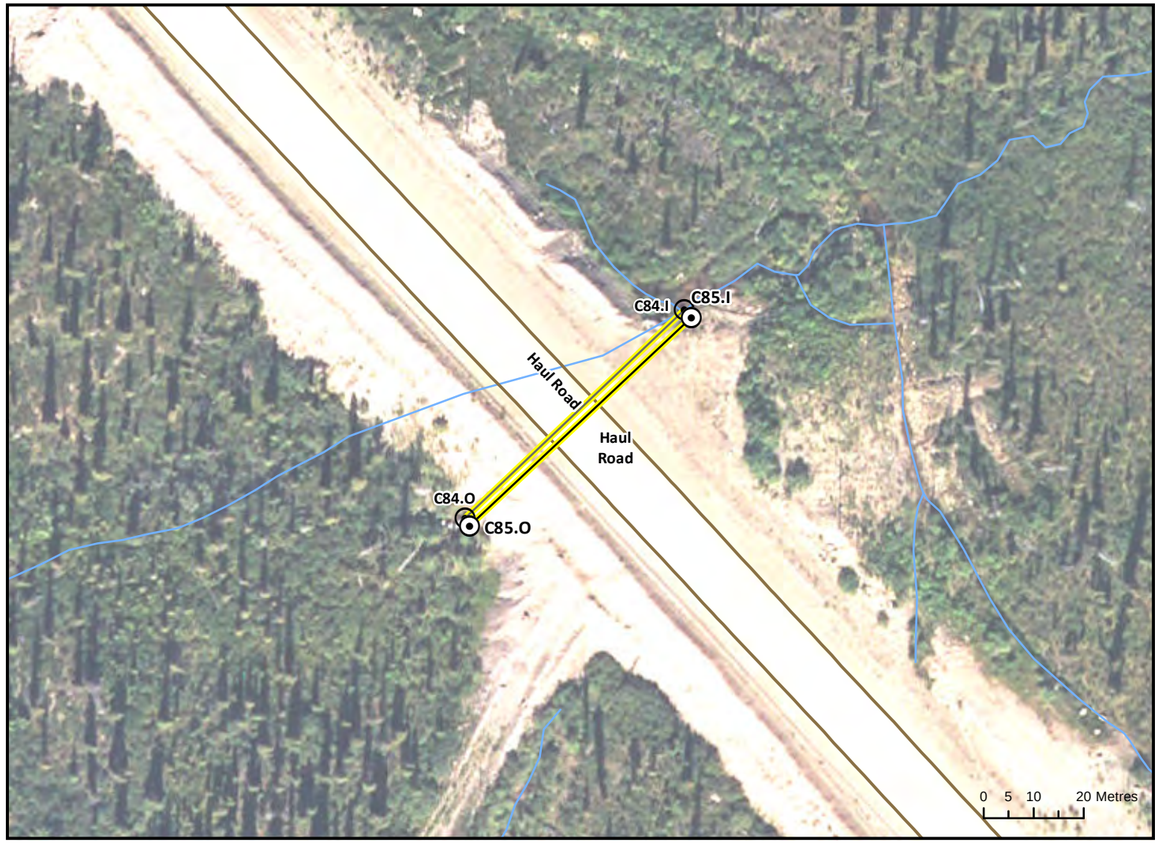
Culvert
Roads Unpaved
Culvert Grid

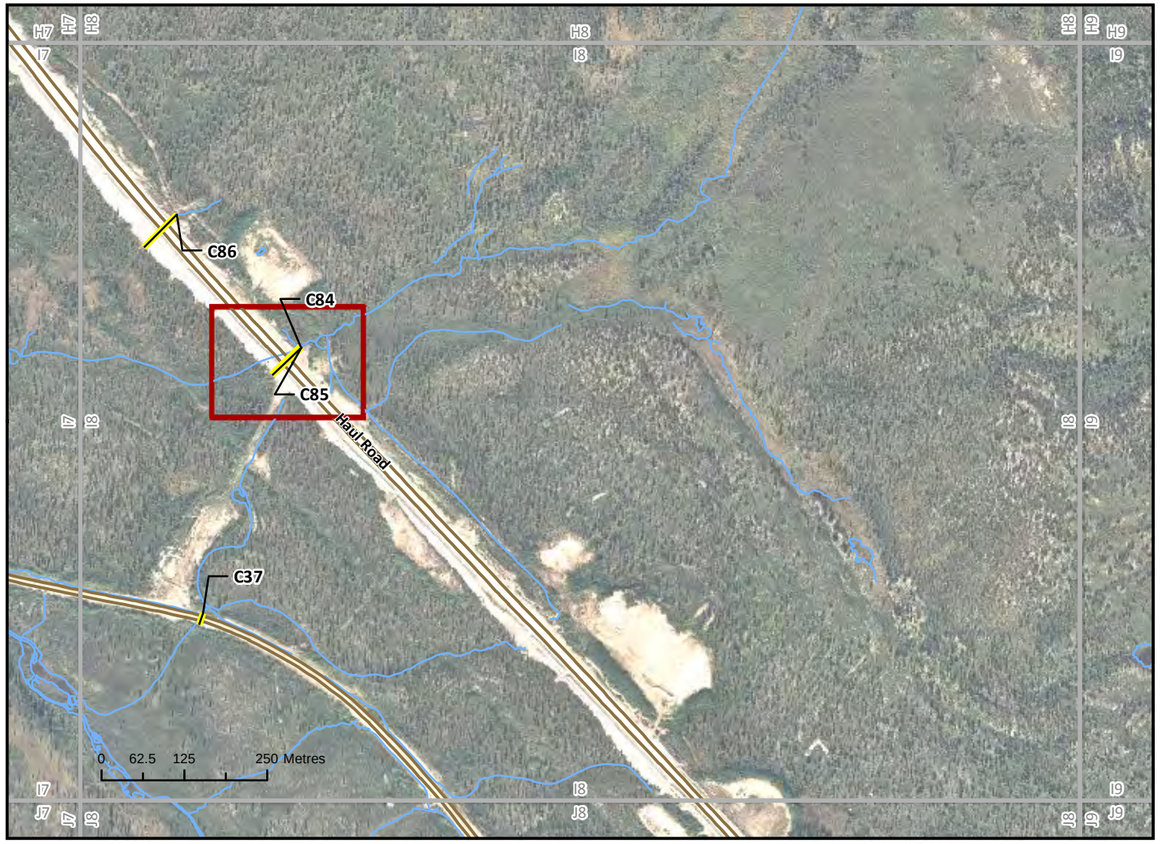
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:92 Culvert: C84 Map Grid: I8
Faro Mine Interim Works

CH2MHILL





CULVERT C85 INLET

UPSTREAM (C85.IU)



DOWNSTREAM (C85.ID)



Northing: 6909316.24
Easting: 588224.95

Invert Elevation: 1216.48
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C85 OUTLET

UPSTREAM (C85.OU)



DOWNSTREAM (C85.OD)

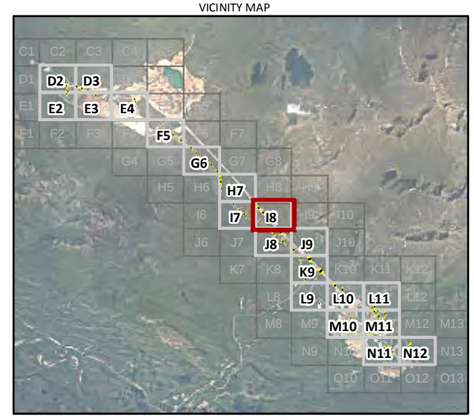


Northing: 6909274.64
Easting: 588180.80

Invert Elevation: 1211.19
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

VICINITY MAP



Created by: CRITIGEN

LEGEND

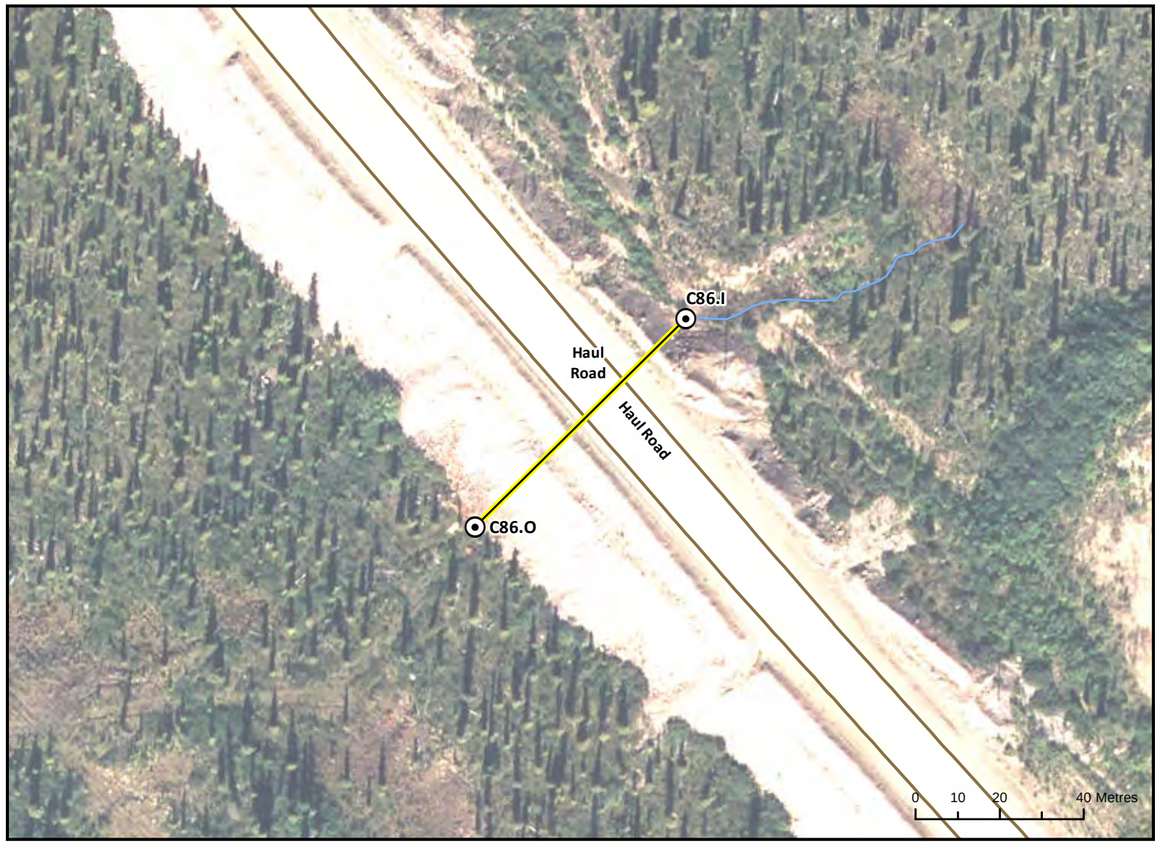
Culvert
Roads Unpaved
Culvert Grid

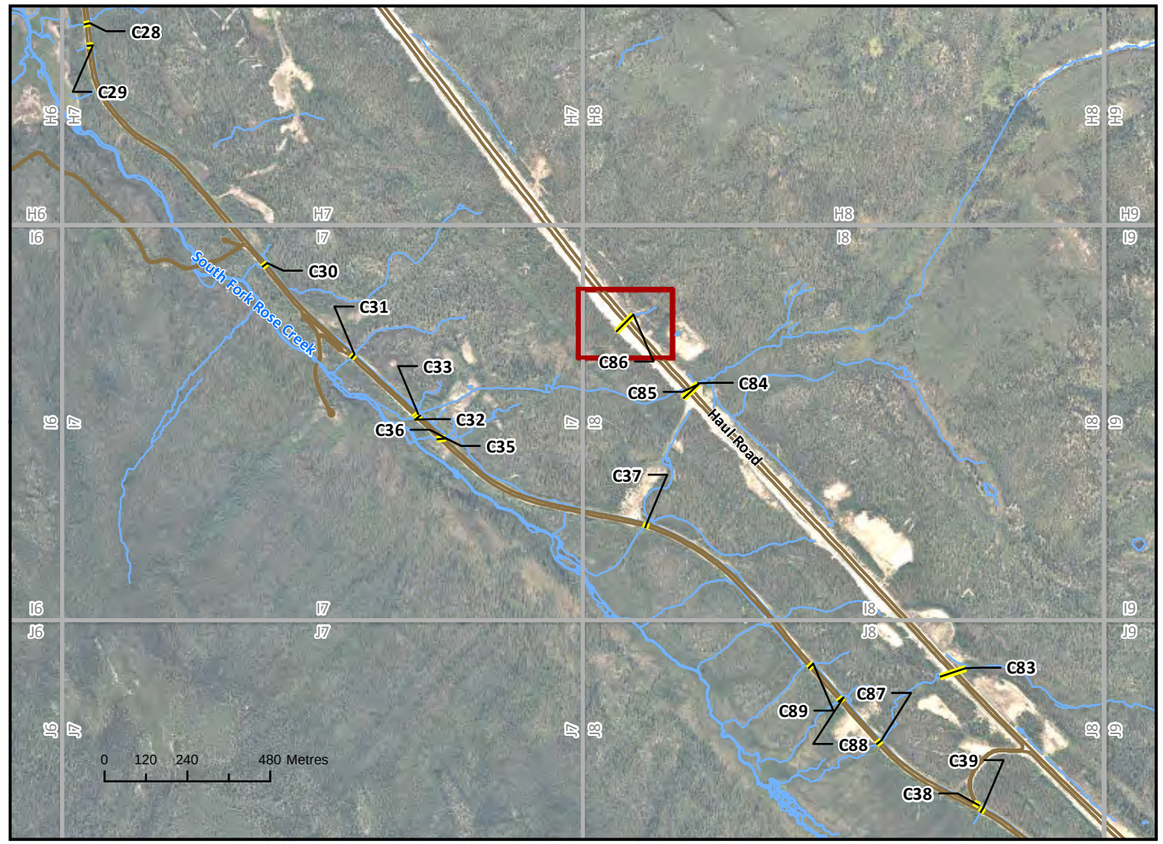
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:93 Culvert: C85 Map Grid: I8
Faro Mine Interim Works

CH2MHILL





CULVERT C86 INLET

UPSTREAM (N/A)

Photo Not Available

DOWNSTREAM (C86.ID)



Northing: 6909517.03
Easting: 588037.20

Invert Elevation: 1214.97
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: CMP: Corrugated

CULVERT C86 OUTLET

UPSTREAM (C86.OU)



DOWNSTREAM (C86.OD)

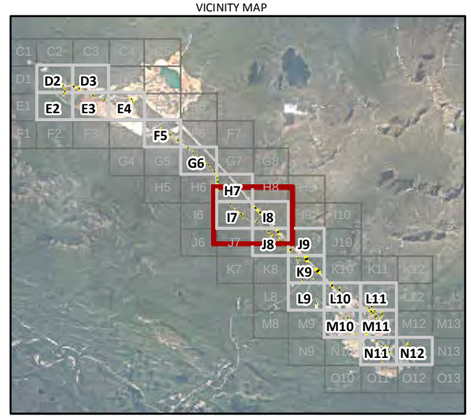


Northing: 6909467.52
Easting: 587986.99

Invert Elevation: 1201.77
Survey Date: 10/7/2012

Diameter (mm): 600
Material Type: N/A

VICINITY MAP



Created by: CRITIGEN

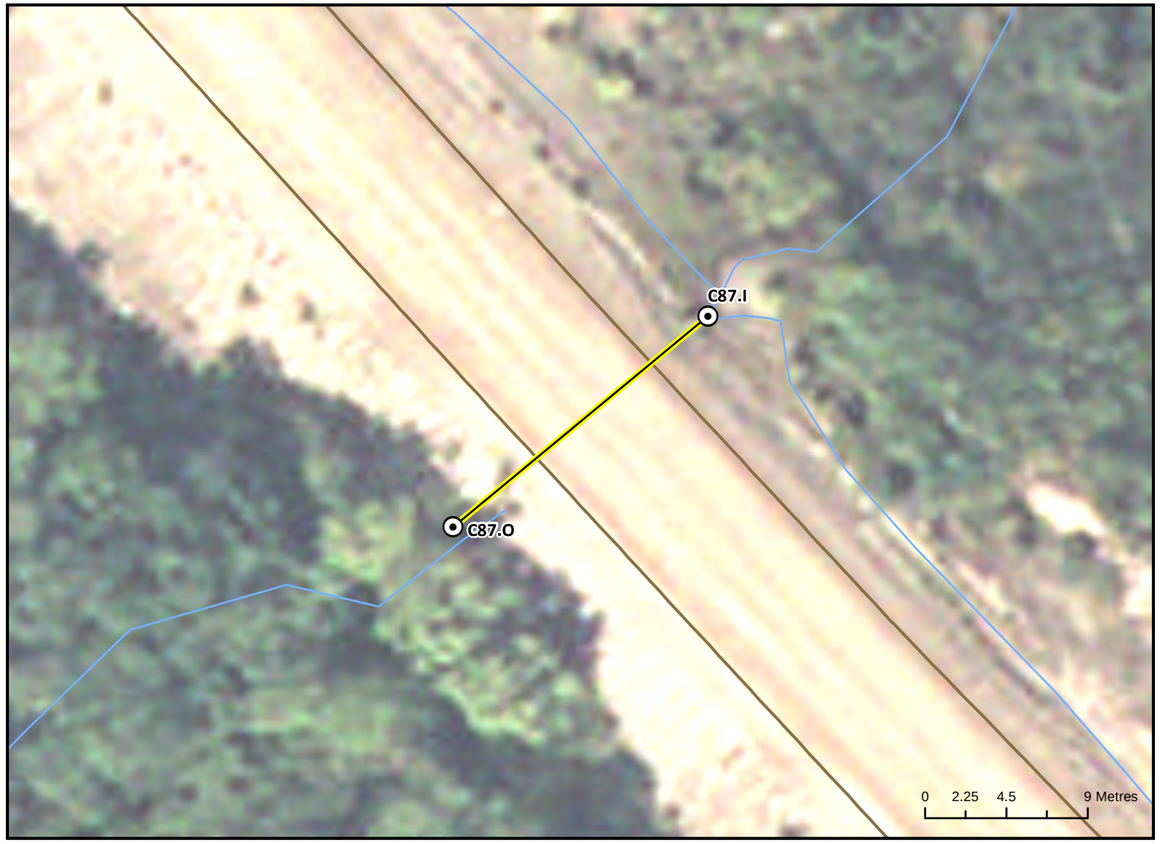
LEGEND

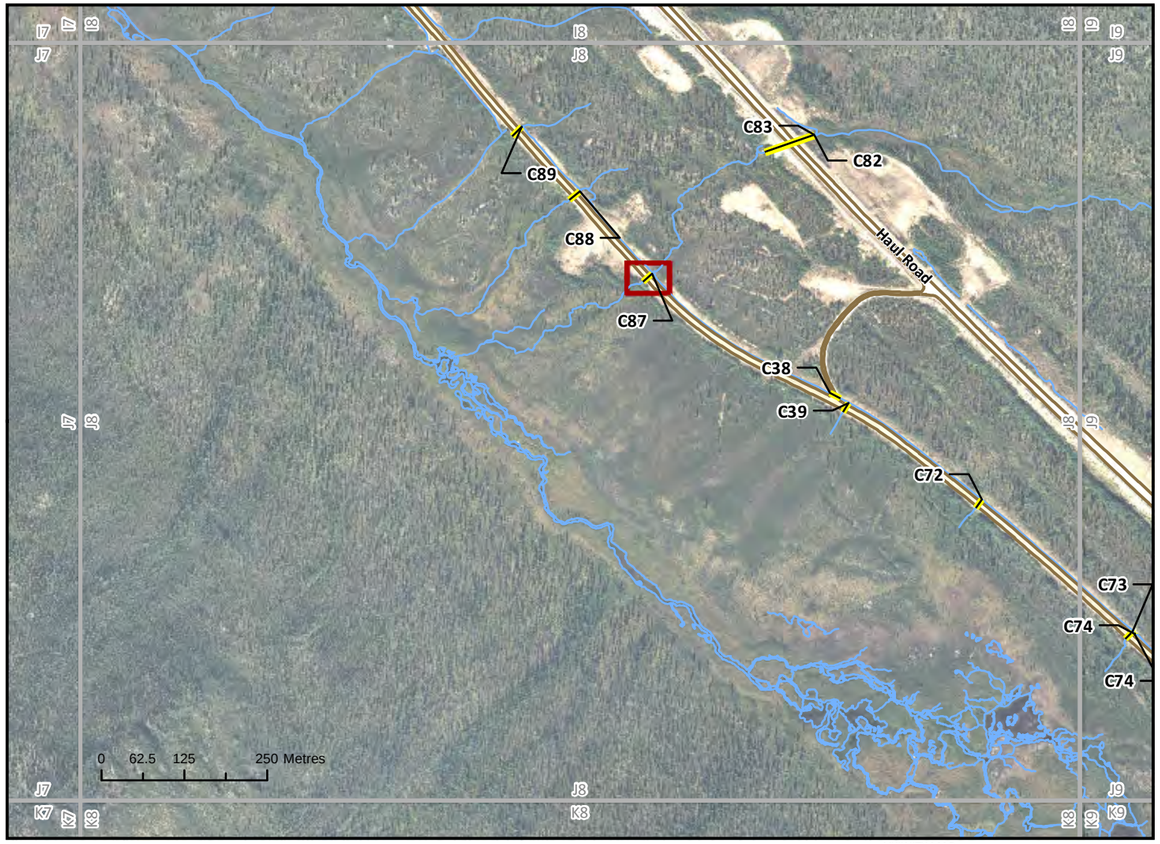
Culvert
Roads Unpaved
Culvert Grid

N

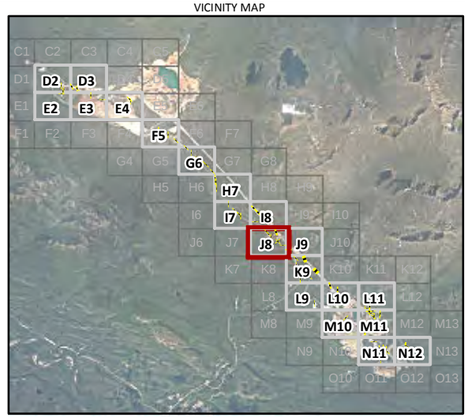
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:94 Culvert: C86 Map Grid: I8
Faro Mine Interim Works





VICINITY MAP



CULVERT C87 INLET

UPSTREAM (C87.IU)



DOWNSTREAM (C87.ID)



Northing: 6908284.49
Easting: 588754.08
Invert Elevation: 1197.90
Survey Date: 10/12/2012
Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C87 OUTLET

UPSTREAM (C87.OU)



DOWNSTREAM (C87.OD)



Northing: 6908272.80
Easting: 588739.99
Invert Elevation: 1197.09
Survey Date: 10/12/2012
Diameter (mm): 450
Material Type: CMP: Corrugated

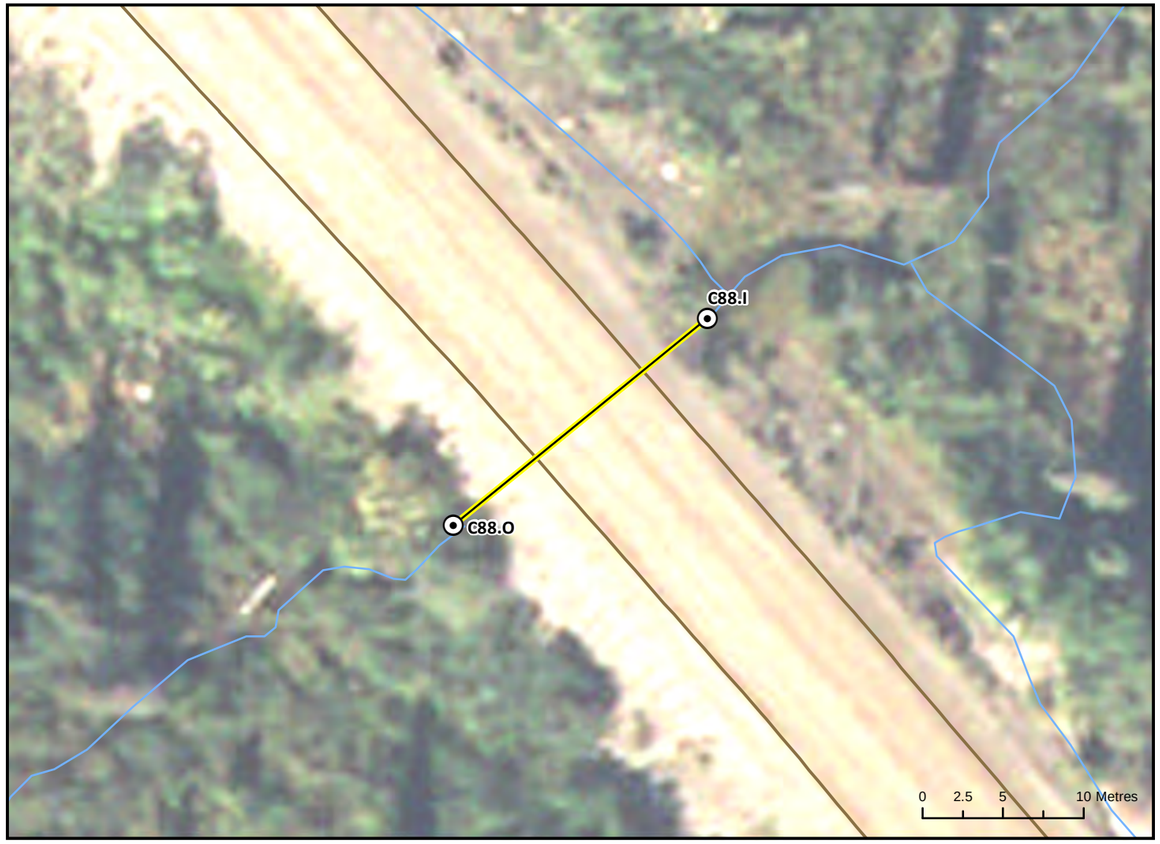
Created by: CRITIGEN

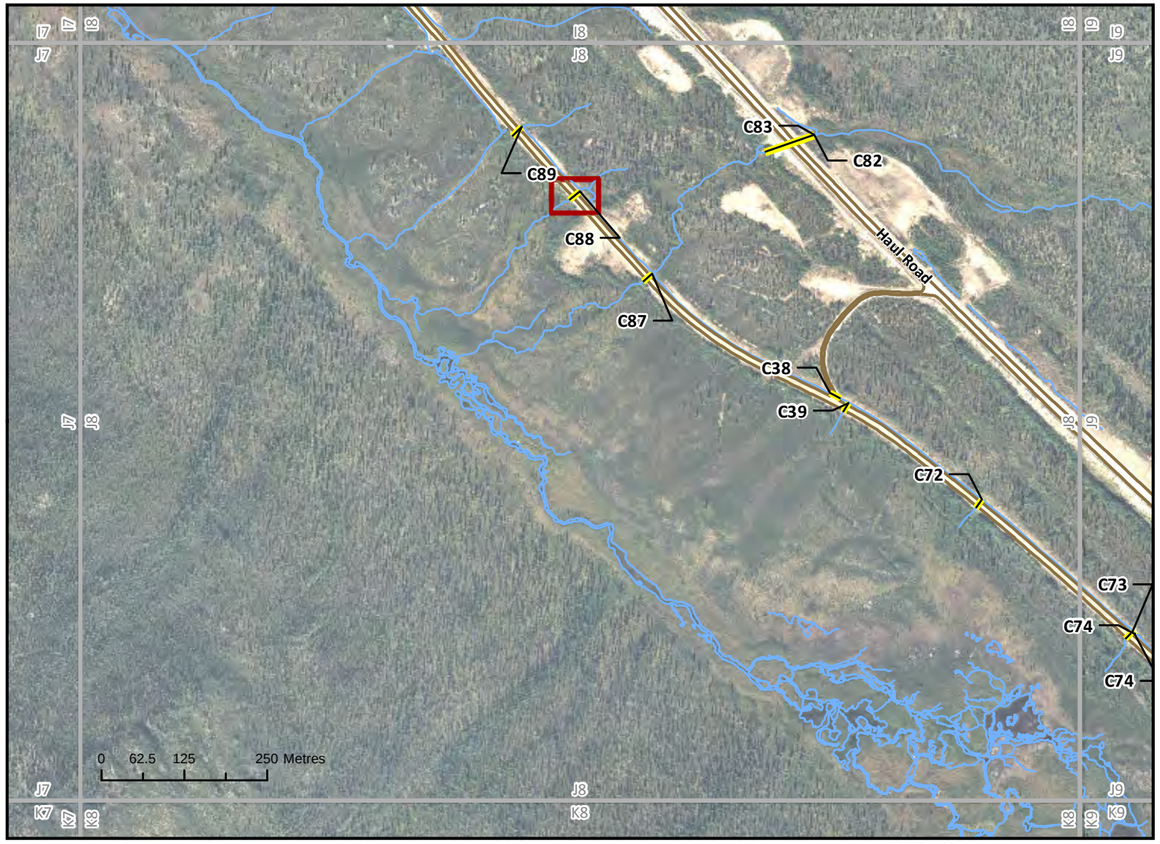
LEGEND
Culvert
Roads Unpaved
Culvert Grid

N

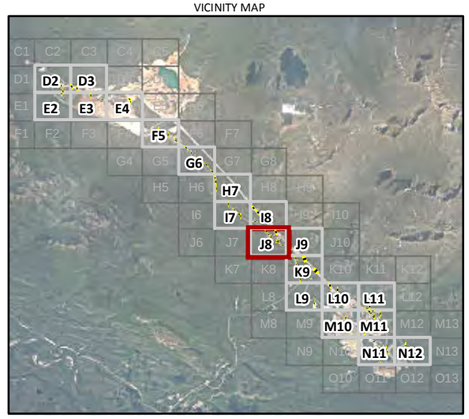
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:95 Culvert: C87 Map Grid: J8
Faro Mine Interim Works





VICINITY MAP



CULVERT C88 INLET

UPSTREAM (C88.IU)



DOWNSTREAM (C88.ID)



Northing: 6908409.05
Easting: 588644.81

Invert Elevation: 1193.61
Survey Date: 10/12/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

CULVERT C88 OUTLET

UPSTREAM (C88.OU)



DOWNSTREAM (C88.OD)



Northing: 6908396.22
Easting: 588629.04

Invert Elevation: 1192.95
Survey Date: 10/12/2012

Diameter (mm): 450
Material Type: CMP: Corrugated

Created by: CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

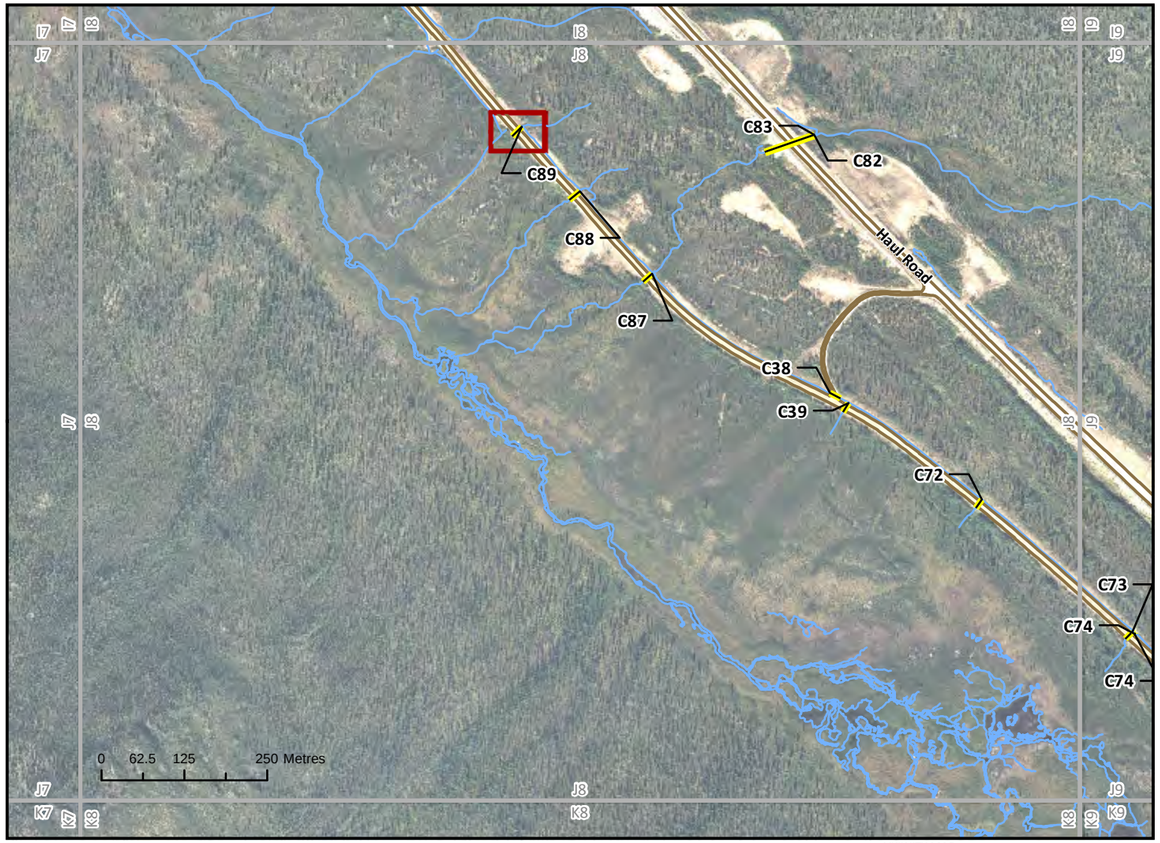
N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

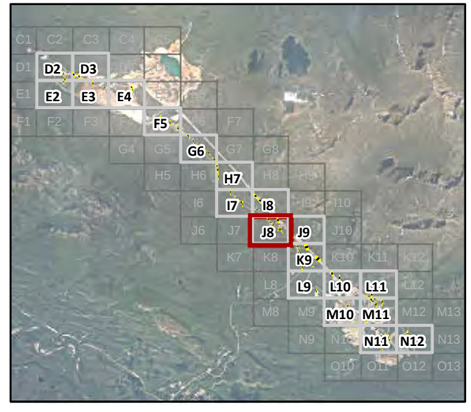
Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:96 Culvert: C88 Map Grid: J8
Faro Mine Interim Works

CH2MHILL





VICINITY MAP



CULVERT C89 INLET

UPSTREAM (C89.IU)



DOWNSTREAM (C89.ID)



Northing: 6908506.43
Easting: 588557.44

Invert Elevation: 1193.84
Survey Date: 10/12/2012

Diameter (mm): 400
Material Type: CMP: Corrugated

CULVERT C89 OUTLET

UPSTREAM (C89.OU)



DOWNSTREAM (C89.OD)



Northing: 6908491.70
Easting: 588542.88

Invert Elevation: 1193.2
Survey Date: 10/12/2012

Diameter (mm): 400
Material Type: CMP: Corrugated

Created by:
CRITIGEN

LEGEND

Culvert
Roads Unpaved
Culvert Grid

N

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

Attachment 6B-1-2
Existing Culvert Survey – Culverts Four-Photo Mapbook
Page:97 Culvert: C89 Map Grid: J8
Faro Mine Interim Works

Appendix 6C
Stability of Major Existing Facilities

Draft

Stability of Major Existing Facilities Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 6, 2014

CH2MHILL®

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Acronyms and Abbreviations

1D	one-dimensional
2D	two-dimensional
AEP	Annual Exceedance Probability
BGC	BGC Engineering
BPT	Becker Penetration Testing
CDA	Canadian Dam Association
CH2M HILL	CH2M HILL Canada Limited
cm	centimetre
cm/s^2	centimetre per second square
CVD	Cross Valley Dam
D_{50}	Sieve size at which 50 percent of the materials are passing (by weight)
EDGM	Earthquake Design Ground Motion
FMC	Faro Mine Complex
g	Acceleration due to gravity equal to 9.81 metres/sec^2
GMPE	ground motion prediction equation
HEC-HMS	Hydrologic Engineering Center–Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center–River Analysis System
H:V	horizontal to vertical
Hz	Hertz
ICAP	Integrated and Comprehensive Abandonment Plan
ID	Intermediate Dam
IDF	Inflow Design Flood
KCB	Klohn Crippen Berger
KCC	Klohn Crippen Consultants
km	kilometre
km^2	Square kilometre
LCD	Little Creek Dam
m	metre
m^2	square metre
m^3	cubic metre
m^3/sec	cubic metre per second
m/s	metre per second
mamsl	metre above mean sea level

mm	millimetre
MCE	Maximum Credible Earthquake
NFRC	North Fork Rose Creek
NFRD	North Fork Rock Drain
NHC	Northwest Hydraulic Consultants Inc.
PGA	peak ground acceleration
PGV	peak ground velocity
PMF	Probable Maximum Flood
PSA	Peak Spectral Acceleration
RCD	Rose Creek Diversion
RCTA	Rose Creek Tailings Area
RGC	Robertson GeoConsultants, Inc.
SD	Secondary Dam
SFRC	South Fork Rose Creek
SPT	Standard Penetration Test
SRK	SRK Consulting Canada Inc.
UHS	Uniform Hazard Spectrum
WSEL	water surface elevation
YG	Government of Yukon

SECTION 1

Introduction

The Faro Mine Complex (FMC) is located near the Town of Faro (Faro) in Yukon. The complex consists of two separate sites: the Faro Mine Area, located approximately 15 kilometres (km) north of Faro, and the Vangorda/ Grum Area approximately 9 km northeast of Faro (Figure 6C-1). The Faro Mine Area (Figure 6C-2) includes the Faro Pit and Waste Dumps, Mill facilities, and a series of tailings impoundments. The Vangorda/Grum Area (Figure 6C-3) includes the Vangorda Pit and Waste Dumps, the Grum Pit and Waste Dumps, as well as treatment facilities. The two sites are connected via a Haul Road.

This appendix describes the current condition of the major civil structures or facilities at the FMC and includes a description of interim measures that are proposed to reduce risks.

The appendix outline is as follows:

1. Description of the major civil structures/facilities. The facilities described in this appendix can be divided in the following categories: (1) dams, (2) open pits, (3) waste dumps, and (4) the Haul Road, including the North Fork Rock Drain (NFRD). Because of the interconnection between the Rose Creek Diversion (RCD) and the tailings dams, the RCD is also discussed in this document. The other clean water diversions, including the Faro Creek and Vangorda Creek Diversions, are discussed in *Hydraulics Characterization of Existing Facilities, Faro Mine Interim Works* (CH2M HILL, 2014b). The emphasis will be on the dams, since the consequence of dam failure is significantly larger than the consequence of failure of the other facilities, and therefore warrants greater attention for the Interim Works period.
2. Design criteria. This will include discussion of the design criteria for the final closure plan as well as for the interim period.
3. Loading conditions. This includes hydrological (flood) loading and seismic loading.
4. Stability evaluation of the major facilities under the various loading conditions.
5. Summary and Conclusions, including description of proposed interim upgrades
6. Works cited in developing this appendix.

To prepare this appendix, the following tasks were performed:

1. Review and extract information from past reports to evaluate the stability of the major structures.
2. Perform stability analyses including seismic analyses (liquefaction and slope stability) of the East Limb of the Secondary Dam (SD), and stability evaluations for the NFRD. These analyses were performed to address gaps from historical reports.

SECTION 2

Description of Major Facilities

2.1 Dams

Most of the dams in the FMC are associated with the Rose Creek Tailings Area (RCTA). These are also the largest dams at the FMC.

Approximately 28.6 million cubic metres (m^3) of flotation-derived process tailings were deposited in the RCTA between 1969 and 1998 (CH2M HILL Canada Limited [CH2M HILL], 2012). The tailings are contained by a series of three dams (Original dam, SD, and Intermediate Dam [ID]) constructed across the Rose Creek Valley, as shown on Figure 6C-4. The Original dam is completely enclosed by tailings on both sides, so it is no longer functioning as a dam structure.

The Cross Valley Dam (CVD) Pond, downstream of the tailings impoundment dams, serves as a polishing pond for the treated effluent from the existing Faro Mill Water Treatment Plant. The ID is the major tailings impoundment structure that also contains flood waters entering the Intermediate Impoundment from a small residual catchment area. Any floodwater routed through the ID spillway would flow into the CVD Pond, and once the storage capacity of the CVD Pond is exceeded, water would flow through the CVD spillway down into the Rose Creek Valley, where it would flow into Rose Creek. However, this water routing is not part of day-to-day operations and has never been used to route flood waters to-date. Upstream flows are currently routed around the tailings facility in the RCD and onsite water management activities convey water from the ID to the water treatment circuit.

The tailings vary in thickness upstream to downstream and across the valley, with an estimated thickness of 5 to 10 metres (m) at the edges of the valley, maximum thickness of more than 25 m upstream of the SD, and maximum thickness of 20 to 25 m upstream of the ID (SRK Consulting Canada Inc. [SRK], 2006). The maximum thickness of the original tailings is also estimated to be 20 to 25 m.

Analyses of Faro Mill production records and assays indicate that the tailings have an average concentration of lead, zinc, and copper of approximately 0.8 percent, 1.3 percent, and 0.12 percent, respectively (Curragh Resources Limited, 1993). Oxidation of the sulphides results in production of low pH (acidic) water with elevated concentrations of sulphate, zinc, and other metals (Robertson GeoConsultants [RGC], 1996). These metals are toxic to aquatic and terrestrial life.

2.1.1 Intermediate Dam

In 1981, the ID was constructed across the Rose Creek Valley to contain supernatant water and tailings solids. It was raised in 1988, 1989, and 1991 to a final crest elevation of 1,049.8 m, a maximum height of about 32 m above the old Rose Creek channel. A typical section through the dam is shown on Figure 6C-5. There is an emergency spillway channel on the right (north) abutment, constructed as a rock-lined channel in natural overburden material.

Based on available drawings, the ID is a zoned earthfill embankment with a sloping upstream low-permeability core and a downstream random fill shell. Granular filter zones were constructed on both sides of the core. The initial construction in 1981 made use of natural terrace material present across the valley. A drainage blanket was placed over this footprint downstream from the core and filter zone, extending to the toe of the planned final dam construction.

Upstream and downstream slopes are at 2H:1V. A 20-m-wide berm was constructed on the downstream slope at about 1,034 mamsl, approximately adjacent to the polishing pond; therefore, the overall downstream slope is at 2.1H:1V. It is assumed that the purpose of the berm is to provide access to the blanket drain exit and to provide stability against drawdown loading from the CVD Pond.

Although there is a cut-off of limited depth (estimated 3-m deep) beneath the core of the dam to reduce seepage through the uppermost natural soils, no deep foundation cut-off is present to reduce seepage through the permeable foundation soils. However, the tailings on the upstream slope and deposited in the area upstream of the dam have small particle sizes that reduce seepage rates to an acceptable level; the hydraulic gradient is reduced because of the longer seepage path through relatively thick layers of fine-grained tailings.

The drains on the dam section are set to just above the design level of the polishing pond. When the polishing pond is full, and there is minimal differential pressure between the groundwater pressure in the dam and the hydrostatic pressure in the polishing pond, the absence of drains and filters in the lower part of the dam is not a major concern. However, if the polishing pond is drained, the absence of drains in the lower half of the dam may become more problematic because of the potential for seepage daylighting on the downstream face. Under such a scenario, some sloughing of the slope may occur, but the potential for backward erosion and piping is considered low because the material below the blanket drain consists of sand and gravel, which would not sustain a roof.

2.1.2 Cross Valley Dam

The CVD was constructed as part of the Down Valley Project in the early 1980s, a project to expand the tailings disposal capacity in the Rose Creek Valley. The CVD retains a polishing pond downstream from the ID. Based on available drawings, the embankment is a zoned dam with core and filters, constructed as a conventional water-retaining dam with no retained tailings. Figure 6C-6 shows the design section of the CVD without the seepage berm at the downstream toe. The seepage berm was constructed at a later date (after the original construction was completed) to collect and monitor seepage that appeared near the toe of the dam.

The crest of the dam is at elevation 1,034 mamsl and the downstream toe is at elevation 1,016 mamsl (nominal). The height of the dam is about 18 m above original grade.

The dam section is a central impervious core, supported by upstream and downstream granular shells at slopes of 2H:1V. The core and downstream shell are separated by a chimney drain that connects to a blanket drain that extends to the toe of the drain. There is also a filter/transition zone on the upstream side of the core that acts as a crack filler. The central impervious core connects to a low-permeability upstream blanket that extends beneath the upstream shell, to 60 m upstream from the toe. A core trench was extended a few metres into existing ground below the stripped grade. This limited depth (estimated 3 m) cut-off and upstream blankets were designed to reduce seepage through the foundation soils. The cut-off and upstream blankets are partially effective, and remaining seepage into the downstream drainage blanket is collected and channeled from the dam in a controlled manner. There are no other cut-offs extended into the pervious Rose Creek sediments.

2.1.3 Emergency Spillways at the Intermediate and Cross Valley Dams

The current spillways at the right (north) abutments of the ID and the CVD are sized to pass runoff from large rainfall events (including the Probable Maximum Precipitation event), where the runoff would only be from the relatively small area of the tailings areas, but would not include any flows from the Rose Creek watershed. Whereas the RCD is designed to approximately pass 1-in-500-year flood flows without overtopping the RCD dike, the current overflow weir configuration would result in overtopping and potential breaching of the weir for much smaller flows (flows of about 70 cubic meters per second). Although the overflow weir has been referred to as a “fuse plug” in previous studies, there is uncertainty whether this structure will breach soon after being overtopped. The existing structure is heavily armoured with large diameter riprap and conveys overflow or breached flows out onto the tailings area through a dedicated relief channel.

The ID spillway only has a capacity equal to about 32 cubic metres per second (m^3/sec) when the pool reaches the top of the core zone, whereas the CVD has a spillway capacity equal to about 300 m^3/sec

(Northwest Hydraulic Consultants Inc. [NHC], 2006). The ID spillway discharges into the CVD Pond. If the CVD Pond fills, additional water would be routed through the CVD spillway down into the Rose Creek Valley, where it would flow into Rose Creek.

Since the existing ID spillway does not have the capacity to safely pass a moderate or major flood event (from Rose Creek catchment area and the surrounding area that drains to the Intermediate Impoundment) without overtopping and potentially breaching the dam, improvements to the spillway and the dam were designed as part of the Down Valley Interim Hydraulic Upgrades as detailed in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a). As part of this work, the hydrology and hydraulics for the RCD was updated, including attenuation of the NFRC flows.

Apart from remediating spill capacity associated with large flood events, an increase in ID spillway capacity would also provide mitigation for other RCD failure mechanisms. These include (1) failure of the RCD dike by piping or slope instability during moderate flood events, (2) landslide or debris flow originating on the mountainous slopes to the south of the RCD that would block the RCD and cause overtopping of the RCD dike, and (3) icing buildup in the RCD resulting in overtopping of the RCD dike.

2.1.4 Secondary Dam

Construction of the SD began in 1974 and was completed in 1975. A failure of the SD occurred in 1975, resulting in more than 200,000 m^3 of decant water and tailings discharged to the Rose Creek Valley. The spill was observed to move downstream several miles from the site (Williams, 1975). A survey conducted almost 30 years later indicated “obvious areas of killed and stressed vegetation” and “many areas of stressed vegetation and dead trees that appear to also have been impacted by the spill” (Gartner Lee Limited, 2004).

The West Limb of the SD is defined as the curved portion of the dam that crosses the Rose Creek Valley in a roughly north–to-south direction. The East Limb is the portion of the SD that is parallel to the south Rose Creek Valley wall. The West Limb of the SD was raised using centerline construction and compacted fill to a maximum height of 27 m. The East Limb is a low retention dike that was constructed of compacted fill. Tailings were deposited behind this dam from 1975 until 1982, and again for approximately 5 months in 1986. When the SD was constructed, Rose Creek was diverted to the Rose Creek Diversion (RCD) that ran parallel to the south Rose Creek Valley wall and emptied into its original channel downstream from the SD. Cross sections and photos of the SD are shown on Figure 6C-7. Elevations shown on figures are in feet relative to the Down Valley Project datum. To convert to mean sea level datum (NAD 27), subtract 106 feet (32.3 m). To convert from feet to m, multiply by 0.3048 m per feet.

2.1.5 Rose Creek Diversion

The RCD, on the south side of the valley, diverts clean water from the North and South Forks of Rose Creek around the RCTA. The RCD was constructed in two stages. An upstream section of the channel was completed in 1974, to carry clean water past the Secondary Impoundment. A longer downstream section was completed in 1981, in preparation for construction of the Intermediate Impoundment downstream (west) of the Secondary Impoundment. This second reach extended the diversion by about 3,800 m, to the location where it discharges back into Rose Creek, downstream from the CVD.

The existing diversion is approximately 4,700 m in total length. Rock weirs were constructed to reduce stream velocities associated with the steep grade of the channel in the lower reaches of the diversion. The weirs were designed on the basis of a 1-in-50-year flood event. The diversion was originally designed to carry a 1-in-50-year flood event (approximately 79 m^3/sec), with 1 m of freeboard. The contingency design capacity, with no freeboard, was such that it would carry a 1-in-500-year flood event of 132 m^3/sec, while spilling a portion of the flow through the overflow weir into the Intermediate Impoundment (assuming that the weir would not breach). Following a review of the RCD capacity in 2003, low sections of crest as a result of settlement were found (BGC Engineering [BGC], 2004), such that the original design flood event would have resulted in overtopping the RCD dike. The low sections were subsequently raised by the required amount (BGC, 2005); after raising these sections, it was concluded that the existing RCD has a flow capacity

(without any freeboard) sufficient to bypass stream flows of 140 m^3/sec, which is slightly more than the previously considered 1-in-500-year flood event (NHC, 2006), when neglecting any flood attenuation by the NFRD. The flow from storm events exceeding the capacity of the RCD will spill through the overflow weir and overtop the RCD dike, such that it will discharge onto the Intermediate Impoundment, flow over the intermediate tailings into the ID Pond, and flow out through the ID spillway into the CVD Pond. A large storm event exceeding the capacity of the RCD will potentially fail the RCD dike. It will most likely do so by overtopping the existing overflow weir location. It is also possible that the dike could fail at other locations by overtopping or fail because of other mechanisms such as piping.

Although hydraulic analyses suggest that the overflow weir should remain stable during the Inflow Design Flood (NHC, 2006), it is uncertain how it was constructed. NHC (2006) noted that the downstream slope is 20 percent with median riprap size of 800 millimetres immediately downstream of the crest of the overflow weir, and a cobble transition zone at 6 percent slope between the structure and the intermediate tailings. It is estimated that about 7 m^3/sec of flow of the 1-in-500-year flood event may occur through the existing overflow weir.

Once the RCD is breached (for example, by overtopping at the overflow weir location or at other locations along the dike) flood water would be conveyed over the intermediate tailings surface and through the ID spillway. This flow could be significantly larger than the capacity of the ID spillway for major floods (> 100-year recurrence interval) resulting in overtopping and breaching of the ID. Even moderate flood events (> 10-year recurrence interval) would overtop and potentially breach the ID if the RCD dike fails by non-overtopping failure modes such as piping. ID failure would result in discharge of a large volume of tailings to the environment. This is because the dynamic flow of a large amount of mobilized tailings is likely to overwhelm the storage of the CVD Pond, such that it would run up and over the crest of the CVD, or would run through the CVD spillway. In both cases, tailings and contaminated water from the Intermediate Pond would then be released into the Rose Creek Valley and Rose Creek downstream of the CVD.

As part of the Down Valley Interim Hydraulic Upgrades as detailed in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a), the hydrology and hydraulics for the RCD was updated, including attenuation of the NFRD flows. The peak un-attenuated inflow at the head of the RCD was calculated as 130 m^3/sec, whereas the attenuated inflow was 111 m^3/sec, i.e., a reduction of about 15 percent due to attenuation. The ID spillway was designed using a 72-hour hydrograph with an attenuated 1-in-500-year peak flow of 121 m^3/sec. This inflow is for the Rose Creek catchment area plus the surrounding area that drains into the Intermediate Impoundment.

2.1.6 Little Creek Dam

The Little Creek Dam (LCD) was completed in 1991, to collect water pumped from the Vangorda Pit and from runoff and seepage at the Vangorda Waste Dump. The location of the dam is shown in Figure 6C-10. The water from the dam was pumped directly to the water treatment plant. Electrical power was supplied by a single line to a transformer located on the dam crest adjacent to the pump house. The pump house, no longer operational, had two 35-horsepower (hp) and one 125-hp pump that were used to pump from the Little Creek Pond to the treatment facilities.

Once mine operation ceased, water management at the site changed. Now only runoff from the Vangorda waste dump collects behind the dam, and this water is pumped in the summer months to the abandoned Vangorda Pit. Water from the Vangorda Pit is now routed directly to the treatment plant. A 30-hp Flyte pump conveys water from the LCD to the Vangorda Pit.

The dam is a homogeneous embankment section of local glacial till, with a cut-off trench and granular drains under the downstream slope (Figure 6C-11). The crest is about 10 m above natural ground, ranging in elevation from 1,114.5 m to 1,120 m. Side slopes are 2H:1V on the downstream side and 2.5H:1V on the upstream side. A zone of permafrost encountered at the south abutment was excavated before till placement.

The dam is inspected daily during the summer months. Instrumentation includes six pneumatic piezometers and three thermistors that are read twice a year, typically in the spring and fall. The site is inspected once a week during the winter months. As described, the pond level is not operated at full supply level. It varies between about elevation 1,108 m and 1,110 m. The crest slopes from north to south with the minimum level at Elevation 1,114.5 m. The minimum freeboard (except for short duration exceedances) is 4.5 m on a 10-m-high dam.

2.2 Open Pits

2.2.1 Faro Pit

Mining from the Faro Pit was conducted from 1969 until 1982, and from 1986 to 1991. The pit is oval in shape with a maximum open length of approximately 1,600 m, and a maximum width of approximately 975 m, measured crest to crest. The major axis of the pit is oriented in a northwest direction. The elevation of the top of the slope at the northwest end of the open pit is approximately 1,320 mamsl, and the elevation of the top of the slope along the east side of the pit is approximately 1,296 mamsl. The bottom of the pit is currently under water, but is estimated to be excavated down to elevation 975 m (RGC, 1996). An aerial photo of Faro Pit is shown in Figure 6C-12.

The Faro Pit was excavated within the Faro Creek Valley. Faro Creek was diverted around the east side of Faro pit into the NFRD. Faro Pit has partially filled with water from surface flow and groundwater sources to an elevation of approximately 1,147.8 m, measured in November 2013. The lowest point around the perimeter of the pit is located at the southeast end of the pit, where an access road enters the pit. The high point on the ramp, or overflow point of the pit, has an invert of approximately 1,175 m. The maximum storage capacity of the pit is about 52.45 million m^3, whereas the volume of the water contained in November 2013 was about 34.54 million m^3.

The exposed materials consist generally of meta-sedimentary rock materials overlain by glacial till. The till generally has a thickness less than a few m, but increases in thickness within the Faro Creek Valley up to approximately 100 m thick.

A smaller pit, referred to as Zone II Pit, was excavated immediately southeast of the Faro Pit. This pit was mined during the initial mine operations up until 1982, and had a depth estimated at 100 m below the original ground surface (RGC, 1996). This pit was entirely backfilled with waste rock in the 1980s.

Underground mining was also conducted through the southwest wall of the Faro Pit, but the extent is not well defined. Approximately 3.4 million m^3 of mine rock were dumped into the Faro Pit from the underground mining operations.

The side slopes are benched where intact, with overall slopes varying between 30 to 45 degrees. The steepest slopes are located around the northwest end of the pit, and the less steep slopes are located along the eastern wall. Many of the benches contain ravelled rock materials; in some cases the benches are completely filled with this material. Pit slope failures have occurred at two separate locations on the eastern pit wall. These failures occurred during mining, and no significant displacements have occurred during the last eight years. Portions of the scarps at the crest of the pit slope failures are retreating from erosion and weathering of the oversteepened slope at a rate of up to 40 centimetres (cm) per year.

2.2.2 Grum Pit

Mining from the Grum Pit was conducted intermittently from 1990 to 1998. The pit is oval in shape, oriented with the long axis in a north to south direction. The pit is approximately 1000 m in length (north to south), and 625 m wide (west to east), measured crest to crest. The elevation of the top of the pit slopes is 1,300 m, except for the southern end of the pit, where an access ramp enters the pit. The access ramp crests at an elevation of 1,232 m. The bottom of the pit is currently underwater, but a bathymetry survey conducted in 2009 by Laberge Environmental Services reported a minimum elevation of 1,134 m. An aerial photo of Grum Pit is shown in Figure 6C-13.

The side slopes are benched, where the rock is of good quality, with overall slopes varying between 33 to 42 degrees. The steepest slopes are located around the west edge, and the northeast portion of the pit. The majority of the eastern slope has failed in till, resulting in very hummocky terrain and variable slopes within the overburden materials. The existing till material at the upper scarp of the failed slope is standing at an approximate angle of 46 degrees in many locations.

The exposure on the east wall reveals a deposit of glacial till materials with an estimated thickness of at least 100 m. Within the overburden, confined layers of cleaner sand and gravel materials have been encountered within soil borings. Rock materials beneath the overburden generally consist of phyllite with some sulphides.

The mining of Grum Pit was shut down during the winter/spring of 1996/1997. Dewatering was discontinued during this time, allowing the rise of subsurface groundwater levels within the till materials. During this time period, a failure of the upper eastern pit wall occurred likely because of the increase of pore pressures within the overburden material.

The Grum Pit is located near a drainage divide, and the catchment area of the pit is approximately 1.5 square km (km^2). Approximately one-third of the surface drainage above the Grum Pit is directed around the east side of the pit within the Grum Interceptor Ditch into the Vangorda Creek drainage, and the remainder of the drainage enters the pit (RGC, 1996) Since the mine operations were shut down, the water level in the Grum Pit has been steadily rising from an elevation of 1,185 m in 2003, to 1,207 m in 2010. The current water elevation measured in October 2013 was 1,215.7 m.

2.2.3 Vangorda Pit

Mining in the Vangorda Pit was conducted intermittently from 1990 to 1998. The pit has a maximum open length of approximately 1,150 m (550 m for the main pit plus a 600 m long slot), and a maximum width of approximately 375 m, measured crest to crest. The major axis of the pit is oriented in a northwest to southeast direction. The elevation of the top of the pit slope varies from 1,140 m along the southwest edge, to approximately 1,170 m along the southeast edge. The bottom of the pit is currently underwater, but is estimated to be excavated down to an elevation of 1,023 m (RGC, 1996). An aerial photo of Vangorda Pit is shown in Figure 6C-14.

The Vangorda Pit was excavated within the Vangorda Creek drainage, and Vangorda Creek was diverted around the west side of the pit, crossing beneath the Haul Road before rejoining the original creek alignment. Water accumulates in the Vangorda Pit, which also serves as a reservoir for storage of contaminated water from the LCD. Seasonal water treatment at the Vangorda Water Treatment Plant (WTP) Sludge Pond is used to manage water levels at safe elevations. The October 2013 water level in the Vangorda Pit was 1,084.7 m. The lowest point around the perimeter of the Vangorda Pit is at the location of the original Vangorda Creek at the west side of the pit. The elevation at the low point is approximately 1,130 m, or approximately 55 feet above the current water level within the pit. The access ramp is a switchback that enters the pit from the southeast side, dropping from an elevation of 1,141 m, down into the pit.

The exposed materials consist generally of phyllite and sulphide rock materials overlain by a veneer of glacial till. Sulphides are prevalent on the northeast pit wall. Several faults intersecting the Vangorda Pit have contributed to some localized pit wall instability (Golder, 2013).

2.3 Waste Dumps

2.3.1 Faro Waste Dumps

2.3.1.1 History and Description of Dumps

The history of development of the Faro Waste Dumps are described in detail in the Integrated and Comprehensive Abandonment Plan (ICAP) report (RGC, 1996), and the following descriptions are summaries from the ICAP report.

The main dumps at the Faro Mine Area are as follow (Figure 6C-15):

- Northwest Dump
- Faro Valley Dump
- Main and Intermediate Dumps
- Northeast Dumps
- Zone II Dumps
- "Near Pit" Dumps
- Low-Grade Stockpiles

The dumps were developed during the period of mining of the Faro Pits, with waste rock being deposited at several dumps over the same time period. The Faro Valley and the Northwest Dumps were the first to be developed, from 1968 to the early 1970s, by receiving waste from early stripping and mining from Faro Main Pit (Zone I Pit). The other rock piles developed during this period were marginal ore or low-grade stockpiles.

The **Northwest Dumps** are located to the west of the main pit, and north of the plant site area. The dumps were constructed primarily by end-dumping, with three major lifts to the dump, namely the Upper, Middle, and Lower Northwest Dumps. These dumps cover a total area of about 393,000 square metres (m^2), with an average height of 21 m.

The **Faro Valley Dump** is located to the north of the open pit, in the original channel of the Faro Creek. Faro Creek was diverted around the pit (this became the Faro Creek Diversion) to the northeast to allow mining of the pit. The dump fills the original creek channel and is, in part, draped over the edge of the pit resulting in a variable dump height, with a maximum waste rock thickness of 23 m and an average thickness of 11 m. The Faro Valley Dump can be divided into two sections: the larger Faro Valley North Dump covering an area of about 360,000 m^2 and a smaller Faro Valley South Dump with an area of about 32,600 m^2. Together they contained a total of about 4.1 million tonnes of waste rock.

The two largest dumps at the Faro Mine Area, the Main and Intermediate Dumps, were also started during the 1970s. These dumps are the largest Waste Dumps and are located to the south and southwest of the Faro open pit, covering a total area of about 1.1 km^2. The two dumps represent over half of the total waste rock onsite at a total of 145 million tonnes.

These dumps continued to be used until 1990, when mining at Faro was nearing completion.

The Northeast Dumps were built in the 1970s, primarily with waste from the Zone I and Zone II Pits. The **Northeast Dumps** can be divided into three areas: the Outer Northeast Dump, the Upper Northeast Dump, and the Lower Northeast Dump. These dumps are located to the northeast of the Zone II Dumps, but are to the southeast of the Main Pit. The Upper and Lower Dumps are relatively large, containing a total of 38.3 million tonnes of waste rock. The western portion of the Upper and Lower Dumps infill the Zone II Pit. Since they are located within the pit, the dumps are high, averaging 31 and 39 m, respectively.

The Parking Lot Dumps were also built in the mid-1970s. These are smaller dumps located immediately north of the mill site, and southwest from the Northwest Dumps.

Dump construction in the early 1980s was primarily in the **Zone II Dumps,** which are located mostly within the old Zone II Pit, to the southeast of the Main Pit. The dumps were built as the pit was mined, with the Zone II East Dump built first. The Zone II East Dump has a maximum height of 137 m and average height of 65 m, compared to values of 67 m and 34 m, respectively for the Zone II West Dump.

Several smaller dumps were built (less than 10,000 tonnes) in the later 1980s. The majority of the waste was deposited in the Outer Haul Road West Dump, with continued deposition on the Main and Intermediate Dumps.

In the 1990s, deposition continued on the Main and Intermediate Dumps, and on the low-grade stockpiles. In addition, waste was also placed on some of the smaller dumps, which were started in the late 1980s.

The "**Near Pit" Dumps** include the Ramp Zone Dump, the Ranch Dump, and the Southwest Pit Wall Dump. These dumps are located immediately to the south and southwest of the pit, and just north of the Main and Intermediate Dumps. Even though they are relatively small dumps with about 4.3 million tonnes of rock, the dumps are quite high with a maximum height of 60 m.

The main **Low-grade Stockpiles** are called Stockpile "A" and "C". These stockpiles were built from 1987 to 1990 with low-grade ore from Zone III of the Faro Main Pit. With regard to geotechnical properties, the low-grade ore is not significantly different from the waste rock.

In general, all the dumps on the site were constructed at their angles of repose on moderately sloping well-drained terrain. The physical stability of the dumps during the interim period is discussed in Section 5.

2.3.1.2 Rock Type Composition

The ICAP report (RGC, 1996) provides estimates of the dump composition; these estimates were based on the understanding of the pit geology, the pit development, and on observations of the dumps. The geochemistry of each of the dumps was considered with reference to the size and the composition of the dumps. Results of geochemical testing were used to estimate the range of acid generation and acid neutralization potential.

The report also provides estimates of contained "soluble load" for each dump, which were estimated from the results of extraction tests, for each rock type, and for both "old" and "young" dumps. These values were then used as a basis for evaluating the comparative environmental concerns associated with each.

2.3.1.3 Dump Hydrology and Drainage

Over the last 20 years, considerable effort has been made to detect and monitor water quality from the dumps. Seep surveys are conducted annually around the site, with emphasis on the waste dumps to identify and sample drainage from the dumps. Sampling and monitoring included digging of test pits immediately downstream of dump toes, water samples taken from shallow piezometers placed in the backfilled pits, and drilling and installation of piezometers and monitoring wells. Appendix 6A describes the geochemistry of waste dumps.

The ICAP report describes the evaluation of the water seepage through the dumps. To evaluate the effect of the seepage on the receiving water hydrology, the original ground topography was reviewed to identify surface water divides, and compared with the current configuration of the dumps. It was concluded that while waste rock placement has significantly changed the surface topography in the area, placement of the dump material did not significantly change the drainage pattern.

2.3.2 Vangorda Waste Dump

The Vangorda Waste Dumps were constructed, beginning in May 1990, to contain mined waste rock from the Vangorda Pit. The dump contains about 16 million tonnes of material and covers about 40 hectares as shown in Figure 6C-16. The two main rock types that were mined from the Vangorda Pit include sulphides and phyllites. Geochemical analyses performed on the rock indicated that both rock types have the potential to generate acid rock drainage. The sulphide rock has a much higher potential for acid generation than the phyllite and therefore the original design called for the construction of separate cells to accommodate the two different rock types.

On the northeastern side of the dump there is an area where baritic fines have been stockpiled in an area of about 11,400 m2. The concept in the SRK Closure Plan (2010a) is that these fines will be covered with a very low infiltration cover, which must be completed prior to regrading the waste rock.

Seepage from the Vangorda Waste Dump is currently collected and treated at the Vangorda WTP Sludge Pond.

The physical stability of the dumps during the interim period is discussed in Section 5.

2.3.3 Grum Waste Dumps

There are three Grum Waste Dumps: the Overburden Dump, the Southwest Dump and the Main Dump. The Grum Overburden Dump (also called Till Dump) contains an estimated 24 million tonnes of glacial till that was stripped from the buried valley in the northeast part of the pit.

The Grum Rock Waste Dumps (i.e., the Southwest Dump and the Main Dump) contains about 28 million tonnes of material and covers about 148 hectares as shown in Figure 6C-16. The Southwest Dump consists mainly of calcerous phyllite of the Vangorda Formation with about one third of the dump being non-calcerous phyllite. The Main Dump is the largest and includes a sulphide cell where most of the Grum sulphide waste was placed. The sulphide cell in the Grum Waste Dump contains strong acid-generating material, but the remainder of the Grum Waste Dump contains only pockets of acid-generating material. The sulphide cell in the main dump has been covered and revegetated at this time.

The dump was built on the moderate northwest slope of the Vangorda Creek Valley, generally dipping 6 to 10 degrees southeast to south, with local areas as steep as 12 degrees and also some flat areas.

Sulphide waste rock was segregated in the Grum Pit and placed in two sulphide waste rock cells or lifts encapsulated by phyllite waste rock in the Main Dump, as a condition of the Water License. The need for internal till layers was abandoned in favor of a final 3-metre till cover.

2.4 Haul Road

The Haul Road was developed for use by heavy duty off-road trucks hauling ore from the Ore Transfer Pad to the Faro Mill, a distance of 13 km (Figure 6C-17). The road extends an additional 3 km past the transfer pad along the south side of the Grum Pit to the pit entrance on the south side of the Vangorda Pit. The road was built by Curragh Resources starting in October 1986 and was completed in 1989. The road surface is approximately 30 m wide and there is a 2 m high safety berm on each side of the road; significant upgrading of the road surface has been done over the years.

The road was mainly built as a fill road; there are two minor cut areas, one on the east side of the West Fork of Vangorda and the other on the west side of the South Fork of Rose Creek. The road was built largely from mine waste rock selected for non-acid generating characteristics. The central 2 km of the road was built from locally borrowed surficial deposits. Most of the rock on the Faro side of the Haul Road (8 km) is schist with lesser calcium-silicate and minor intrusive, all from the Faro Pit. The rock on the Vangorda Plateau side is calcareous phyllite from the Grum Pit.

The Haul Road crosses several major streams including the north and south forks of the Rose Creek, as well as the West Fork and main stem of Vangorda Creek. The NFRD crossing is a rock drain and is discussed in detail under the dam sections. A second, smaller rock drain crosses Reservoir Creek, whereas the other crossings are corrugated metal pipes of 600 to 1600 millimetres (mm) diameter, with 600 mm culverts at most crossings. Culvert crossings were sized for a 1-in-25-year flood event and were not designed to allow for fish passage. Side slopes of the road embankment are generally 2H:1V for sections built from overburden and 1.5H:1V for sections built from pit rock.

2.4.1.1 North Fork Rock Drain

Although the Haul Road embankment, including the NFRD, was not designed or intended to impound water, it may temporarily retain a significant pool of water during very large flood events. As part of the design of the Down Valley Interim Hydraulic Upgrades (CH2M HILL, 2014a) breach analyses of the NFRD were performed to gain an understanding of the consequences of failure in the case the NFRD would be to fail under the inflow design flood (500-year recurrence interval). The consequences of NFRD breach will vary depending on the volume of water retained at the time of breach. This volume depends on the assumed flow rates through the NFRD; these flow rates are uncertain and difficult to evaluate or estimate. For a high flow-through capacity, the volume of water impounded behind the rock drain would be significantly less than the volume of water that would be stored if a lower flow-through capacity is assumed.

Breach analyses were performed for the medium and low flow-through assumptions, as well as a low flow-through condition assuming a 25 percent reduction in flow-through capacity (possibly because of debris blockage). Since it was found that, for all three cases, the rock drain would not be overtopped, it was assumed that other failure modes would initiate a breach. However, overtopping may be possible in conjunction with a ravelling failure, wherein material is removed from the downstream face of the embankment, resulting in an oversteepened slope that could lead to slope failure, lowering of the crest, and overtopping. For the purpose of the breach analyses it was assumed that a piping failure is more likely than an overtopping failure. The potential piping failure modes for the Haul Road embankment include (1) wash-out of finer particles within the schistose fill material leaving concentrated flow paths that could result in piping and (2) piping through the foundation.

It was found that a breach of the NFRD, assuming a low flow-through condition or a low flow-through condition with 25-percent reduction in capacity because of debris blockage could lead to overtopping of the ID crest. Under these scenarios, the flood wave resulting from the breach would exceed the RCD capacity, resulting in overtopping and breach of the overflow weir and the RCD dike, such that the flood wave would spill into the Intermediate Impoundment. Assuming that all the flow will go into the Intermediate Impoundment, the flow would fill the ID Pond and exceed the capacity of the modified ID spillway and overtop the ID.

For the medium flow-through scenario, the flow from the NFRD breach may result in overtopping and breach of the RCD dike, but the flow through the Intermediate Impoundment would spill through the modified ID spillway without overtopping the ID. For this scenario, the potential for loss of life, impacts to infrastructure and economics, and impacts to the environmental and cultural values in the area are relatively low.

SECTION 3

Interim Closure Criteria

3.1 Dams

3.1.1 Hazard Classification

Different dams on the site pose different levels of hazard; the RCTA dams are considered the most hazardous.

3.1.1.1 Intermediate Dam

The most severe consequence of a dam breach are associated with the ID, which contains more than 11.9 million m^3 of copper, lead, and zinc-laden tailings that are toxic to aquatic and terrestrial life. The total tailings volume of all three impoundments (original, secondary, and intermediate) is 28.6 million m^3 (RGC, 1996). Failure of the ID could result in a significant or major loss or deterioration of critical fish or wildlife habitat downstream of the FMC within Rose Creek, Anvil Creek, and possible extending to the Pelly River.

KCB (2008) estimated that the ID has a "High" risk classification, but it is noted that this estimate was made in the absence of a formal dam breach and inundation study. Government of Yukon (YG) will be conducting dam breach and inundation studies for the ID and the CVD in conjunction with the 2014 dam safety evaluation. These studies will assess downstream consequences of dam failure and may result in a modification of the hazard classifications for these facilities. Considering the Canadian Dam Association (CDA) dam safety guidelines as shown in Table 6C-1 (CDA, 2007), and noting that a large spill would likely make restoration or compensation impractical or impossible, it is quite likely that the hazard classification may change once these updated studies have been completed.

The ID (and CVD) needs to accommodate hydraulic loading from Rose Creek, as well as seismic loading. Rose Creek flows would overtop into the Intermediate Impoundment in case the capacity of the RCD is exceeded during severe flooding, or during moderate flooding when the diversion is blocked due to icing, debris flow/landslide, or woody debris. Rose Creek flows would also enter the RCTA in case the RCD dike would breach as a result of slope stability failure or piping.

TABLE 6C-1
Dam Classification – CDA 2007
Faro Mine Interim Works

Dam Class	Population at Risk [a]	Incremental losses		
		Loss of Life [b]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss No long-term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary only	Unspecified	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 people or fewer	Significant loss or deterioration of *important* fish or wildlife habitat Restoration or compensation in kind highly possible	High economic loses affecting infrastructure, public transportation, and commercial facilities

TABLE 6C-1
Dam Classification – CDA 2007
Faro Mine Interim Works

Dam Class	Population at Risk [a]	Incremental losses		
		Loss of Life [b]	Environmental and Cultural Values	Infrastructure and Economics
Very high	Permanent	100 people or fewer	Significant loss or deterioration of *critical* fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)
Extreme	Permanent	More than 100 people	Major loss of *critical* fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

Notes:

[a] Definitions for population at risk:

None = There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary = People are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent = The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more-detailed estimates of potential loss of life (to assist in decision making if the appropriate analysis is carried out).

[b] Implications for loss of life:

Unspecified = The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirements, for example, might not be higher if the temporary population is not likely to be present during the flood season.

3.1.1.2 Cross Valley Dam

The CVD has the same hazard classification as the ID. The main hazard from a CVD breach is not only the uncontrolled release of water from the CVD Pond, but sudden release of the polishing pond could also cause significant danger to the ID. The ID does not have filter and drainage systems in the lower part of the embankment below the downstream bench, and it depends on the polishing pond to provide a counterbalancing hydrostatic head to reduce seepage and the need for filtering. A sudden drawdown of the pond is likely to result in significant seepage from the saturated ID downstream slope, which in turn could lead to progressive sloughing, even more seepage, possibly backward erosion, and eventually could result in piping or loss of the crest from larger slope stability failures. Based on this potential impact to the ID, the CVD is considered to have the same potential hazard classification as the ID, i.e. a classification of 'High" risk, as estimated by KCB (2008). As for the ID, it is possible that the hazard classification of the CVD may change once a formal dam breach and inundation study is performed.

3.1.1.3 Secondary Dam

A breach of the SD could also lead to a loss of tailings into the environment, but the magnitude of such a tailings loss would be much smaller and more contained than the tailings loss associated with an ID breach. Whereas the ID and CVD need to accommodate hydraulic (flood) loading from Rose Creek, as well as seismic loading, the SD only needs to be designed for seismic loading. The SD does not need to be designed for hydraulic loading because its associated tailings area are elevated high above the RCD, and the only runoff it needs to contain or pass is the surface water associated with the surface area of the tailings itself. Under

severe flood loading conditions, the floodwater in the upper regions of the RCD will be against the downstream slope of the East Limb of the SD, however, the velocities will be too low to cause significant scour of the embankment during the anticipated duration of such an event (see hydraulic calculations in Down Valley Interim Hydraulic Upgrades Design [CH2M HILL, 2014a]).

Seismic loading could cause liquefaction of the dam foundation, and specifically at the locations where Rose Creek sediments occur beneath the dam. At the West Limb, which is the curved portion of the SD that crosses the valley roughly north to south, there are intermediate tailings on the downstream toe of the SD. These intermediate tailings would prevent failure of the dam during seismic loading even if the foundation soils liquefy. Even if some tailings loss would occur along this portion, the tailings are likely to be contained within the Intermediate Impoundment.

A breach of the East Limb of the SD, which is the portion of the SD that is parallel to the RCD and where there are no tailings at the toe, could result in tailings flowing into the RCD. It is noted that the likelihood of tailings loss is low even when losing a portion of the East Limb crest; given that the upper layers of the secondary tailings are not saturated and given the relatively small height of about 4.6 m. KCB (2008) did not estimate the risk classification for this dam, but since a breach of the East Limb of the SD could result in tailings loss into the RCD and from there into the areas downstream of the tailings areas, it can be conservatively assumed that the SD has the same risk classification as the ID, which is “High.”

3.1.1.4 Little Creek Dam

The LCD is typically not operated at full supply level. Since the dam contains a small volume of potential water release, KCB (2008) assigned a “Low” risk classification, based on the fact that (1) there would be relatively small economic loss, (2) there is limited Infrastructure or services downstream, and (3) there would be loss of marginal habitat only and/or restoration or compensation in kind would be highly possible.

3.1.2 Design Criteria for Spillway Capacity and Earthquake Loading

Table 6C-1 provides the CDA-recommended guidelines (CDA, 2007) for required spillway capacity and stability under earthquake conditions based on the dam risk classification. According to these guidelines, dams with a “High” risk classification should be designed to pass an IDF of 1/3rd, between a 1,000-year flood and a PMF, and be able to withstand an earthquake with a 2,500-year recurrence interval.

Since it may take several years (approximately 10 years) to prepare for and initiate construction of the final closure plan for the FMC, it is necessary to provide adequate levels of security of the dams and to implement interim works activities necessary to manage potential risks to human health and safety, and to the environment. Until the closure conveyance strategy and structures are agreed upon and implemented, the existing conveyance structures are to be capable of safely conveying the 1-in-500-year flood as required in the conditions of the expired water license (Water Use License QZ03-059), in which it is stated:

> *40. The Rose Creek Diversion shall have a capacity to carry a 1:500 year design flow.*
>
> *41. The spillways on the Intermediate Dam and the Cross Valley Dam shall have a capacity to carry a 1:500 year design flow of Rose Creek.*
>
> *42. The overflow structure on the Rose Creek Diversion shall be maintained to ensure that peak flows can freely pass through it.*

To evaluate whether this criteria is reasonable, the likelihood of a 1-in-500-year flood event during an interim period of 10 years can be compared with the likelihood of exceeding the design flows for typical design diversion schemes when constructing high hazard dams; typically, these schemes are designed for a 10- to 20-year flood event with the diversion in place for 2 to 3 years. The likelihood that a 10-year flood or greater could occur during a 2-year construction period is 18 percent, whereas the likelihood that a 1-in-500-year flood or greater could occur during a 10-year period is 2 percent. If it is assumed that the PMF would have a recurrence interval of 10,000 years, the likelihood that it could occur during a 100-year period is about 1 percent. It seems appropriate that the tailings dams be designed to a flood event with a much

lower annual probability of occurrence than for a temporary diversion scheme, given that the consequence of failure for the tailings dams could be significantly higher than consequence of failure of typical diversion works. On the other hand, it also seems reasonable to design it to a flood event with a higher annual probability of occurrence than that of the permanent dam.

The expired water license (Water Use License QZ03-059), also provided criteria for seismic loading for the interim period. Under Part D, Modification and Construction, it is stated:

33. All dams and diversions shall be designed to withstand the 1:475 year return period.

Until the closure concepts are agreed upon and implemented, the existing dams shall therefore be capable of withstanding the 1-in-500-year earthquake event.

The final closure concepts for the CVD have not been determined at this time, but it is unlikely to continue to function as a polishing pond. In the future it is likely to be operated in a dewatered state and will only contain significant amounts of liquid when needed for emergency storage. Since it will generally be empty, it is not considered necessary to design the dam for the maximum credible earthquake, but to design it to withstand the 1-in-500-year earthquake. Considering hydraulic loading, however, it is recommended that the CVD be required to pass the PMF, since it would contain a significant pool during flood loading conditions. In addition, the CVD is the last dam in a series of dams, where the upstream dams (SD and ID) will be required to pass the PMF.

The LCD is typically not operated at full supply level. Since the dam contains a small volume (about 120.0 m^3) of potential water release, KCB (2008) estimated that it has a “Low” risk classification. According to the CDA guidelines (CDA, 2007), dams with a “Low” risk classification should be designed to pass a 1 in 100-year flood and to withstand an earthquake with a recurrence interval of 500 years (Table 6C-2).

TABLE 6C-2
CDA Dam Safety Guidelines – Suggested Design Flood and Earthquake Levels (for Use in Deterministic Assessments)
Faro Mine Interim Works

	Annual Exceedance Probability (AEP)	
Dam Class [a]	**Inflow Design Flood [b]**	**Earthquake Design Ground Motion (EDGM) [c]**
Low	1/100	1/500
Significant	Between 1/100 and 1/1,000 [d]	1/1,000
High	1/3 between 1/1,000 and PMF [e]	1/2,500 [f]
Very high	2/3 between 1/1,000 and PMF [e]	1/5,000 [f]
Extreme	PMF [e]	1/10,000

Notes:

[a] As defined in Table E4-1 Dam Classification – CDA 2007.

[b] Extrapolation of flood statistics beyond 1/1000-year flood (10^{-3} AEP) is discouraged.

[c] AEP levels for EDGM are to be used for mean rather than median estimates of the hazard.

[d] Selected on the basis of incremental flood analysis, exposure, and consequences of failure.

[e] PMF has no associated AEP. The flood defined as “1/3 between 1/1000 year and PMF” or “2/3 between 1/1000 year and PMF” has no defined AEP.

[f] The EDGM value must be justified to demonstrate conformance to societal norms of acceptable risk. Justification can be provided with the help of failure modes analysis focused on the particular modes that can contribute to failure initiated by a seismic event. If the justification cannot be provided, the EDGM should be 1/10,000.

SECTION 4

Loading Conditions

4.1 Hydrotechnical

Since the existing ID spillway does not have the capacity to safely pass a moderate or major flood event (from Rose Creek catchment area and the surrounding area that drains to the Intermediate Impoundment) without overtopping and potentially breaching the dam, improvements to the spillway and the dam were designed as part of the Down Valley Interim Hydraulic Upgrades as detailed in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a). As part of this work, the hydrology and hydraulics for the RCD was updated, including attenuation of the NFRC flows. This section provides some of the results of those analyses, but more details can be found in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a).

4.1.1 Previous Hydrologic Studies

Previous hydrologic studies for the FMC have generally focused on determining instantaneous peak flows for a range of recurrence interval events. The studies have relied on regional analyses to determine discharge yield based on catchment area for a range of flood events. Regional analyses involve the use of runoff records from gauges in a geographic region that are expected to be hydrologically similar to catchments in the FMC. The recurrence interval events for the gauges containing longer periods of record are typically fit with a curve relating drainage area to peak flow rate. These curves are then used to predict recurrence interval flood events for the site of interest (Faro mine catchments) based on known drainage areas for various locations.

NHC (2001) conducted a regional analysis based on data obtained from seven regional gauges. At the time of the study, the period of record represented by the gauges ranged from 14 years to 37 years. The catchment areas for the gauges ranged from 91 square kilometres (km^2) to 7,250 km^2. Instantaneous peak discharges were estimated for the 1-in-2-, 1-in-50-, 1-in-100-, 1-in-200-, and 1-in-500-year return period flood events. NHC and BGC (2004) updated the return period flood estimates from NHC (2001) using additional stream gage observations. As part of the study, they also added an estimate of the mean annual flood and the 1-in-1,000-year return period flood.

Another regional study was conducted by Hydrotechnical Consulting (2006) to determine average daily flows for the 1-in-2-, 1-in-100-, 1-in-200-, 1-in-500-, and 1-in-1,000-year flood events. The recurrence interval floods were determined for flow durations ranging from 1 to 365 days. Using plots of peak discharge vs. catchment area, a relatively constant discharge per square kilometer was observed for flow records representing catchment areas ranging from 13.7 km^2 to 7,250 km^2. This observation led to the conclusion that catchment response to floods could be estimated by using recurrence interval estimates from a single gauge with the most extensive period of record (because catchment unit discharge during recurrence interval events appeared to be independent of total catchment area).

SRK Consulting (SRK) performed a regional analysis to estimate instantaneous peak on Vangorda Creek, as part of a draft design report for the Vangorda Creek Diversion (SRK, 2010b). Relationships between catchment area and peak instantaneous flood discharge were developed for the 1-in-2-, 1-in-100-, 1-in-500-, and 1-in-1,000-year flood events. Upper envelope and best-guess equations were developed for the 1-in-500-year flood event.

A PMF analysis was conducted by Water Management Consultants (2006) for the Rose Creek watershed. The PMF study applied the 24-hour probable maximum precipitation (Taylor and Hale, 2006) to the Rose Creek catchment. The antecedent conditions assumed saturated soil conditions and a shallow snowpack across the entire Rose Creek catchment. The Hydrologic Engineering Center–Hydrologic Modeling System (HEC-HMS) software was used to simulate the rainfall-runoff processes occurring during the probable

maximum precipitation event. Outflow hydrographs at the NFRD, South Fork Rose Creek (SFRC) outlet, and lower end of the diversion channel (assumed to be near gauge X14) indicate that the PMF response to the probable maximum precipitation occurs over a period of approximately 2 to 3 days. Peak flows occur between 16 and 17 hours after the initiation of the probable maximum precipitation event for all catchments. The analysis assumed that the NFRD would not be in place during the PMF, and therefore no attenuation was modelled through the NFRD. Peak flood discharges in the NFRD and SFRC were estimated to be approximately 384 and 300 m^3/sec, respectively. Peak flood discharge at the lower end of the diversion channel was estimated to be approximately 692 m^3/sec.

The regional analyses conducted for either instantaneous or sustained (i.e. daily or 7-day) periods were used to select design discharges at various locations within the FMC. The locations were selected to define design flows at strategic locations within the FMC for hydraulic analyses of structures. Instantaneous peak discharges can be used for design of channels and conveyance elements where peak discharge is the only parameter that affects sizing of such elements. Hydrographs detailing flows during the duration of the design flood are required for design when flow attenuation and routing effects need to be taken into account.

Table 6C-3 summarizes the FMC locations and associated design peak discharges during the 1-in-50, 1-in-100-year, 1-in-500-year, 1-in-1000-year, and PMF events.

TABLE 6C-3
Summary of Peak Discharge Hydrology
Faro Mine Interim Works

Location	Drainage Area (km^2)	Instantaneous Design Peak Discharge (m^3/sec)				
		1-in-50 year	1-in-100 year	1-in-500 year	1-in-1000 year	PMF
R7 gauge	99	37	42	63	77	*Not Reported*
NFRD	118	44	49	72	93	384
SFRC	73	29	33	49	61	300
RCD (Head of diversion)	203	71	75	111	150	*674*
X14 gauge	229	79	83	122	167	692

The Inflow Design Flood for the interim period is the 1-in-500-year flood event. Table 6C-4 summarizes peak unattenuated discharges during the 1-in-500-year flood event for all catchments upstream of the ID spillway.

TABLE 6C-4
Down Valley Interim Hydraulic Upgrades 1-in-500-year Design Peak Discharge
Faro Mine Interim Works

Location	Drainage Area (km^2)	1-in-500-year peak discharge (m^3/sec)
NFRD	118	72
Downstream of NFRD	1.24	1.9
SFRC	73	49
South Slope adjacent to RCD, discharging to head of RCD	6.8	7.5
South Slope adjacent to RCD, discharging to RCD downstream of overflow weir	4.5	5.4
North Slope and Tailings area, discharging to ID Pond	9.1	9.4

4.1.2 Flood Hydrograph Development

Flood hydrographs were developed for the PMF event (Water Management Consultants, 2006) since rainfall-runoff characteristics were explicitly modeled using the HEC-HMS software. No flood hydrographs representative of the 1-in-50-year, 1-in-100-year, 1-in-500-year, and 1-in-1000-year were available for the NFRD, SFRC, or RCD from previous studies since regional analyses do not account for the hydrological conditions that would produce the estimated instantaneous peak discharges. Flood hydrographs at various recurrence interval events are necessary in order to determine routing characteristics and response of FMC elements to incoming flow rates and volume. In the absence of hydrological modeling to estimate flood hydrographs for recurrence interval events, flood hydrographs were constructed using predicted instantaneous peak discharge estimates (Section 4.1.1) and a non-dimensional hydrograph developed from an observed flood on Vangorda Creek in 1993 (NHC, 2001).

1-in-500-year design flow hydrographs were developed for the NFRD, SFRC, additional NFRD downstream, South Slope catchment draining to the head of the RCD, South Slope catchment draining to the RCD downstream of the overflow weir, and the Intermediate Impoundment using the non-dimensional hydrograph proposed by NHC (2001).The instantaneous peak discharge from each catchment was constrained to match the instantaneous peak discharge as reported in Table 6C-4.

The shape, duration, and timing of the developed hydrographs for NFRD, SFRC, South Slope, and Intermediate Impoundment catchments are expected to represent the potential runoff response during a 1-in-500-year event. The predicted volume of the runoff hydrographs were compared to regional precipitation data and determined to be feasible for larger basins such as the NFRC and SFRC basins (i.e., flood hydrograph volumetric yield is reasonable compared to available annual precipitation during a year in which the 1-in-500-year flood may occur). Hydrograph volumes for smaller basins are conservative, meaning that during a 1-in-500-year flood event, the actual volume would likely be less than what is predicted by applying the non-dimensional hydrograph from NHC (2001). However, the overall volume contribution from smaller drainage basins is small compared to the contribution from the larger NFRC and SFRC basins so the level of conservatism is assumed to be acceptable. Figure 6C-18 shows the design flood hydrographs.

4.2 Seismic

The seismic hazard assessment for the site was updated in 2013 by Atkinson and Assatourians (2013), resulting in significantly lower estimated ground surface motions associated with local seismic conditions than those presented by Atkinson's previous seismic hazard assessment (2004). The main reason for this re-evaluation of ground motions at Faro is due to the insights gained in several studies performed since 2004.

A significant study involved the evaluation of the tectonic setting of the Tintina Fault, considered to be the controlling fault for the site. In a report by CH2M HILL Canada Limited (CH2M HILL, 2013), the most recent interpretation of the 30-km wide fault zone is that it no longer accommodates significant seismic deformation. The fault is currently characterized by low slip rates and activity rates. Also, it was concluded that the fault is structured more as aerial source zone comprised of several faults, rather than a distinct linear active fault.

The most important factor warranting a re-evaluation is the improvement of ground motion prediction equations (GMPE). GMPEs provide an estimate of ground shaking based upon earthquake magnitude, distance from site, and site conditions. The databases used to compile GMPEs are actively growing, promoting continual refinement to the models. Following the recommendations by Atkinson and Adams (2013) for the 2015 NBCC National Seismic Hazard Maps, the GMPEs were developed for the site, based upon B/C site conditions ("Site Class B/C" denotes the boundary between rock and soil materials and is defined as material with average shear wave velocity of 760 metres per second [m/s] in upper 30 m of soil profile). Amplification factors converting spectral accelerations from Site Class B/C to other site classes, such as Site Class C (450 m/s), can be applied to account for change in ground motions due to softer soil conditions.

Based upon the recent studies, the ground motions were reduced significantly for the site, particularly for an earthquake with a 10,000-year return period, which can be considered as the MCE for the site. Atkinson and Assatourians (2013) reduced the MCE peak ground acceleration (PGA) for the site from 0.5 g (mean value from Atkinson, 2004) to 0.25 g at the B/C boundary, a 50-percent reduction, where "g" is the acceleration because of gravity equal to 9.81 metres per square seconds.

Ground motions were also evaluated for the subduction zone bordering Alaska. Although the subduction zone is located approximately 500 km from the site, a magnitude M9 subduction event is capable of producing high ground motions at low frequencies, affecting structures with larger periods.

In Table 6C-4, the spectral accelerations (in centimetres per seconds square [cm/s^2]) are provided for return periods of 500, 1,000, 2,500, 5000, and 10,000 years for frequencies between 0.1 to 20 Hertz (Hz), in addition to PGA and PGV. Ground motions, as determined from the deterministic evaluation of a magnitude M9 subduction zone earthquake along the Alaska border, are also provided. The spectral accelerations are provided in Figures 6C-19 and 6C-20 at the B/C boundary and Site Class C conditions, respectively.

TABLE 6C-4
Mean Hazard UHS Results (average horizontal-component PSA, 5% damped in cm/s2) for Faro (from Atkinson and Assatourians, 2013)
Shown for B/C Site Class Conditions, with amplification factor for Site Class C conditions provided.
Faro Mine Interim Works

	Return Period							
Frequency (Hz)	**100-yr**	**500-yr**	**1,000-yr**	**2,500-yr**	**5,000-yr**	**10,000-yr**	**M9 scenario (deterministic)**	**B/C to C**
0.1	1.2	2.7	3.6	5.0	6.4	8.0	6.4	1.47
0.2	2.6	6.0	8.2	11.8	15.3	20.6	27.0	1.47
0.33	5.0	11.3	15.2	22.1	29.0	38.7	30.0	1.47
0.5	8.5	19.4	26.0	37.9	50.5	70.6	32.0	1.47
1.0	16.5	38.8	53.7	80.3	111.4	154.5	34.0	1.44
2.0	25.2	64.7	93.0	148.7	211.1	302.2	22.0	1.37
3.3	31.5	88.5	130.2	214.0	303.2	424.8	14.0	1.26
5.0	30.8	99.0	152.3	258.5	372.2	536.9	12.0	1.18
10	21.1	79.9	130.9	232.4	348.9	501.4	12.0	1.14
20	14.2	52.8	85.7	151.3	226.8	325.8	15.0	1.14
PGA (m/s^2)	11.6	42.1	66.9	116.0	169.6	240.4	18.0	1.21
PGV (m/s)	1.6	3.8	5.5	8.5	12.2	16.9	5.9	1.37

Notes:
UHS = Uniform Hazard Spectra
PSA = Peak Spectral Acceleration
PGA = Peak Ground Acceleration
PGV = Peak Ground Velocity

SECTION 5

Stability Evaluation of Major Physical Structures

5.1 Dams

Evaluation of dam stability includes two components: (1) the adequacy of the associated conveyance structures (such as spillways and diversions) to pass the IDF, and (2) the structural stability of the dams under normal, flood loading, and earthquake loading conditions. For this Interim Works Project Proposal, the evaluations were limited to dam stability for the interim period.

5.1.1 Adequacy of Conveyance Structures to Withstand Hydraulic Loading

The following specific major conveyance structures were considered (upstream to downstream) in this evaluation:

- RCD
- Overflow Weir in RCD Dike
- ID Spillway
- CVD Spillway

The general approach to assess the adequacy of the existing dams to withstand the design hydraulic loads for each conveyance structure during this interim period was as follows:

1. Assemble the 1-in-500-year IDF estimates for each conveyance structure based on routing scenarios and area-based hydrologic estimates.
2. Compare the existing capacity of the specific conveyance structure with the IDF. The existing capacity is determined by hydraulic modeling and the development of rating curves for the structures.
3. Identify required modifications to address insufficient conveyance capacity.

5.1.1.1 Inflow Design Floods

Section 4.1 summarizes the development of design flood hydrographs used to evaluate the adequacy of the major conveyance structures. The routing of these design hydrographs to evaluate interaction of flood flows and various conveyance structures was completed using hydraulic models as described in the following sections.

5.1.1.2 Capacity of Conveyance Structures

Using topographic and bathymetric data available for the FMC, RCD, and proposed improvements, CH2M HILL prepared one-dimensional (1D) and two-dimensional (2D) hydraulic models to evaluate hydraulic conditions for design flood flow rates with a recurrence interval of 500 years. The 1D hydraulic model was used to route flood hydrographs from the NFRC and SFRC to the upstream end of the RCD. The rock drain and upstream impoundment were included in the 1D model to estimate attenuation characteristics of the rock drain during flood events.

The 2D hydraulic model was used to route flood hydrographs from the upstream end of the RCD through the RCD, spilling over the overflow weir into the Intermediate Impoundment, and through the ID spillway.

5.1.1.2.1 Attenuation in the North Fork Rock Drain

Similar to the methodology followed by BGC (2006), stage-discharge relationships for the rock drain were estimated by assuming a range of possible parameters to represent the flowthrough area and characteristics of the rockfill within the drain. Assumptions were also made about the extent and behavior of the calcium-silicate and schistose rock zones. Using a range of discharge and attenuation values results in potential high, moderate, and low discharge scenarios for flow through the rock drain. Low flow-through scenarios further assumed various degrees of debris blockage (25-, 50-, and 75-percent). Estimating upper and lower limits for flowthrough provides a range of potential scenarios that may occur during the 1-in-500-year flood event. Each scenario is briefly summarized as follows:

- **High-Flow Scenario**: The high-flow scenario is similar to the scenario presented by BGC (2006). The dominant rock size for the entire embankment is assumed to be 0.25 m. The void ratio for both calcium-silicate and schistose rock is assumed to be approximately 0.4. While it is possible that the void ratio of certain portions or pockets of the schistose rock may change as some particles breakdown, if there is not significant settlement the overall void ratio of the schistose rock may not be changed significantly. A high void ratio of 0.4 was selected for the schistose rock to obtain higher flow-through capacities including a higher upper bound estimate for high flow-through (i.e., a higher upper bound value for flow-through capacity). Since a zero flow was assumed for the schistose rock in the low-flow scenario, this facilitates consideration of a wider range in flow-through capacities. It was assumed that both the schistose and calcium-silicate areas would be available for flow-through.
- **Medium-Flow Scenario**: The medium-flow scenario assumes that the dominant rock size for the calcium-silicate zone is approximately 0. 25 m. The dominant rock size for the schistose is assumed to be 0.05 m. The void ratio for both rock types is again assumed to be approximately 0.4. It was assumed that both the schistose and calcium-silicate areas would be available for flow-through, but the smaller dominant diameter for the schistose rock would reduce flows through this zone compared with the calcium-silicate zone.
- **Low-Flow Scenario**: The low-flow scenario assumes that there is no flow through the schistose rock. All flow through the NFRD is conveyed through the calcium-silicate zone, which is assumed to have a dominant rock size of 0.25 m. The void ratio for the calcium-silicate rock is assumed to be approximately 0.4.
- **Low-Flow Scenario plus 25-Percent Reduction in Flow-Through Capacity:** The low-flow plus 25-percent reduction in flow-through capacity scenario assumes the same parameters as the low-flow scenario, but imposes a 25-percent reduction in flow-through capacity. This capacity reduction is intended to represent a minor blockage resulting from conditions such as debris racking on the NFRD face or plugging of interstitial spaces within the NFRD by soil or other material.
- **Low-Flow Scenario plus 50-Percent Reduction in Flow-Through Capacity:** The low-flow plus 50-percent reduction in flow-through capacity scenario assumes the same parameters as the low-flow scenario, but imposes a 50-percent reduction in flow-through capacity. This capacity reduction is intended to represent a mid-range blockage resulting from conditions such as debris racking on the NFRD face or plugging of interstitial spaces within the NFRD by soil or other material
- **Low-Flow Scenario plus 75-Percent Reduction in Flow-Through Capacity:** The low-flow plus 75-percent reduction in flow-through capacity scenario assumes the same parameters as the low-flow scenario, but imposes a 75-percent reduction in flow-through capacity. This capacity reduction is intended to represent a major blockage resulting from conditions such as debris racking on the NFRD face or plugging of interstitial spaces within the NFRD by soil or other material.

To route flood hydrographs through the NFRD and downstream in NFRC and also from the SFRC to the upstream end of the RCD, CH2M HILL used Hydrologic Engineering Center–River Analysis System (HEC-RAS) version 4.1.0, a 1D hydraulic model developed by the U.S. Army Corps of Engineers. The HEC-RAS model was created using HEC-GeoRAS version 10, which allows HEC-RAS geometry elements to be defined in a Geographic Information System environment and results in a georeferenced, spatially consistent hydraulic model. The topography of the NFRC and SFRC catchments results in flowpaths that are more easily defined than for the RCD and tailings area. The less complex flowpaths, lack of off-channel storage elements, and relatively short distance between the NFRD and the head of the RCD result in a model geometry that is well-represented by a 1D modelling tool. Since 1D and 2D modelling tools provide equally suitable results under these conditions, the 1D hydraulic model was considered a reasonable means for routing flood hydrographs to the upstream end of the RCD.

The flowthrough scenarios predict varying attenuation of flows ranging from 18- to 38-percent through the NFRD during the 1-in-500-year flood under unblocked conditions. A potential reduction in flow-through capacity, which would occur when there is significant woody debris blockage of the upstream face, would cause further attenuation of peak flows. A 75-percent reduction in flow capacity of the low-flow scenario is estimated to attenuate the peak flow for the 1-in-500-year flood by approximately 68 percent.

5.1.1.2.2 Rose Creek Diversion

A 2D model to describe existing conditions was prepared to simulate flow and estimate capacity in the RCD. Hydraulic modeling results predict that the existing configuration of the RCD does not provide adequate capacity to convey the 1-in-50-year flood flow of 71 m^3/sec before overtopping the overflow weir.

To evaluate the effectiveness of vegetation removal in the RCD, the existing conditions 2D model was re-run with revised roughness mapping to represent the channel cleared of vegetation on the right bank only, and then on both the left and right banks. Model input requires an evaluation of flow resistance expressed as Manning's roughness coefficient, *n*. Vegetation characteristics are commonly represented with the roughness coefficient. Areas mapped as large and small vegetation were revised to represent the same channel area without vegetation. For example, areas classified as large vegetation (n = 0.12) were revised to bare rock (n = 0.047) or bare soil (n = 0.03).

To compute the required increase in capacity for the RCD to convey the 1-in-500-year flood, the existing conditions model described in the previous section was modified in the location of the overflow weir to raise the elevation of the overflow weir to the modeled water surface elevation during the 1-in-500-year flood. The elevation of the overflow weir was set to elevation 1,058 m. This elevation provides zero freeboard at the overflow weir during the 1-in-500-year flood event. Other locations along the dike were modelled assuming a minimum freeboard requirement of 0.5 m.

The 2D model was used to evaluate the effectiveness of interim measures. Model simulations with the 1-in-500-year flow rate predict the following:

- 1-in-500-year flow at upstream end of RCD = 111 m^3/sec
- 1-in-500-year flow in RCD downstream of the overflow weir = 116 m^3/sec
- 1-in-500-year flow in the Intermediate Impoundment assuming failure of the overflow weir (or of the RCD dike), and zero flow in the RCD = 121 m^3/sec

5.1.1.2.3 Intermediate Dam Spillway

The existing ID spillway does not have the capacity to safely pass a moderate or major flood event without overtopping and potentially failing the dam and releasing tailings to the downstream environment. NHC (2006) determined that the ID spillway capacity is 32 m^3/sec if the top of flood water surface elevation is limited to the top of the dam core estimated at elevation 1,048.5 m. The capacity is 63 m^3/sec if the flood water surface is allowed to rise to the dam crest (approximately elevation 1,049.0 m).

5.1.1.2.4 Cross Valley Dam Spillway

According to NHC (2006), the CVD spillway has a capacity of 300 m^3/sec, which is enough capacity to convey the IDF.

5.1.1.3 Interim Modifications

5.1.1.3.1 Rose Creek Diversion

Design criteria dictate that the RCD maintain 0.5 m freeboard at the 1-in-500-year flow. Table 6C-5 summarizes results of 2D modeling, existing elevation of the right bank of the RCD, and the additional embankment fill placement required to meet minimum freeboard requirements.

TABLE 6C-5
Summary of 2D Model Results in the RCD and Elevation of Right Bank
Faro Mine Interim Works

RCD Station [a]	WSEL with 1-in-500-Year Flowrate (m)	Min. RCD Crest Elevation (m)	Total Fill Required (m)
2+700	1058.12	1058.12	0.92
2+800	1057.62	1058.12	0.28
2+900	1057.28	1057.78	0.42
3+000	1057.06	1057.56	0.25
3+100	1056.87	1057.37	0.05
3+200	1056.82	1057.32	0
3+300	1056.76	1057.26	0.22
3+400	1056.65	1057.15	0.68
3+500	1056.46	1056.96	0.57
3+600	1056.19	1056.69	0.67
3+700	1056.03	1056.53	0.76
3+800	1055.97	1056.47	0.78
3+900	1055.8	1056.3	0.06
4+000	1055.51	1056.01	0.62
4+100	1055.34	1055.84	0.57
4+200	1055.18	1055.68	0.72
4+300	1054.86	1055.36	0.56
4+400	1054.59	1055.09	0.41
4+500	1054.42	1054.92	0.48
4+600	1054.27	1054.77	0.53
4+700	1054.19	1054.69	0.96
4+800	1053.88	1054.38	0.71
4+900	1053.61	1054.11	0.32
5+000	1053.34	1053.84	0.44
5+100	1053.01	1053.51	0.01
5+200	1052.75	1053.25	0.24

[a] RCD station as indicated for interim improvements.

In addition to raising the crest of the RCD dike to meet freeboard criteria, vegetation needs to be removed from the dike and riprap, and slope sloughing needs to be repaired at some locations as needed. Reasons for vegetation removal includes the following: (a) allow proper inspection, surveillance, and monitoring for seepage, cracking, displacement, and any other signs of distress in the dike; (b) allow access for Operations and Maintenance activities; and (c) limit those habitat characteristics that encourage the creation of animal burrows.

Interim measures specify that the elevation of the overflow weir be raised to elevation 1,058.2 m, which corresponds to the water surface elevation that is predicted for conveyance of the 1-in-500-year flowrate

(elevation 1,058.0 m) plus a 200 mm-thick layer of native sand and gravel covering the crest to provide a road surface (i.e., the structure will have a freeboard of 0.2 m).

5.1.1.3.2 Intermediate Dam Spillway

The improvements at the ID spillway consist of excavating the existing channel by a maximum of about 2 m, and placing a 0.45-m-thick gabion mattress on the excavated surface and side slopes of the channel. The proposed channel will follow the same footprint of the existing channel, so there will not be any significant widening of the channel. Gabion cells that are 0.9 m by 0.9 m in cross section will be used on the sides of the channel, with a geotextile between the gabions and the excavated soil surface. Waste rock was considered as a potential material for the gabion structures. However, given the irregular shape of the calcium-silicate waste rock, high sulfate content, and the fact that borrow material in the Rose Creek Borrow Area will already be processed to generate other materials needed for this project, only the Rose Creek Borrow Area is considered a cost-effective and suitable source of cobbles for the gabions.

To raise the effective ID crest, a geomembrane will be installed vertically in a trench between the dam core and the crest surface, and a single row of 0.9-m by 0.9-m gabions will be placed along this line to further raise the effective crest to an estimated elevation of 1,049.6 m. The gabions will be partially embedded (depth of about 0.2 m) in the upper portion of the excavated trench on top of the compacted backfill. It is noted that the ID crest is at an average elevation of about 1,048.9 m, and, based on the test pit exploration results, the top of the dam core at the center of the dam crest varies with a low elevation of about 1,048.3 m. To tie the geomembrane into the existing core, the upstream edge of the installation trench will be located 1 m from the top of the upstream slope, with a depth of 1.5 m. Low-permeability glacial till material will be imported from a nearby borrow area and will be placed in the lower 0.5 m of the installation trench. The material excavated from the trench would be used for backfill in the upper 1.0 m. The crest surfacing will be reinstated as shown on the drawings, by placing a 0.2-m-thick layer of gravel and sand at the crest.

The 2D model was used to evaluate some proposed improvements to the ID spillway capacity. Model simulations assume that the overflow weir has blown out with subsequent erosion of the right bank levee at that location, resulting in the entire design flow conveyed onto the tailings. Model simulations were run with the 1-in-500-year design hydrograph accounting for attenuation of flow through the NFRD. The peak flowrate in the Intermediate Impoundment is approximately 117 m^3/sec. At the start of the model simulations, the water surface elevation in the Intermediate Impoundment is assumed to be 1,046.5 m corresponding to the ID spillway invert elevation. As the simulation runs, water is first conveyed down the RCD, then out the overflow weir opening, across the tailings, and through the spillway. Spillway discharge is a function of the headwater depth that builds behind the ID. The 2D modelling takes the storage of the Intermediate Impoundment into account while routing the 1-in-500-year design hydrograph through the ID spillway with the result that the peak ID spillway discharge is less than the peak inflow rate into the Intermediate Impoundment.

Model simulations with the 1-in-500-year flow rate routed down the RCD, discharged into the Intermediate Impoundment, assuming that the overflow weir and/or the RCD dike would breach such that all the RCD flow will be conveyed over the tailings predict the following:

- Flow over the ID spillway = 115 m^3/sec
- Headwater elevation = 1048.6 m
- Freeboard at ID = 1.0 m

5.1.2 Structural Stability of Dams

Stability of the following dams was evaluated:

- ID
- CVD
- SD
- LCD

Numerous studies have been undertaken by different consultants over the last 10 years to assess the stability of the dams. Many of these evaluations were seismic stability assessments by Golder (2004) and Klohn Crippen Consultants [KCC] (later KCB) for the tailings dams and the CVD; other studies (NHC, 2006, etc.) were performed to assess the flood vulnerability of the ID and CVD. The results of these studies formed the basis for evaluating the embankment slope stability under static and seismic loading conditions, for the interim period.

To evaluate the potential for other failure mechanisms, including the potential for excessive seepage, internal erosion and piping, we have relied upon the results of periodic dam safety reviews and annual dam safety inspections that were performed and documented by various consultants (KCB, Golder, SRK, and BGC) over the last 10 to 15 years. Periodic dam safety reviews are performed every 5 to 7 years, and typically include a review of all the potential failure modes. The first dam safety review by KCC (2002) triggered a number of the seismic and flood studies referenced above. The 2002 report also reviewed the safety of the Fresh Water Dam on the south fork of Rose Creek upstream of the tailings area. In 2003 that dam was breached to release the pond so it was no longer a hazard to the downstream environment and facilities.

A subsequent dam safety review was performed in 2007 by KCB (2008) for the ID, CVD and channels at the Faro Mine Site. The report presented information on dam classification and methods to improve the dam safety program at the Faro Mine. Additional studies were performed since that time including:

1. BGC (2008a) wrote an Emergency Response Plan (ERP) for potential failure of the dams at the FMC.
2. BGC (2008b), with input from SRK, prepared an Operations, Maintenance, and Surveillance manual for the dams at the FMC (including LCD near the Vangorda/Grum Area)
3. Golder (2009) reported on the performance of the stability of the soil slope between the Faro Pit and the Faro Creek Diversion Canal
4. BGC (2009) wrote a report that updated recommendations on a rapid drawdown for the ID and CVD Ponds.

Other sources for condition assessment of the dams were associated with annual dam safety inspections, such as the dam safety inspections performed by KCB, BGC, and SRK. Evaluation of the stability of the dams also includes the results of seismic slope stability analyses of the East Limb of the SD performed by CH2M HILL. Analyses were previously performed to evaluate the seismic stability at this location, and it was concluded that the dam had insufficient margin of safety against slope failure as a result of foundation liquefaction, and will require seismic mitigation to meet the long-term design criteria. These analyses were performed for a 10,000-year earthquake event, which is the criterion for final closure (long term). To assess the seismic stability of the embankment for the interim period of 10 to 15 years, analyses were performed for a seismic event with a recurrence interval of 500 years, with the analyses also incorporating the updated seismicity for the site (Atkinson and Assatourians, 2013).

5.1.2.1 Intermediate Dam

Extensive seismic stability assessments were performed to determine the liquefaction potential in the ID foundations and to evaluate seismic slope stability (KCB, 2006a; KCB, 2006b). The evaluations included a geotechnical exploration program using the Becker Penetration Testing (BPT). A plan showing the BPT locations are provided in Figure 6C-21. BPT was used because the methods traditionally used for liquefaction assessment, the Standard Penetration Test (SPT) and the Cone Penetration Test could not be used because of the known presence of gravel and larger particle sizes in the natural foundation soils. All the liquefaction potential evaluations were performed assuming MCE ground motions.

The BPT results showed that the terrace or glaciofluvial deposits which form most of the uppermost foundation soils of the ID (Figure 6C-22), the northern foundation of the East Limb of the SD, and most of the foundation of the East Limb of the SD are not liquefiable.

However, it was found that the recent Rose Creek sediments were generally liquefiable under MCE loading (for example, beneath the West Limb of the SD and the southeast corner of the East Limb). The only exception where the recent Rose Creek alluvial sediments were found to be not liquefiable was beneath the maximum section of the ID. KCB (2006b) noted that "*to check this apparently contradictory result, two more BPTs and SPTs/LPTs were*

conducted at the Intermediate Dam with the same result. The Recent Rose Creek alluvial sediments at the Intermediate Dam are not liquefiable so remediation is not necessary for present conditions."

KCB (2006a) described post-seismic stability analyses performed for the ID. In these analyses it was assumed that the tailings would liquefy completely, but that no liquefaction would occur in the dam foundation or in the embankment. It was shown that the dam would be stable with a factor of safety of more than 1.5 for all failure surfaces through the crest and foundation of the dam, but with factors of safety slightly less than 1.5 for shallower failure surfaces. From these results, it can be concluded that the dam also has ample margins of safety under static (normal) loading conditions. It is noted that no shaking (seismic coefficient) is applied when performing post-seismic stability analyses.

In addition, Newmark sliding block type of analyses were carried out to estimate the permanent seismic displacements of the ID. Calculated displacements varied from 13 cm for the Makdisi and Seed (1978) method to 55 cm for the Hynes and Franklin (1984) method.

Since the design earthquake for the interim period only has a recurrence interval of 500 years, with ground motions much smaller than the MCE motions (1-in-10,000-year motions), the ID should be stable for this level of shaking, and permanent seismic displacements should be small. Also note that all the evaluations described used the ground motions from the Atkinson (2004) study, which are significantly higher than the ground motions of the recent updates to the seismic hazard assessment (Atkinson and Assatourians, 2013). Therefore, the actual margins of safety would be even larger than suggested by the analysis results presented.

Based on the historical performance of the dam and the observations from periodic dam safety reviews and the annual dam safety inspections, stability concerns pertaining to seepage and/or piping have not been identified. KCB (2008) noted that there is no evidence of seepage along the downstream berm, which implies that the phreatic surface is below the ground surface and apparently lower than the horizontal drain, so that groundwater seepage bypasses the drain and discharges into the polishing pond below the water surface elevation of the polishing pond. There is thus no observed water seepage at an exit face that can lead to backward erosion and piping.

KCB (2008) further noted that some riprap benching (forming of small bench at stable water line by long term wave action) is evident on the upstream slope, but stated that the riprap is generally in good condition, but will require periodic maintenance as was done in 2007.

5.1.2.1.1 Recommended Maintenance Activities for Intermediate Dam

BGC (2010) documented their 2009 Annual Geotechnical Evaluation and Instrumentation review and noted some items for maintenance. The latest Annual Geotechnical Review was performed by Klohn Crippen Berger in 2011 (KCB, 2012) and they also made recommendations for ongoing maintenance. A summary of potential maintenance items are as follow:

- The downstream face experienced rill erosion and some slumping. BGC (2010) noted that this has occurred on the face of the dam over the last four or five years, ever since sand and gravel was applied to the face of the dam. The rill erosion and slumping occurs within this surfacing material. KCB (2012) recommended that the ongoing rill development and related longitudinal cracking and slope slumps should be monitored. KCB (2012) also suggested that experimenting with potential remedial measures, such as grass planting or placement of riprap, should be considered.
- Monitor sediment deposition over the discharge face of the drainage zone above the downstream berm face (KCB, 2012). This sediment tends to collect on the road surface as it is eroded down the face of the dam. BGC (2010) noted that it would be advisable to extend the gravel drain onto the prepared surface of the road, to prevent blockage of the drain by future erosion on the face of the dam.
- Continue to monitor the upstream slope wave erosion zone because the ID Pond has been drawn to below the riprap protection zone since 2010. KCB (2012) suggested that remedial measures, such as replacement of riprap, may be required if excessive erosion is observed. Remedial measures must take into consideration the works required for permanent closure of the pond.

- Repair shoulder erosions of the downstream berm (KCB, 2012).
- Check piezometric data to check potential blockage of drains (KCB, 2012).

5.1.2.2 Cross Valley Dam

Final closure concepts for the CVD have not been developed at this stage. Initial concepts are that the CVD will be retained for the following: (1) provide emergency storage; (2) allow a facility for sedimentation of tailings that may erode during extreme runoff events; and (3) capture any contaminated water that may surface downstream of the ID. Under this scenario, the CVD Pond will be drained and maintained in a dry condition, i.e., effectively decommissioned, which will require installation of a low-level outlet. KCB (2006b) had showed that the dam in its present configuration would not be stable if subjected to the design earthquake event (MCE with 10,000-year return interval); however, as discussed in Section 3.1.2.2, the design earthquake for the interim period has a recurrence interval of 500 years.

KCB (2007) also performed seismic stability analyses of the dam for the 1-in-500-year earthquake. Ground motions from the Atkinson (2004) study were used for those analyses. The results of the analyses showed that the foundation soils do not liquefy under the 1-in-500-year motions, and that the dam would be able to withstand the 1-in-500-year earthquake. KCB (2007) noted that there will still be seismic deformations of the dam during an earthquake event of this magnitude. Such movements will be permanent but should be small and would not lead to release of the reservoir, provided the freeboard is more than 1.5 m.

Since the analyses performed in 2007 (KCB, 2007) used the ground motions from the Atkinson (2004) study, which are significantly higher than the ground motions of the recent updates to the seismic hazard assessment (Atkinson and Assatourians, 2013), it is concluded that the CVD is stable under the design seismic loading for the interim period. Therefore, CH2M HILL has concluded that the dam would have a significant margin of safety for the 1-in-500-year seismic loading.

Results from a Dam Safety Assessment by Klohn Crippen Consultants (2002) indicate that the CVD also met static stability criteria.

5.1.2.3 Secondary Dam

As for the ID, seismic stability assessments for the SD included BPT, liquefaction potential evaluations, and seismic slope stability computations (KCC, 2006a; KCC, 2006b). All the liquefaction potential evaluations were performed assuming MCE ground motions as determined by Atkinson (2004).

The BPT results showed that the recent Rose Creek sediments beneath the West Limb of the SD and the southeast corner of the East Limb (see Figure 6C-23) are liquefiable under MCE seismic loading. Using liquefied strengths in the foundation soil and the retained tailings, KCB (2006a, 2006b) found that the southeast section of the East Limb of the SD will not be stable for long-term design criteria, i.e., the factor of safety against flow sliding was less than 1.0. The southeast section is where the embankment is underlain by the recent Rose Creek alluvial sediments.

Because of the stabilizing force provided by the intermediate tailings at its downstream toe, it was found that the West Limb of the SD was stable, even at the locations where the foundation consists of liquefiable Rose Creek sediments.

Because the evaluations discussed were performed for 1-in-10,000-year motions, and since the design earthquake for the interim period has a recurrence interval of 500 years, additional analyses were performed by CH2M HILL to assess its stability and need for seismic mitigation for the interim period. The analyses and its results are documented in Attachment 6C-1. Analysis results showed no liquefaction in the foundation soils (including the recent Rose Creek sediments) for a 1-in-500-year seismic event. It also showed that the dam will be stable with factors of safety of 1.5 or greater under all considered load cases, including static, pseudo-static and post-seismic loading. It is anticipated that small deformations will occur and such deformations would be tolerable; the dam will not breach and no tailings would be released.

5.1.2.4 Little Creek Dam

Based on the observations from periodic dam safety reviews and the annual dam safety inspections, the dam appears to be stable. KCB (2008) noted that the upstream slope of the dam showed no evidence of slumping or erosion on the upstream slope and that the crest was also in good shape. Although there is no riprap on the upstream slope, the fetch of the reservoir is too small to generate waves that can cause wave erosion.

However, KCB (2008) reported some erosion and sloughing on the downstream slope of the dam which would require repair. Because the downstream slope is glacial till it is subject to freeze-thaw softening, and rainfall then tends to erode gullies into the loose surficial slope material. Gully-forming can only be rectified by placing a suitable frost protection fill (sand and gravel layer) on the slope, with a thickness that is more than the frost depth. Alternatively, any damage can be controlled by performing annual inspections and to implement maintenance measures as needed.

Instrumentation in the dam includes six pneumatic piezometers and three thermistors. KCB (2008) noted that from 1994 to middle of 2006 the piezometer readings are very uniform, but in the middle of 2006 there was a rise in the levels of two of the piezometers that could not be explained. It was hypothesized that downstream slope erosion may be blocking drainage on the downstream slope of the dam and foundation slope beyond the toe of the dam. It is concluded that the static safety of the dam is acceptable, and that gully erosion can be managed by inspections, monitoring and maintenance repairs in the interim period. In the long term, and especially if it is desirable to limit maintenance, it would be desirable to remediate the slope by placing frost protection on the downstream slope.

5.2 Open Pits

5.2.1 Faro Pit

Two slope failures have been identified along the east slope of the Faro Pit, referred to as the North and South Instability Zones (Golder, 2013). These instabilities have resulted from planar, westerly dipping rock structures that intersected the slope of the open pit as it was excavated. The North Instability Zone includes overburden material above the rock slope, while the South Instability Zone is entirely within rock. The slope displacements occurred progressively over an extended time during active mining within the pit. Catastrophic failures were not observed. Overall, the slopes within the instability zones have become relatively stable, with only localized sloughing or raveling occurring in the oversteepened head scarp areas within the overburden.

For the interim period, catastrophic failure of the slopes of the Faro Pit is a low risk. The greatest risk to the existing infrastructure is posed by the progressive raveling, erosion, and sloughing of the steep head scarp area of the North Instability Zone. The exposed overburden soils become weathered over time from repeated wetting, drying, and freezing, causing a loss of cohesion and sloughing down the slope. The newly exposed fresh till material then becomes weathered, leading to a progressive retreat of the crest of the slope. This progressive loss of soil could reach the Faro Creek Diversion and access road that run along the top of the East slope of the Faro Pit over time. A more detailed description of the slope instability zones can be reviewed in the FMC annual pit slope stability inspection report (Golder, 2013).

The Faro Pit instability zones are currently being monitored on a periodic basis. Measurements of displacements are being made around the crest of the East Pit slope. A total of nine survey prism posts and six measurement bars have been installed. Also, visual inspections are made to identify any changes in conditions observed between the inspections. The instability zones have not shown significant displacement since the time that observations were started in 2002. The rate of crest retreat is anticipated to continue similar to the rates observed during the last few years. Only localized erosion, sloughing, and raveling have been observed, but these processes could eventually undermine the Faro Creek Diversion and access road in the long term. The periodic observations and surveys should continue through the interim period on an annual basis in order to evaluate trends and give advance warning of potential safety hazards.

No changes to the current monitoring observations and surveying are necessary during the interim period given the slow rate of crest retreat and absence of movement within the slide area. For the long term, an evaluation of

the estimated maximum area that could be affected above the slope instabilities should be performed. This should be completed for cross sections through both the north and south instabilities. The maximum retreat of the top of the pit slope will provide an idea of which sections of the Faro Creek Diversion and access road is at greatest risk of being affected, assuming the angle of repose is reached for the overburden and rock failure area. A plan to stabilize these sections could be developed for the overall closure plan where the Faro Creek Diversion and access road are at risk in the long term.

Drainage from the access road above the East pit slope is currently discharged into the east slope of the pit in a few areas. Erosion is occurring, and the water appears to be infiltrating the materials at the top of the slope. As part of the overall closure activities, this drainage should be regraded and be controlled and directed away from the slope to limit long-term erosion losses and saturation of the pit slope.

5.2.2 Grum Pit

Slope failure has been observed on the East wall of the Grum Pit within the glacial till materials overlying rock (Golder, 2013). A large portion of the East pit slope, approximately 300-m wide, initially failed during a temporary shutdown of the mine operations and a stop in dewatering in winter/spring of 1996/1997. It is unknown whether the failure was entirely within overburden soils or whether the failure extended into underlying rock. Based on visual observations over the last ten years, the slope failure has increased in size, with a current width of approximately 350 m. Multiple tension cracks have been observed around the perimeter crest of the East pit wall showing horizontal displacement up to 30 cm, and vertical displacement up to 60 cm. It is unknown how long the various cracks have existed. Slumping of existing slide debris appears to be occurring within the landslide over the last few years (Golder, 2013). Additional smaller failures around the perimeter and within the existing landslide area are imminent based on existing tension cracks and oversteepened slope configurations.

The Grum Interceptor Ditch and electrical substation could be affected by slope instability on the East pit slope, but whether these could be affected within the interim period is not clear with the available data. Based on visual observations, continuing displacement is occurring within the instability zone, but the rate and magnitude of these displacements are unknown. If displacement is occurring within the lower portions of the slide area, this will affect the rate of progression of instability of the upper head scarp. In order to quantify these movements during the interim period, monitoring points should be installed within the slide area and around the perimeter above the slope. A total of 14 points were recommended by Golder (2010). Four of these have been installed during 2013, and the remainder will be installed in 2014.

During the interim period, smaller progressive failures within and around the existing failure may occur. It is possible that the blocks of soil hanging at the top of the slope could break free at any time. Monitoring pins have been installed to track crest movement at two locations (Golder, 2013). In addition, survey points will be installed within the landslide area to track further displacement of the slide. Recommendations for measurement and monitoring of these features are presented by Golder (2013). The recommended monitoring is important to protect the safety of workers entering the pits during the interim period. Additional observations should be made immediately before entering the eastern side of the Grum Pit as recommended by Golder (2013). After enough data points are available to evaluate trends of movement, the frequency of measurement can be decreased to a frequency relevant to the initially collected data.

For the overall closure, stability analyses should be performed to evaluate the potential extents of further slope displacements during the long term. To begin, a back calculation of the shear strength of the till material should be performed based on the original pit slopes before failure, along with soil laboratory testing. This information can be used to evaluate the stability of the existing pit slope configuration, and to make a determination of whether actions need to be taken to protect the Grum Interceptor Ditch and electrical substation. As recommended by Golder (2013), the effect of water levels on the pit slopes should be evaluated. As part of the stability analyses, the potential for slide movement to affect water storage volume within the pit, or to cause a wave that overtops the access road invert, should be evaluated.

The ground surface above the east pit wall is poorly drained in some areas, resulting in ponded water (Golder, 2013). These areas should be graded for the overall closure to limit the amount of water that infiltrates into the east pit wall soil material or that flows over the pit wall.

5.2.3 Vangorda Pit

Pit wall failures occurred within the north-west end of the pit during mining where there are several faults (RGC, 1996). This area appears to be stable for overall slope failure for the existing pit slope configuration. However, localized sloughing from the sheared fault zones continues to occur over time (Golder, 2013).

Within the overburden of glacial till along the southwest pit wall, there is evidence of slope movement, and signs of instability including arc-shaped oversteepened head scarps and tension cracks within the safety berm along the Haul Road. Failures within the southwest pit wall could undermine the Haul Road and water conveyance piping running between the Haul Road and the Vangorda Pit. The tension cracks should be monitored by installing extensometers and/or displacement monitoring pins. The cracks should be monitored initially at a minimum of twice per year to determine whether there is active movement and to track any trends in rate of movement. A stability analysis should be performed to identify the extents of the Haul Road that could be affected by progressive slope failure.

The rock within the northwest portion of the Vangorda Pit is generally weak and altered, and the bench crests have raveled and filled lower benches in many places, creating talus slopes from crest to toe (Golder, 2013). These slopes are sometimes interrupted by narrow bench crests that have remained intact. The risk of large-scale failure within the northwest portion of the pit is considered low.

The rock slopes within the northeast portion of the pit are more competent, but the benches are almost full of debris from interbench sloughing failures. In some areas, bench failures have occurred along large-scale joints parallel to the slope face. The upper portion of the northeast pit slopes consist of overburden that is irregular because of erosion and sloughing. However, no facilities above this area of the pit are at risk of being affected by the overburden instability in this area.

There is a high risk of rockfall along the access road slopes, as identified by Golder (2013). Unprotected work in this area should be restricted unless safety catch berms are constructed to protect workers from rock falls.

5.3 Waste Dumps

5.3.1 Faro Waste Dumps

Most of the Faro Waste Dumps were constructed at the waste rock material's angle of repose on moderately sloping, well-drained terrain. The dumps have been stable since construction (over 40 years ago) and there are no signs of any significant instability. Over time, as the surficial rock weathers, some shallow slope creep and slumping of the surficial layers on the relatively steep dump faces may occur.

An exception is the Faro Valley Waste Dumps, which are located on the deep Faro Valley alluvium and immediately adjacent to the Faro Pit, which impounds a shallow water pool on the upstream side. Stability of the southern slopes of the dump is dependent on the stability of the north wall of Faro Pit. The valley alluvium is an aquifer and has a relatively high water table which is drawn down as seepage occurs into the Faro Pit. Over time, the alluvium has slumped and ravelled into the pit and this should be expected to continue.

Other than the periodic site inspections, no specific measures to address the physical stability of the dumps are recommended for the interim period.

5.3.2 Vangorda and Grum Waste Dumps

As for the Faro Waste Dumps, the Vangorda and Grum Waste Dumps have been stable since construction, with no signs of significant instability. Shallow slope creep and slumping of surficial layers on the dump faces may occur as surficial rock weathers. Other than the periodic site inspections, no specific measures to address the physical stability of the dumps are recommended for the interim period.

5.4 Haul Road

The Haul Road embankments have been stable since construction, including the embankments where several major streams including the north and south forks of the Rose Creek, and the west fork and main stem of Vangorda Creek. With the exception of the crossing of the NFRC, which is the location of the NFRD, the consequences of failure of any of these crossings are relatively minor. Risks associated with the performance of the NFRD during large flood events are discussed in the next subsection.

5.4.1 North Fork Rock Drain

Under normal flow conditions, the NFRD does not retain much water. It is only during large flood events when more significant ponding will occur that the structure will be subjected to significant water head. As detailed in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a), the risk posed by excessive ponding behind the NFRD during very large floods were considered by (1) evaluating the consequence if the NFRD was to fail, and (2) evaluating the likelihood of NFRD failure. These two aspects are discussed in the following sections.

5.4.1.1 Consequence of NFRD Failure

Stability of the Haul Road embankment, including the NFRD, must be considered in the context of the objective of the Down Valley Interim Hydraulic Upgrades, which is primarily to protect the ID until implementation of the final closure plan. If a 1-in-500-year flood is likely to result in failure of the Haul Road embankment, the objective of the Down Valley Interim Hydraulic Upgrades could be compromised. To evaluate the consequences of failure under the 1-in-500-year flood event, breach analyses of the Haul Road embankment were performed. Since there is much uncertainty in the flow-through capacity of the NFRD (which includes seepage through the adjacent schistose rockfill zones), the analyses were performed for the following different flow-through scenarios: (1) a best estimate flow-through scenario, (2) a low flow-through scenario, and (3) a low flow-through with 25-percent reduction in capacity scenario.

A 2D hydraulic model was used to route the breach flood hydrographs from the upstream end of the RCD through the RCD, resulting in overtopping and breach of the overflow weir or the RDC dike, and spilling into the Intermediate Impoundment and through the ID spillway. All breach scenarios assumed that, once the RCD dike is breached, 100 percent of the 1-in-500-year flood event and breach flood wave flow would be conveyed into the Intermediate Impoundment.

Table 6C-6 summarizes the key information associated with each model simulation. As shown in the table, the low-flow condition and low-flow condition with 25-percent blockage result in overtopping of the ID. Overtopping because of a breach of the NFRD under the low-flow condition is minor, with a maximum predicted water surface elevation of 1,049.9 m and duration of overtopping of less than 1 hour. This is considered to be the threshold case.

TABLE 6C-6
Summary of Breach Simulations
Faro Mine Interim Works

NFRD Flow-through Condition	Blockage	Peak Flow (m^3/sec)	Maximum WSEL (m)	Overtopping at ID
Medium	zero	640	1049.3	No
Low	zero	1,262	1,049.9	Yes[a]
Low	25%	1,669	1,050.1	Yes

[a] Minimal overtopping of ID crest occurs for breach scenario assuming low flow-through condition and no blockage. This is considered the threshold case.

Based on this analysis, overtopping is expected for any breach scenario with a peak flow discharge greater than approximately 1,200 m^3/sec. This estimate of the overtopping flow is dependent on the following conditions occurring concomitantly.

- Initial conditions assume that the ID Pond is at full pool elevation of 1046.5 m. This assumption limits storage in the ID Pond and subsequently reduces potential attenuation of the peak discharge.
- In the model simulation, the RCD is blocked off at the overflow weir so that flow is not conveyed down the RCD once the flood is directed onto the Intermediate Impoundment. Model simulations that provide for conveyance down the RCD result in an approximate decrease of 0.3 m in water surface elevations at the ID.
- A low flow-through condition was assumed at the NFRD, the most conservative estimate of flow-through capacity.
- Blockage (25 percent) of flow was assumed at the NFRD which reduces capacity further and results in greater impounded volume at the NFRD.

5.4.1.2 Likelihood of NFRD Failure

There is successful precedent in Canada, and elsewhere, to use flow-through rockfill in mine rock waste dumps, which has saved the cost of culverts or diversion works around the waste dumps (Minalta and Piteau, 1999). The precedent, however, does not include reliance of the mine waste dumps as water-retaining dams, but perhaps as temporary non-engineered pervious barriers to flow-through.

Comparing the construction of the NFRD with the general recommendations provided in the British Columbia Rock Drain Research Program report, *Mined Rock and Overburden Piles* (Minalta and Piteau, 1999), it was concluded that the Haul Road embankment does not include elements that should be included where rock drains could become water retaining structures. These elements are discussed in detail in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a) and include (1) limited foundation preparation, (2) absence of filter layer (such as gravel or small size rockfill) between foundation soils and rockfill embankment material, and (3) absence of filters/drains for the lower permeability schistose material zones adjacent to the calcium-silicate rock.

BGC (2006) identifies evidence of sediment and wood debris accumulation at the entrance to the NFRD. The scope of BGC's work included an assessment of natural hazards of the terrain in the NFRC Basin and the natural slopes above the RCD Canal. However, it did not include potential hazards from man-made structures (such as those from the waste rock dumps). These hazards add to the uncertainties in assessing the reliability of the Haul Road embankment and NFRD.

The potential blockage of debris on the NFRD face and plugging of the interstitial space within the NFRD by soil or other material arising from man-made activities had not been examined by BGC (2006), nor assessed during this study. Effects of sediment produced by erosion of the Faro Waste Dump and the upper (predominantly sand and gravel) part of the embankment are examples of this type of contamination.

Ravelling and slope stability evaluations were performed to gain an understanding of the embankment stability. However, there are other potential failure modes that could be more critical but do not readily lend themselves to quantitative analyses. One such failure mode is wash-out of finer particles in the schistose rockfill resulting in preferential seepage paths and eventual piping of the embankment. Another such failure mode is piping through the foundation under significant flood pool conditions. Because only two out of numerous potential failure modes were considered in analyses, the results of these analyses could not be considered a complete measure of the stability of the rock drain.

The two potential failure modes considered under estimated flood pool conditions include the following:

- Ravelling failure initiated by high discharge velocities exiting the downstream toe
- Slope stability failure with high phreatic surfaces in the embankment

The analyses and results are provided in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a).

Results from the ravelling analysis suggest that there should be an adequate margin of safety against slope ravelling under high flow-through conditions. By inspection, the reported as-constructed D_{50} diameter of the NFRD (1 m) is more than 3 times as large as the critical D_{50} diameter for the worst-case 1-in-500-year flood event flow.

The factors of safety developed for all slope stability cases analyzed meet the recommended minimum criteria, indicating that deep-seated slope stability issues should not be a major issue for the embankment. It should be noted that, during the life of the structure, shallow surface sloughing is a likely occurrence on the upstream or downstream face. While this sloughing is not considered to be critical to overall stability of the embankment, the effects of the sloughing could have other impacts on conditions near the toe of the embankment, particularly if left unchecked. For example, sloughing of finer material onto the NFRD slope surface could impair the flow-through. Signs of sloughing need to be monitored and maintenance performed as needed.

5.4.1.3 Conclusions

The objective of the interim improvements is to prevent an environmentally damaging discharge of metals-laden tailings to the Rose Creek Valley and downstream creeks and rivers. This objective will be met by preventing overtopping of the ID during the 1-in-500-year flood. Breach analysis results indicate that overtopping of the ID would occur for any NFRD breach with a peak flow discharge greater than approximately 1,200 m^3/sec. During a 1-in-500-year flood event, such a discharge is predicted for an NFRD breach when assuming a low-flow-through capacity in the NFRD.

Based on a review of the design and construction records of the NFRD, the objective of ID protection cannot be met with a high degree of confidence by relying on the haul road embankment to act safely and reliably as a flood retarding structure. To achieve a high confidence level in its performance, more positive measures would need to be implemented to pass large flood events safely at the Haul Road embankment and NFRD to prevent formation of large flood pools against the Haul Road embankment. One such measure might include installation of culverts or tunnels under the embankment.

In the absence of such measures, a significant flood pool may form against the Haul Road embankment and NFRD. A risk analysis would be helpful in determining acceptability of the Haul Road embankment and NFRD in the interim period. Since the probability of a 1-in-500-year flood occurring within a 10-year interim period is 2 percent, and the conditional probability of failure of the Haul Road embankment given this flood event is less than 1, the probability of failure of the Haul Road embankment would be less than 2 percent over a 10-year period. A risk analyses would not only consider the 1-in-500-year flood, but would combine the probability of failures during the interim period with the consequence of failure for the full range of flood loading up to the 1-in-500-year event.

Monitoring of the Haul Road embankment and NFRD should continue and maintenance measures should include prevention of blockage of the inlet to the NFRD by removing any buildup of debris.

SECTION 6

Summary and Conclusions

From the evaluation of the different types of structures on the site, it was concluded that most of the major existing facilities can be considered physically stable for the interim period. However, it was found that some of the existing flood conveyance structures are undersized and inadequate to convey the IDF for the interim period (500-year return period flood event). Interim measures will be implemented to upgrade the capacity of the structures as discussed in this section.

6.1 Dam Stability during the Interim Period

Evaluation of dam stability included the adequacy of the associated conveyance structures (such as spillways and diversions) to pass the IDF, as well as the structural stability of the dams under normal, flood loading, and earthquake loading conditions.

It was concluded that the dams meet the design criteria for earthquake and flood loading for the interim period. The loading for the interim period is significant smaller than the loading for the long term. Some maintenance needs to occur during the interim period to maintain the stability of the dams.

It was found that some of the existing flood conveyance structures are undersized and inadequate to convey the IDF for the interim period (500-year return period flood event). Interim measures will be implemented to upgrade the capacity of the structures as discussed in the following section.

6.2 Recommended Interim Hydraulic Upgrades

6.2.1 ID Spillway

The most severe deficiency is for the ID Spillway. In the case of a breach of the overflow weir or at another location along the RCD dike, the existing ID spillway does not have the capacity to safely pass a moderate or major Rose Creek flood event without overtopping and potentially failing the ID and releasing tailings to the downstream environment. NHC (2006) determined that the existing ID spillway capacity is only 32 m^3/sec if the top of flood water surface elevation is limited to the top of the core. The capacity is 63 m^3/sec if the flood water surface is allowed to rise to the dam crest (approximately elevation 1,048.9 feet). Because of this deficiency, modifications to the spillway are proposed and currently under design.

A freeboard analysis was performed in accordance with technical guidelines from CDA (2007) to determine minimum and normal freeboard requirements. The minimum required crest elevation to provide suitable freeboard was determined to be approximately 1,047.4 m for the normal freeboard case and 1,049.3 m for the minimum freeboard case. The design crest elevation of 1,049.6 m provides suitable freeboard under both conditions. Additional information regarding the wind analysis and freeboard calculations can be found in Down Valley Interim Hydraulic Upgrades Design (CH2M HILL, 2014a).

Apart from remediating spill capacity associated with large flood events, an increase in ID spillway capacity would also provide mitigation for other RCD failure mechanisms. These include (1) failure of the RCD dike by piping or slope instability during moderate flood events, (2) landslide or debris flow originating on the mountainous slopes to the south of the RCD that would block the RCD and cause overtopping of the RCD dike, and (3) icing buildup in the RCD resulting in overtopping of the RCD dike.

The improvements at the ID spillway will consist of excavating the existing channel by about 2 m, and placing a 0.45-m-thick gabion mattress on the excavated surface of the channel. The proposed channel will follow the same footprint of the existing channel, so there will not be significant widening of the channel. Three layers of gabion cells 0.9 m by 0.9 m in cross section will be used on the sides of the excavation. Geotextile will be placed between the gabion mattress and the excavated soil surface. It is assumed that calcite waste rock could be used as material to fill the gabion mattress and gabion cells.

To raise the effective crest ID crest, a geomembrane will be installed vertically in a trench between the dam core and the crest surface, and concrete traffic barriers will be placed along this line to further raise the effective crest to an estimated elevation of 1,049.6 m. The gabions will be partially embedded (depth of about 0.2 m) in the upper portion of the excavated trench on top of the compacted backfill. It is noted that the ID crest is at an average elevation of about 1,048.9 m and based on the test pit exploration results the top of the dam core at the center of the dam crest varies with a low elevation of about 1,048.3 m. It is assumed that the material excavated from the trench would be used for backfill again. The gravel and sand crest surfacing will be reinstated.

6.2.2 Rose Creek Diversion Dike

Hydraulic modelling results indicate that the existing crest elevation is deficient to contain the predicted 1-in-500-year flood event flows. Over some portions of the dike, it would overtop and at other locations there would not be adequate freeboard. To mitigate this deficiency, the dike crest needs to be raised over some sections of the dike.

The crest elevation of the overflow weir will be raised to elevation 1058.2 m, which corresponds to the water surface elevation predicted for the 1-in-500-year flood event flow rate (elevation 1,058.0 m) plus a 200 mm-thick layer of native sand and gravel covering the crest to provide a road surface, i.e., the structure will have a freeboard of 0.2 m. This implies that the overflow weir will have to be raised by about 0.95 m.

Apart from the required raise of the dike crest and overflow weir, it is also proposed to remove woody vegetation from the dike and to perform some repairs of slope sloughing and riprap, and to add riprap where slopes are unprotected.

6.2.3 Embankment Haul Road and North Fork Rock Drain

Results of breach analyses of the NFRD indicate that overtopping of the ID would occur during a 1-in-500-year flood event when assuming a low-flow-through capacity in the NFRD. Based on review of the design and construction records of the NFRD and the embankment haul road, the Main Haul Road Embankment and NFRD cannot be relied upon to serve as a reliable attenuation barrier and provide protection to the ID.

To achieve a high confidence level, more positive measures would need to be implemented to pass large flood events safely and prevent formation of large flood pools against the Haul Road embankment. One such measure might include installation of culverts or tunnels under the embankment. In the absence of such measures, a risk analysis might be helpful in determining acceptability in the interim period. Monitoring of the Haul Road embankment and NFRD should continue and maintenance measures should include removing buildup of debris upstream of NFRD.

SECTION 7

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Figures



VICINITY MAP



LEGEND

Road

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 750 1,500 2,250 3,000

Metres

Created by: CRITIGEN

FIGURE 6C-1

Faro Mine Complex

Faro Mine Interim Works



VICINITY MAP



LEGEND

Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 250 500 750 1,000

Metres

Created by:
CRITIGEN

FIGURE 6C-2
Faro Mine Area
Faro Mine Interim Works

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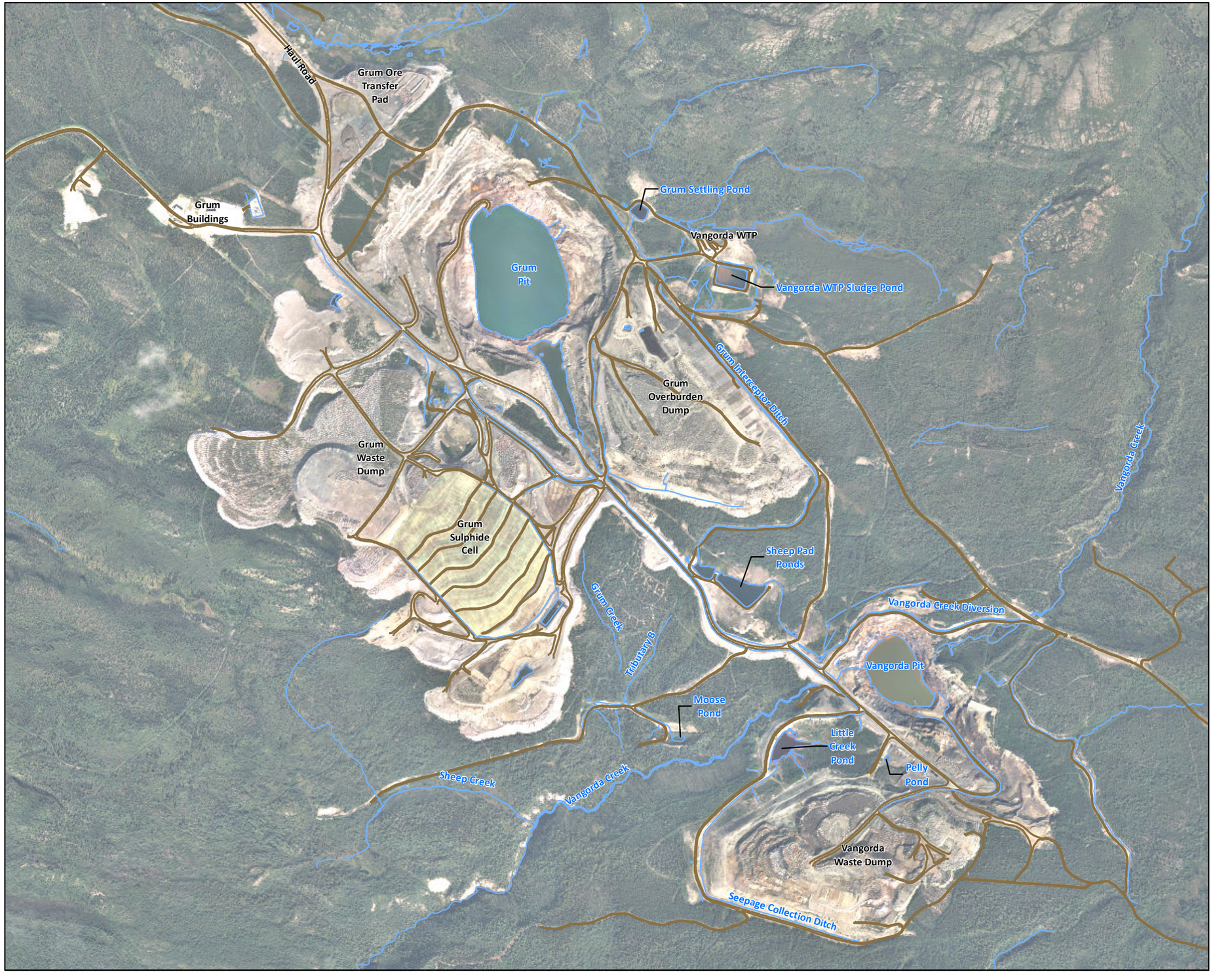


VICINITY MAP



LEGEND

Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

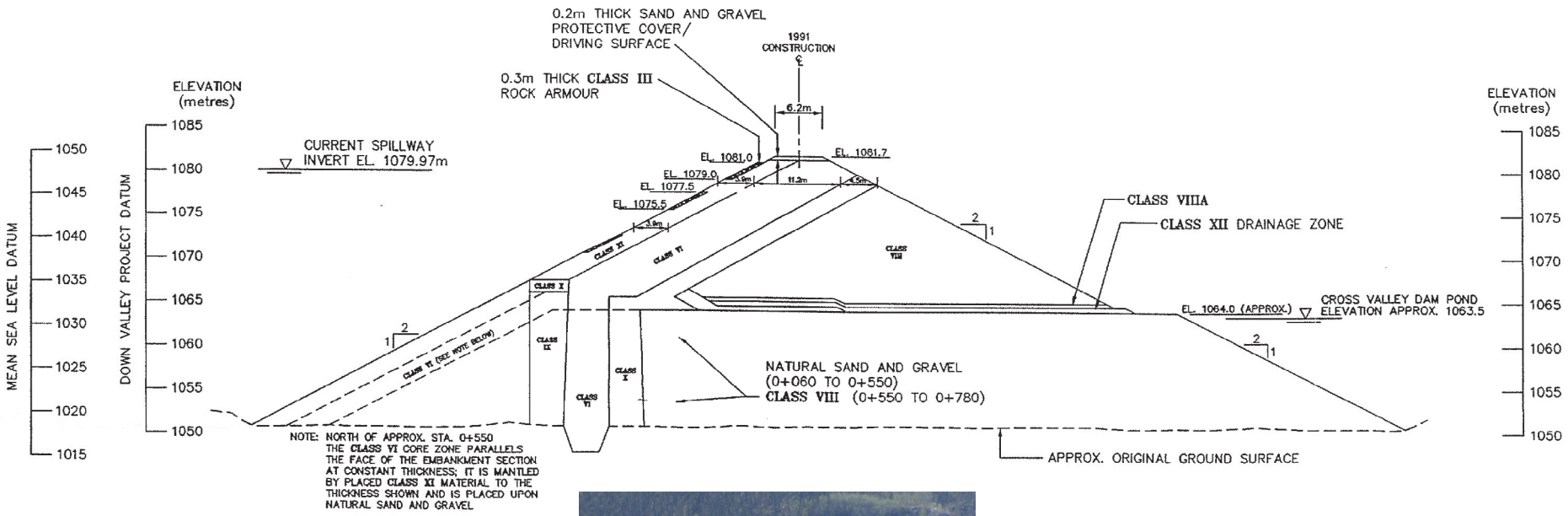
0 250 500 750 1,000
Metres

Created by:
CRITIGEN

FIGURE 6C-3
Vangorda/Grum Area
Faro Mine Interim Works



FIGURE 6C-4
Rose Creek Tailings Area
Faro Mine Interim Works



NOTES :

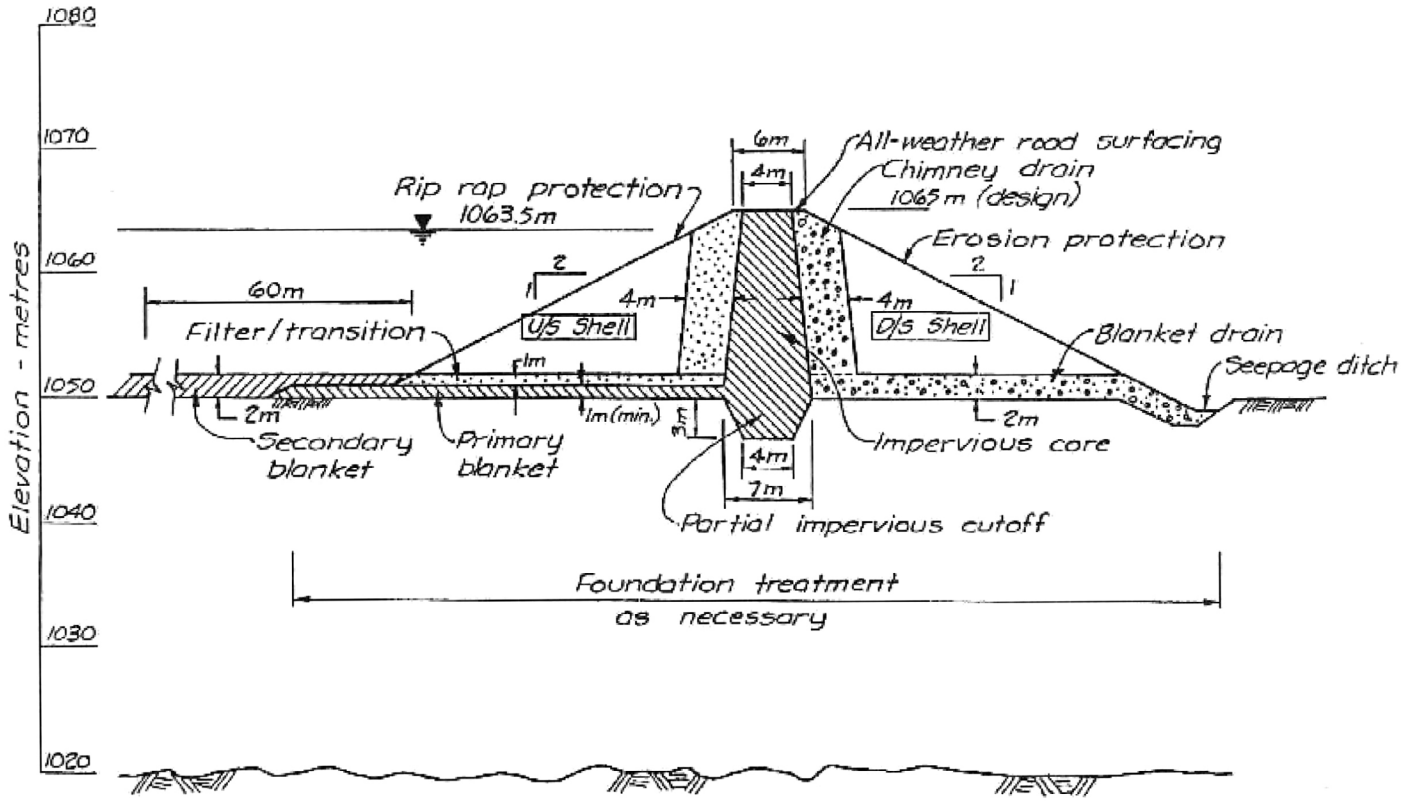
1. Embankment geometry and internal zoning as shown in Golder Associates Drawing 912-2402-3, Int. Dam Raising & C.V. Dam Toe Drain, Cross Section and Detailed Plan, Rev. 1, Aug. 8, 1991.
2. All elevations are referenced to Down Valley Project Datum. Subtract 32.3m from elevations shown to convert to mean sea level (NAD27) datum.
3. Refer to Golder Associates as built reports for detailed descriptions of material classes. General descriptions as follows :

CLASS VI	Dam Core (glacial till)
CLASS VII	Upstream Shell (silty sand and gravel)
CLASS VIII	Downstream Shell (sand and gravel)
CLASS VIIIA	Drainage Filter (sand and gravel)
CLASS IX	Upstream Filter (silty sand)
CLASS X	Downstream Filter (sand and gravel)
CLASS XI	Tailings Sand (fine to medium sand)
CLASS XII	Drainage Zone (gravel)



FIGURE 6C-5
As-built Cross Section and Photograph of the Intermediate Dam
Faro Mine Interim Works

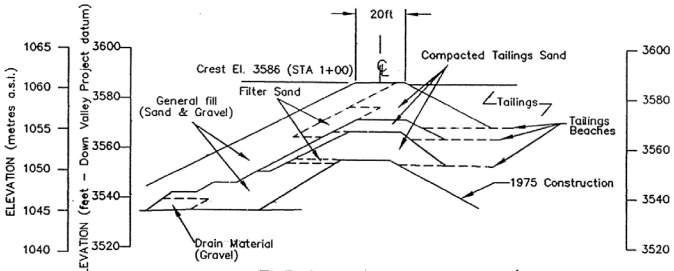
Source: Klonn Crippen Berger Ltc. (2008); modified with the Government of Yukon's Permission





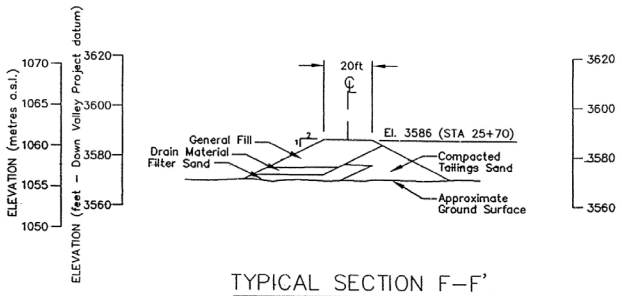
Source: Klonn Crippen Berger Ltd. (2008); modified with the Government of Yukon's Permission

FIGURE 6C-6
As-built Cross Section and Photograph of the Cross Valley Dam
Faro Mine Interim Works



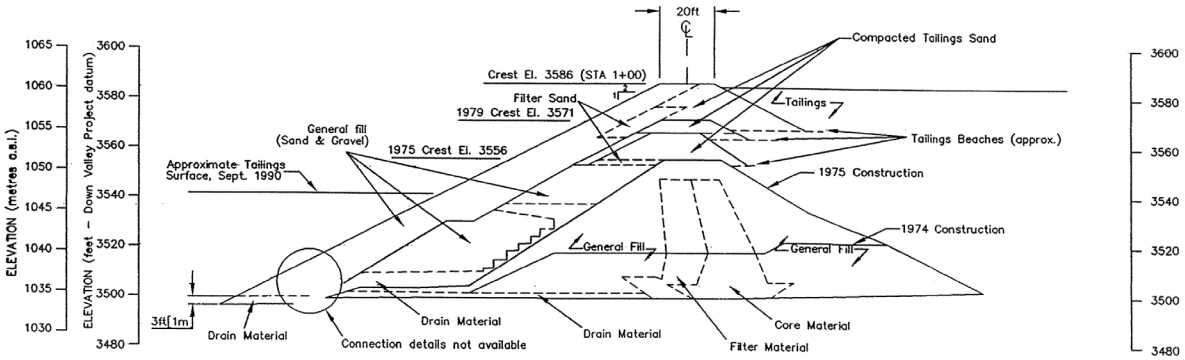
TYPICAL SECTION D–D'

(REPRESENTS STATIONS 0+00 TO 10+00, AND 19+00 TO 26+00)



TYPICAL SECTION F–F'

(REPRESENTS STATIONS 26+00 TO 27+86)



TYPICAL SECTION E–E'

(REPRESENTS STATIONS 10+00 TO 19+00)

REFERENCES

1. Golder, Brawner & Associates Dwg. V74011, "Construction Carried Out to End of 1975"' Sept. 1975.
2. Golder Associates, Report No. 782–2736, "1978 Dyke Raising for the Tailings Retention Facility, Faro, Yukon Territory", April 1979, Figure 2 "Tailings Dam, 1978 Construction".
3. Golder Associates, Report no. 802–2024, "Construction Report, Cyprus Anvil Mining Corporation, 1980 Raising of the Tailings Dam, Faro, Yukon Territory", Appendix II, (Tender Drawings).

NOTES

1. All elevations are in feet relative to the Down Valley Project datum. To convert to sea level datum (NAD 27), subtract 106ft (32.3m). To convert from feet to metres, multiply by 0.3048m/ft.

0 20 40 60 80 feet

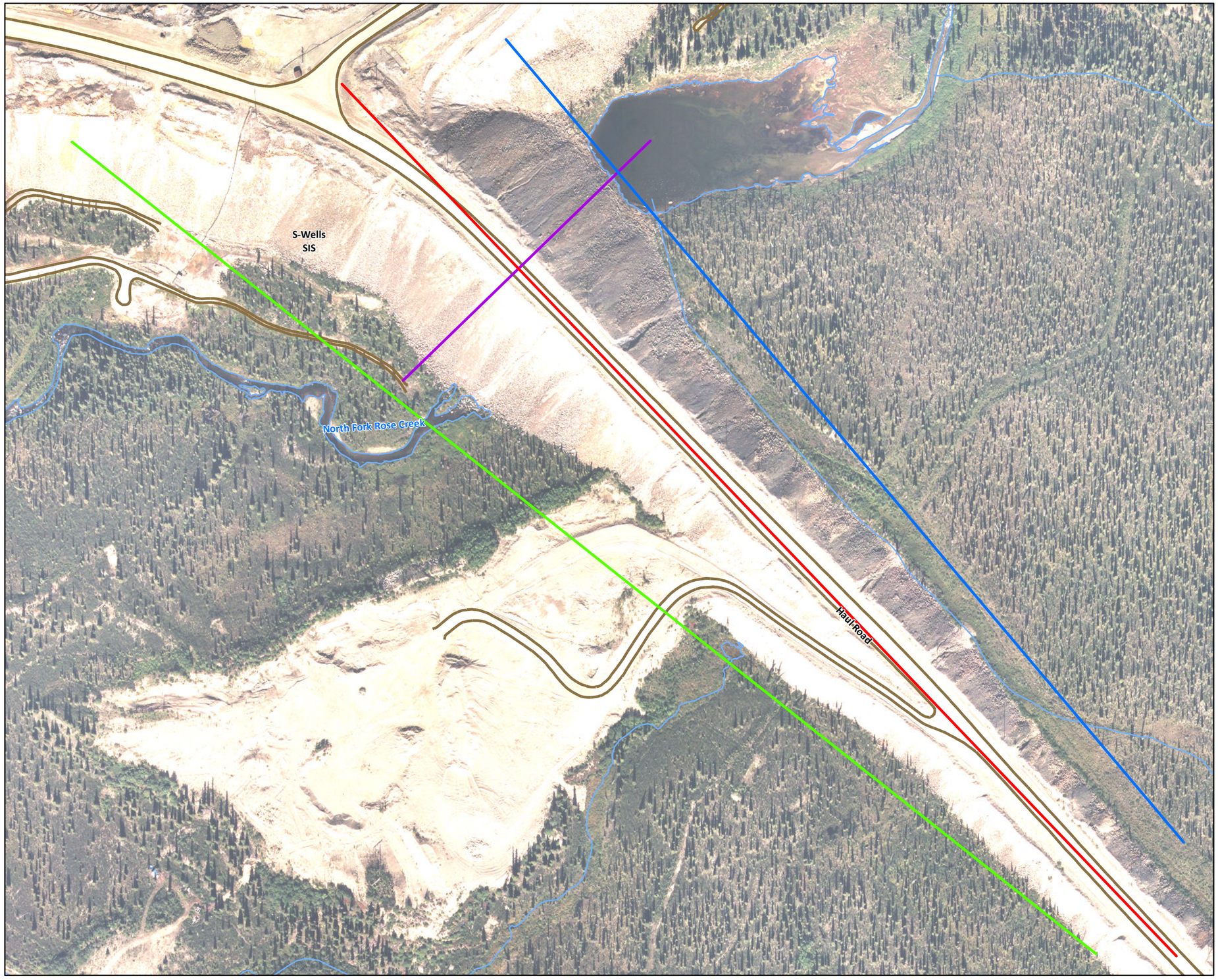
Scale 1"= 50'





Source: Klonn Crippen Berger Ltc. (2006a); modified with the Government of Yukon's Permission

FIGURE 6C-7
As-built Cross Section and Photographs of the Secondary Dam
Faro Mine Interim Works



VICINITY MAP



LEGEND

- Downstream of Haul Road
- Haul Road Centerline
- Maximum Haul Road Section
- Upstream of Haul Road
- Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 37.5 75 112.5 150

Metres

Created by:
CRITIGEN

FIGURE 6C-8
North Fork Rock Drain
Faro Mine Interim Works

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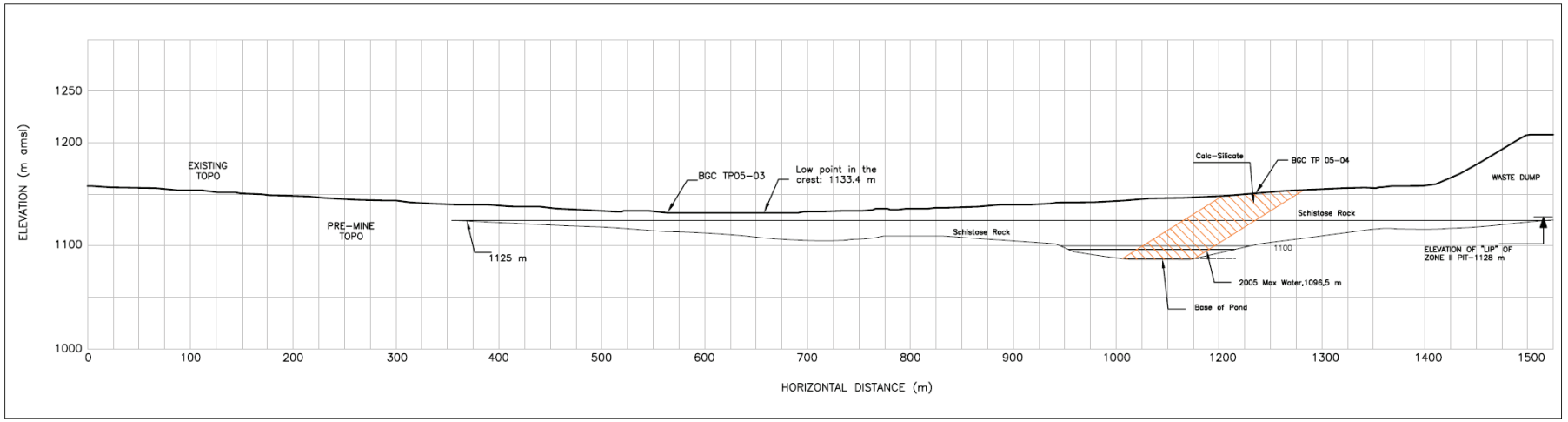



NOTE:

1. EXISTING AND CURRENT TOPOGRAPHIC INFORMATION FROM ORTHOSHOP 2003.
2. LOCATION OF CALC-SILICATE PART OF EMBANKMENT FROM GOLDER 1986 a.
3. ELEVATION OF "LIP" OF ZONE II PIT TAKEN FROM RBC 1996.
4. THE HORIZONTAL LINE DRAWN AT ELEVATION 1125 m amsl IS THE PRESUMED MAXIMUM ALLOWABLE WATER ELEVATION TO PREVENT WATER FLOW INTO THE ZONE II PIT.

FIGURE 6C-9
North Fork Rock Drain Profile
Faro Mine Interim Works

Source: BGC Engineering Inc. (2006); modified with the Government of Yukon's Permission



VICINITY MAP



LEGEND

Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 50 100 150 200

Metres

Created by:
CRITIGEN

FIGURE 6C-10
Location of the Little Creek Dam
Faro Mine Interim Works

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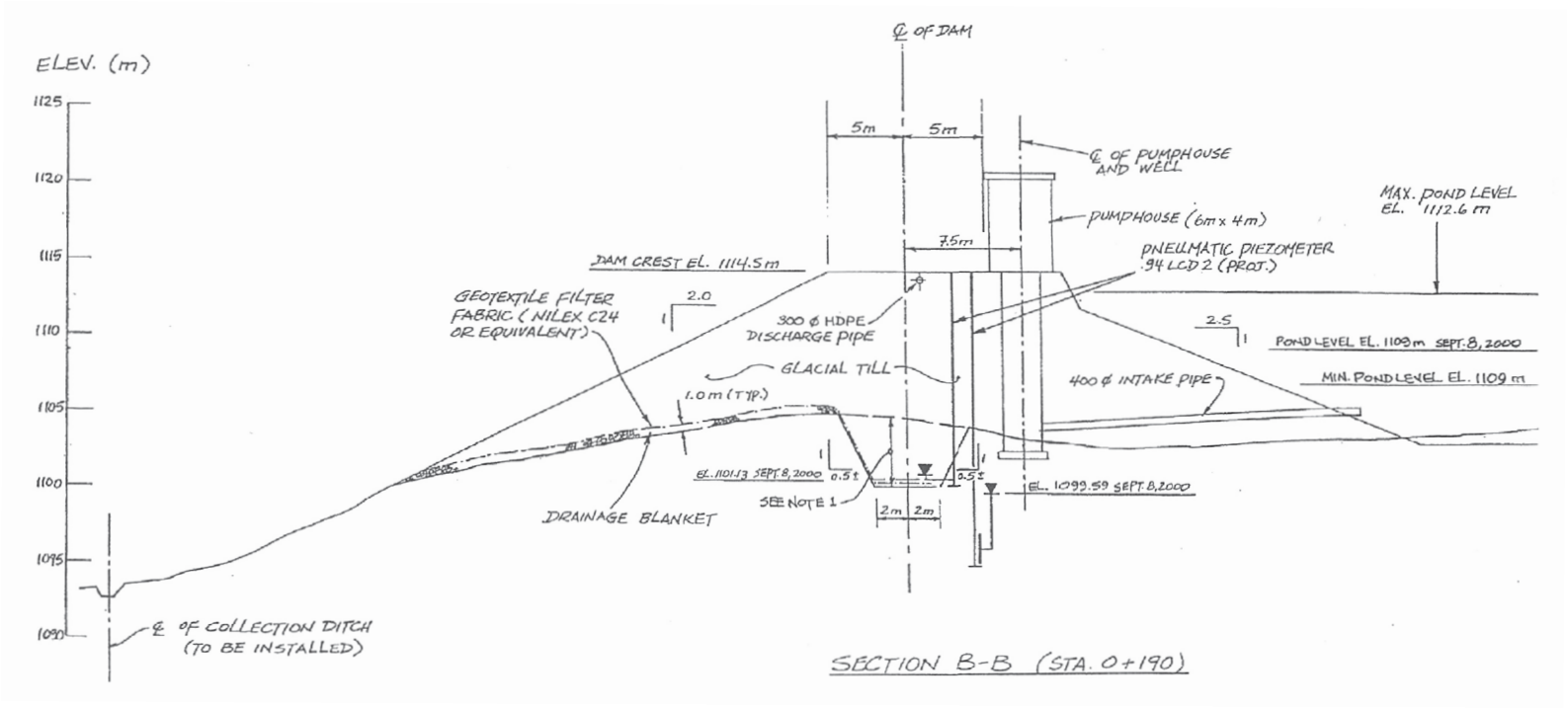
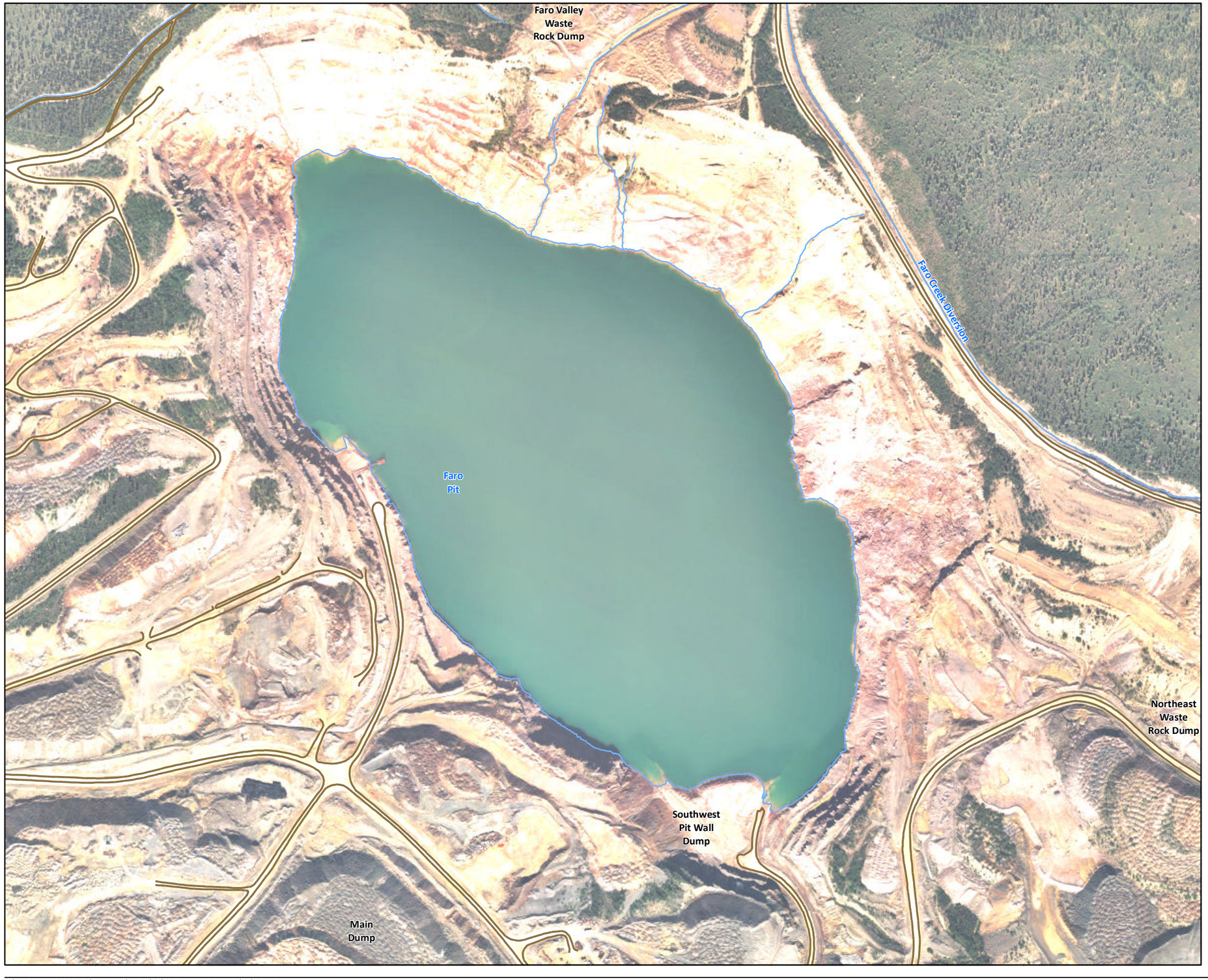


FIGURE 6C-11
Cross Section and Photographs of the Little Creek Dam
Faro Mine Interim Works

Source: Klonn Crippen Berger Ltd. (2008); modified with the Government of Yukon's Permission



VICINITY MAP



LEGEND

Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 75 150 225 300

Metres

Created by:
CRITIGEN

FIGURE 6C-12
Faro Pit
Faro Mine Interim Works

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VICINITY MAP



LEGEND

Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 50 100 150 200

Metres

Created by:
CRITIGEN

FIGURE 6C-13
Grum Pit
Faro Mine Interim Works

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VICINITY MAP



LEGEND

Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 37.5 75 112.5 150

Metres

Created by:
CRITIGEN

FIGURE 6C-14
Vangorda Pit
Faro Mine Interim Works



VICINITY MAP



LEGEND

Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. LGSP = Low-grade Stockpile
4. MGO = Medium-grade Ore

N

0 175 350 525 700

Metres

Created by: CRITIGEN

FIGURE 6C-15

Waste Dump - Faro Mine Area

Faro Mine Interim Works

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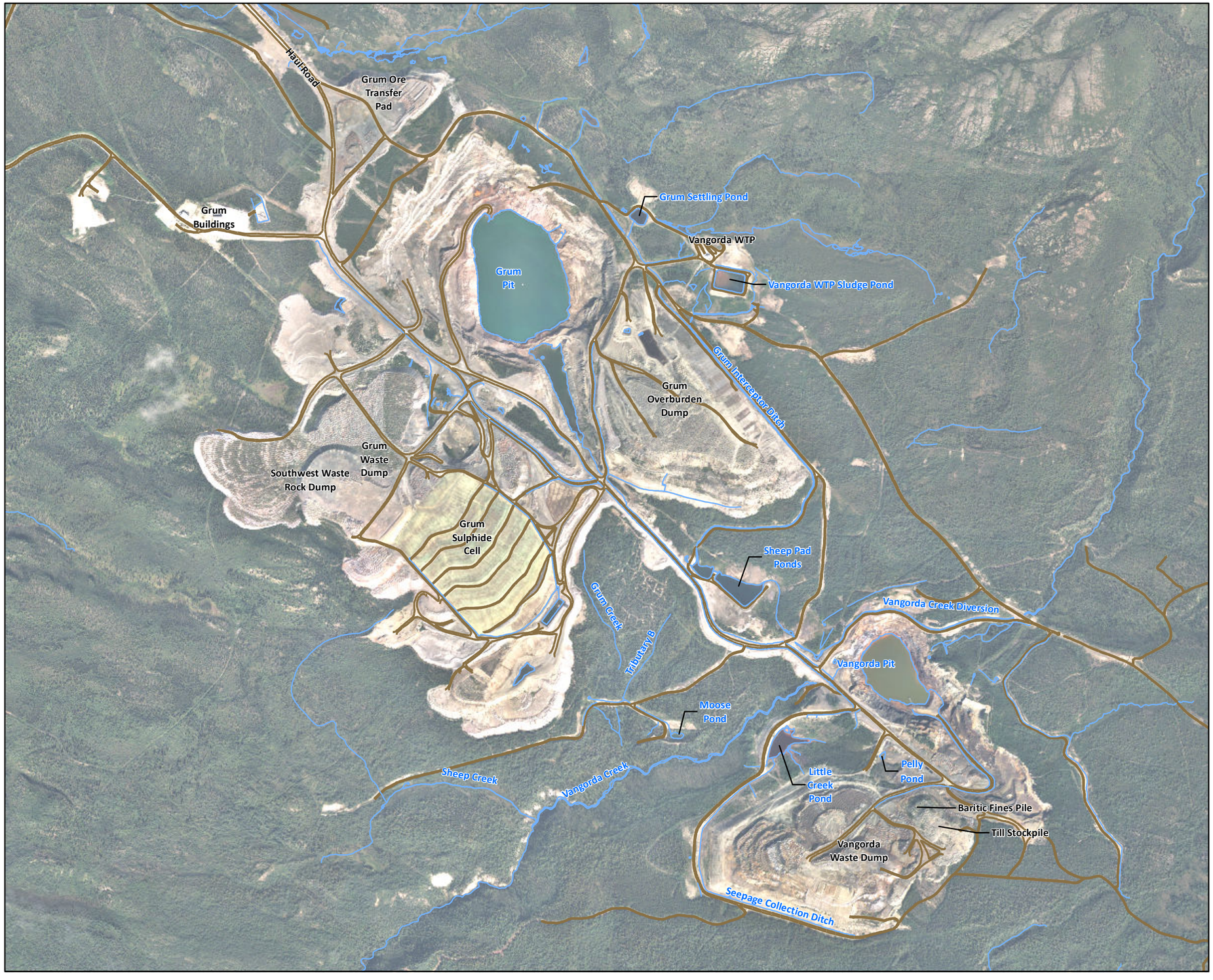


VICINITY MAP



LEGEND

Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 200 400 600 800

Metres

Created by: CRITIGEN

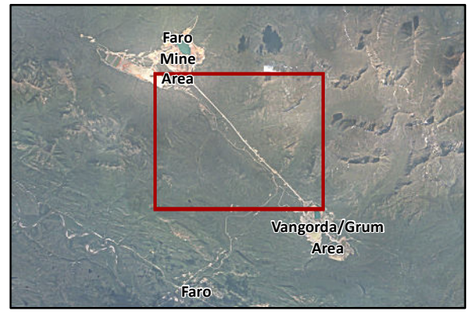
FIGURE 6C-16

Waste Dumps - Vangorda/Grum Area

Faro Mine Interim Works



VICINITY MAP



LEGEND

Road Unpaved

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 400 800 1,200 1,600

Metres

Created by:
CRITIGEN

FIGURE 6C-17
Haul Road and Potential Breach Locations
Faro Mine Interim Works

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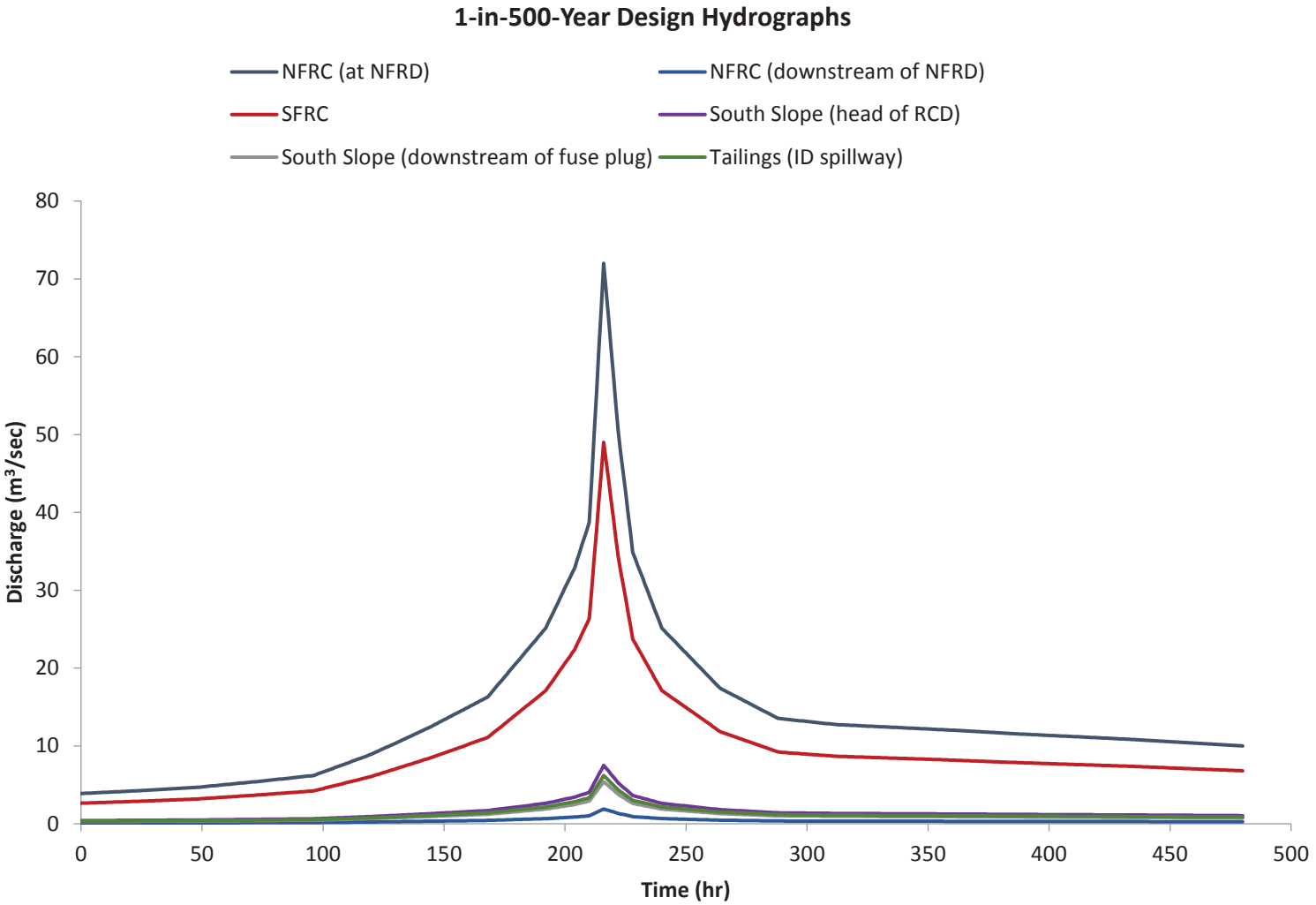
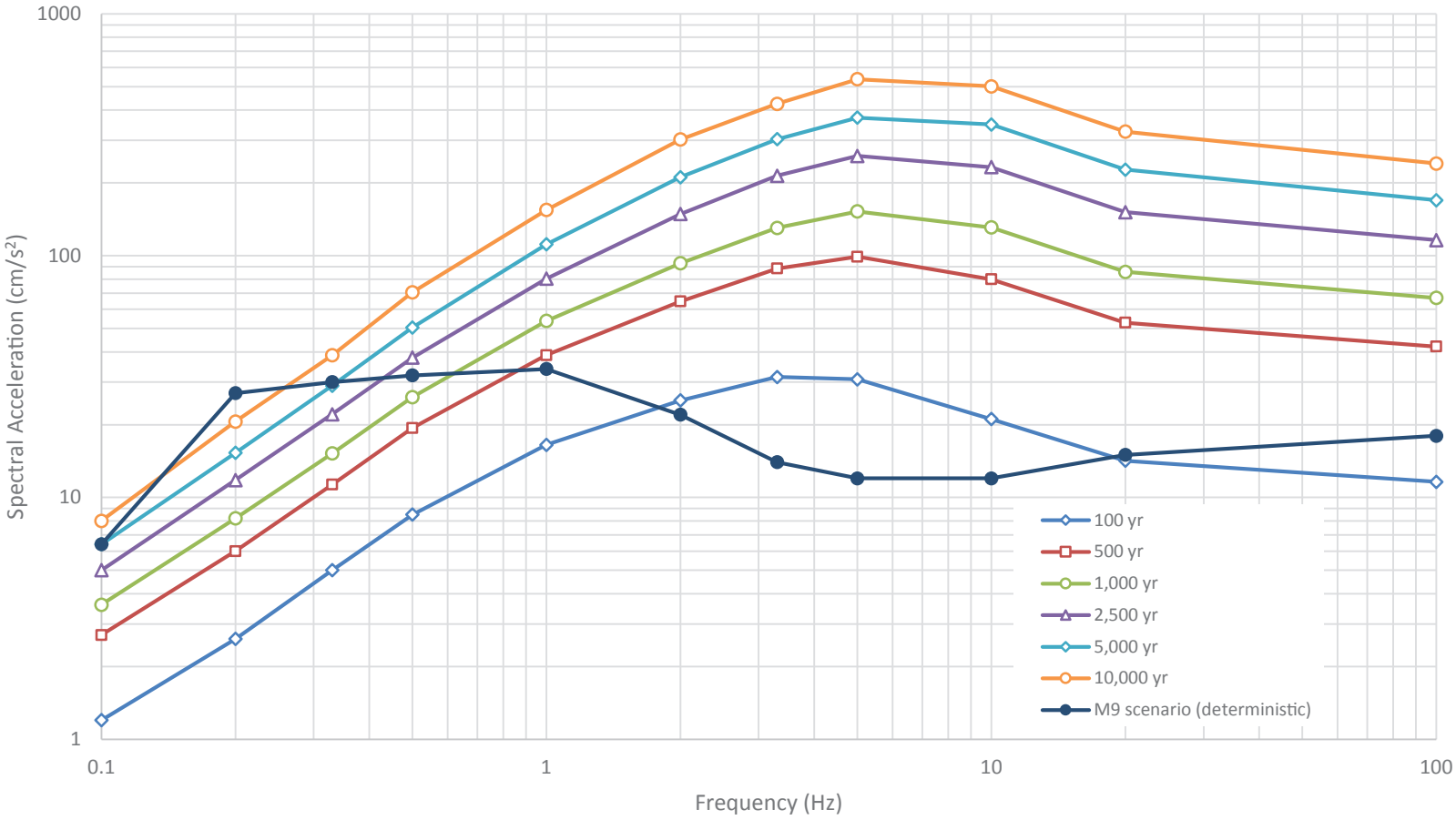


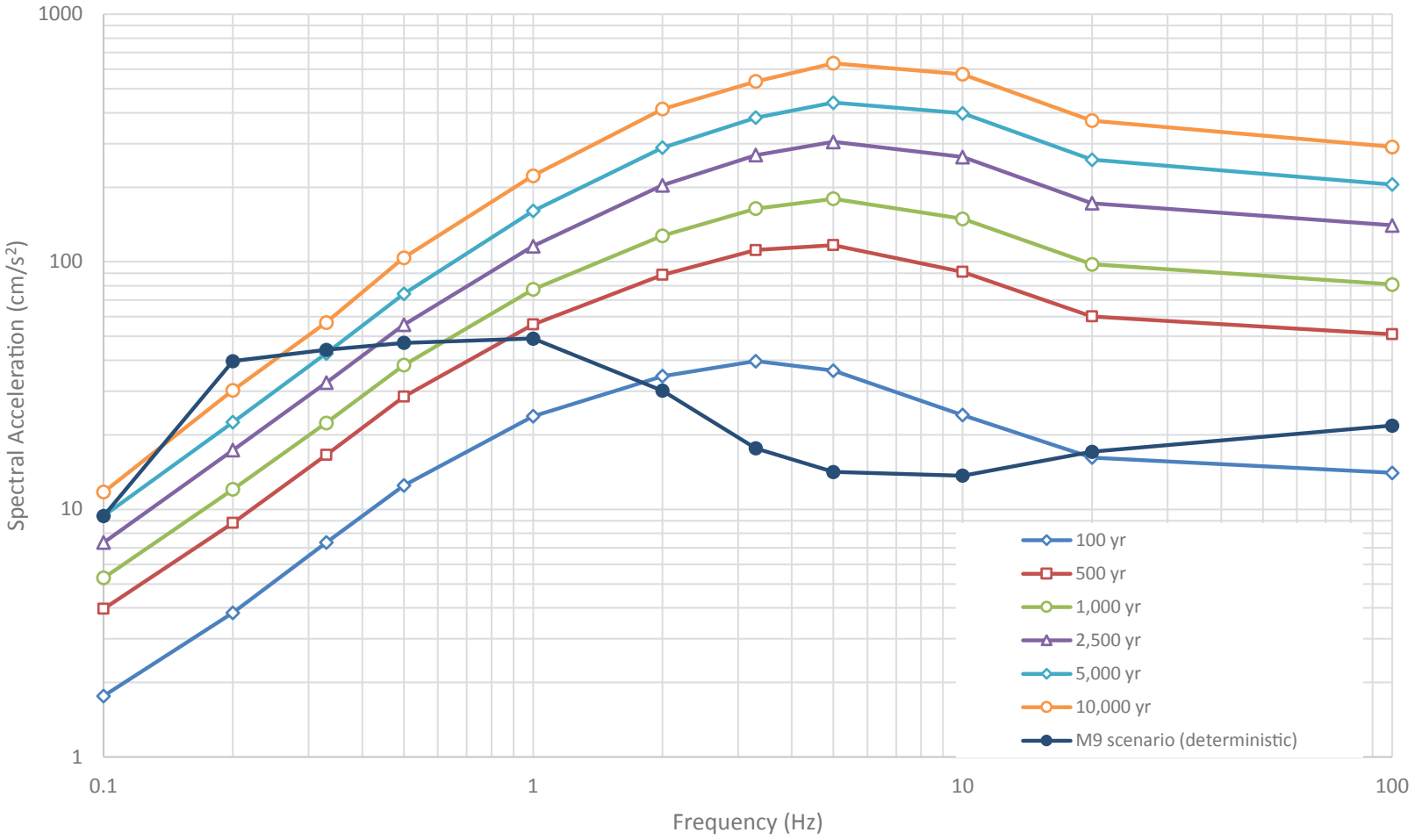
FIGURE 6C-18
1-in-500-Year Design Hydrographs
Faro Mine Interim Works



Notes:
1. Mean, shown with B/C conditions.
2. PGA shown for reference frequency of at 100 Hz.

Source: Atkinson and Assatourians, (2013)

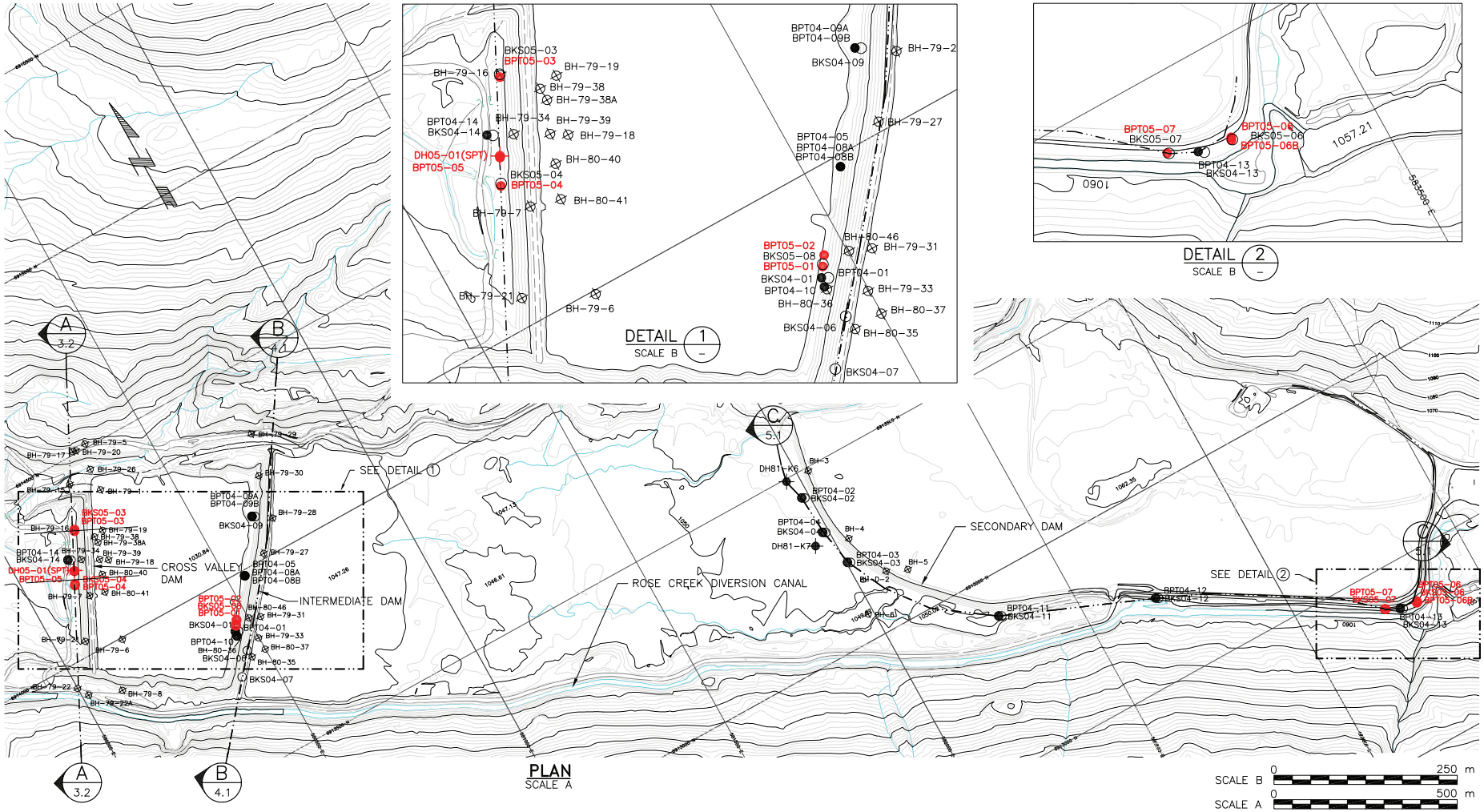
FIGURE 6C-19
Faro Uniform Hazard Spectra – B/C Conditions
Faro Mine Interim Works



Notes:
1. Mean, shown for Site Class C conditions.
2. PGA shown for reference frequency of at 100 Hz.

Source: Atkinson and Assatourians, (2013)

FIGURE 6C-20
Faro Uniform Hazard Spectra – Site Class C Conditions
Faro Mine Interim Works



LEGEND

- BH-80-36 — GOLDER TEST HOLE
- BKS05-03 — KLOHN CRIPPEN OPEN BECKER TEST
- BPT05-04 — KLOHN CRIPPEN CLOSED BECKER TEST
- DH05-01 — KLOHN CRIPPEN TEST HOLE

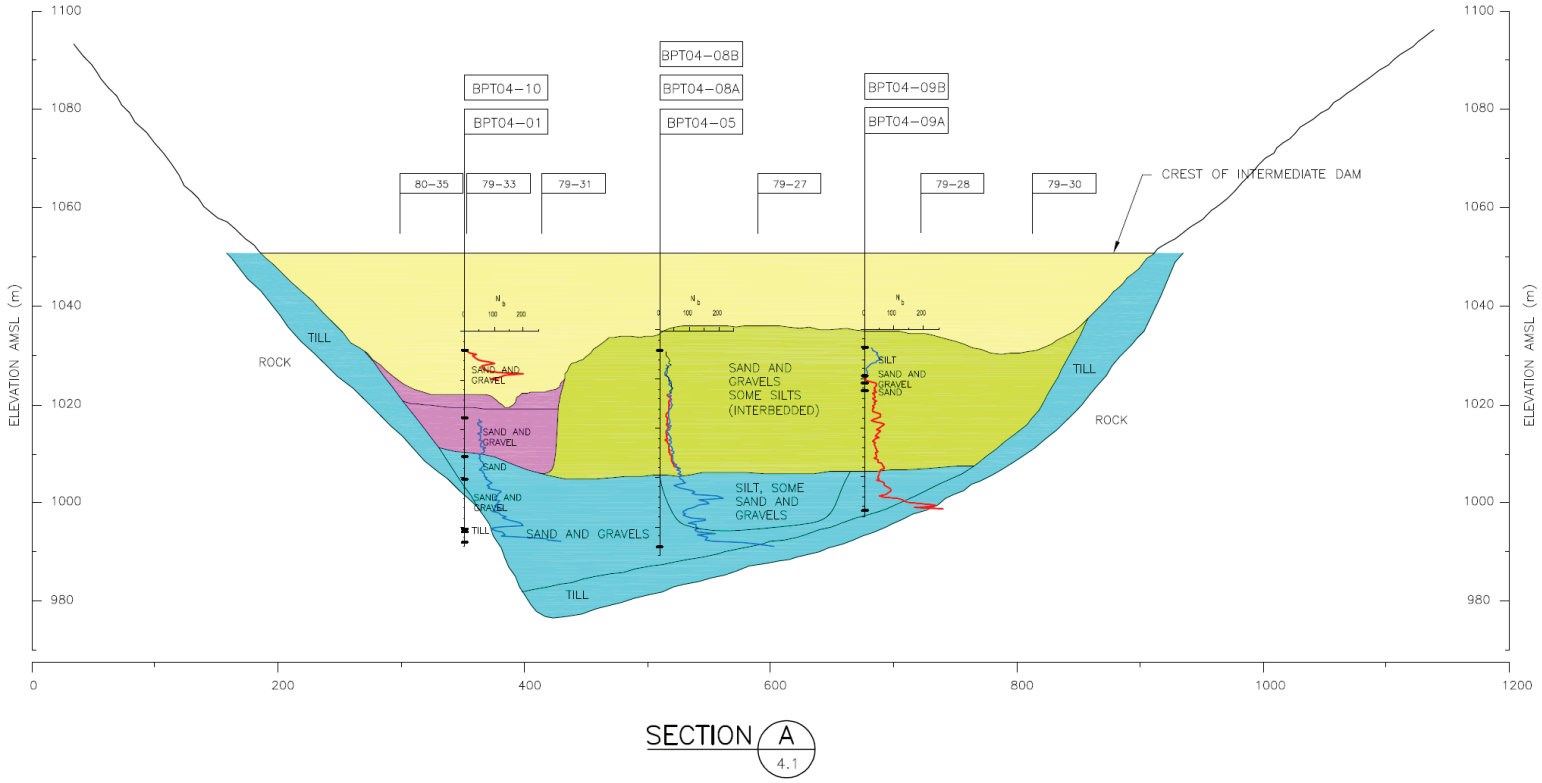
NOTES:

1. BASE PLAN TAKEN FROM 2003 FARO SITE PLAN1_Ver2000.DWG PROVIDED BY SRK.
2. CONTOUR INTERVAL IS 2m RELATIVE TO MEAN SEA LEVEL.
3. BH3 TO BH6 AND BH-D-2 LOCATIONS ARE APPROXIMATE.

FIGURE 6C-21
Test Hole Location Plan
Faro Mine Interim Works

Source: Klohn Crippen Berger Ltd. (2006b); modified with the Government of Yukon's Permission

CH2MHILL



SECTION A
4.1

VERTICAL SCALE 0 50 m

HORIZONTAL SCALE 0 200 m

LEGEND

- FILL
- ROSE CREEK SEDIMENTS
- GLACIO-FLUVIAL SEDIMENTS-TERRACE
- PLEISTOCENE SEDIMENTS

NOTE:

1. SECTION IS TAKEN FROM KLOHN LEONOFF (1981) DRAWING FOR GROUND CONDITIONS BENEATH CENTERLINE OF INTERMEDIATE DAM. KC BECKER HOLE INFORMATION IS SUPERIMPOSED AND WAS OBTAINED ON DOWNSTREAM BERM.

Source: Klohn Crippen Berger Ltd. (2006b); modified with the Government of Yukon's Permission

FIGURE 6C-22
Intermediate Dam Foundation Stratigraphy
Faro Mine Interim Works

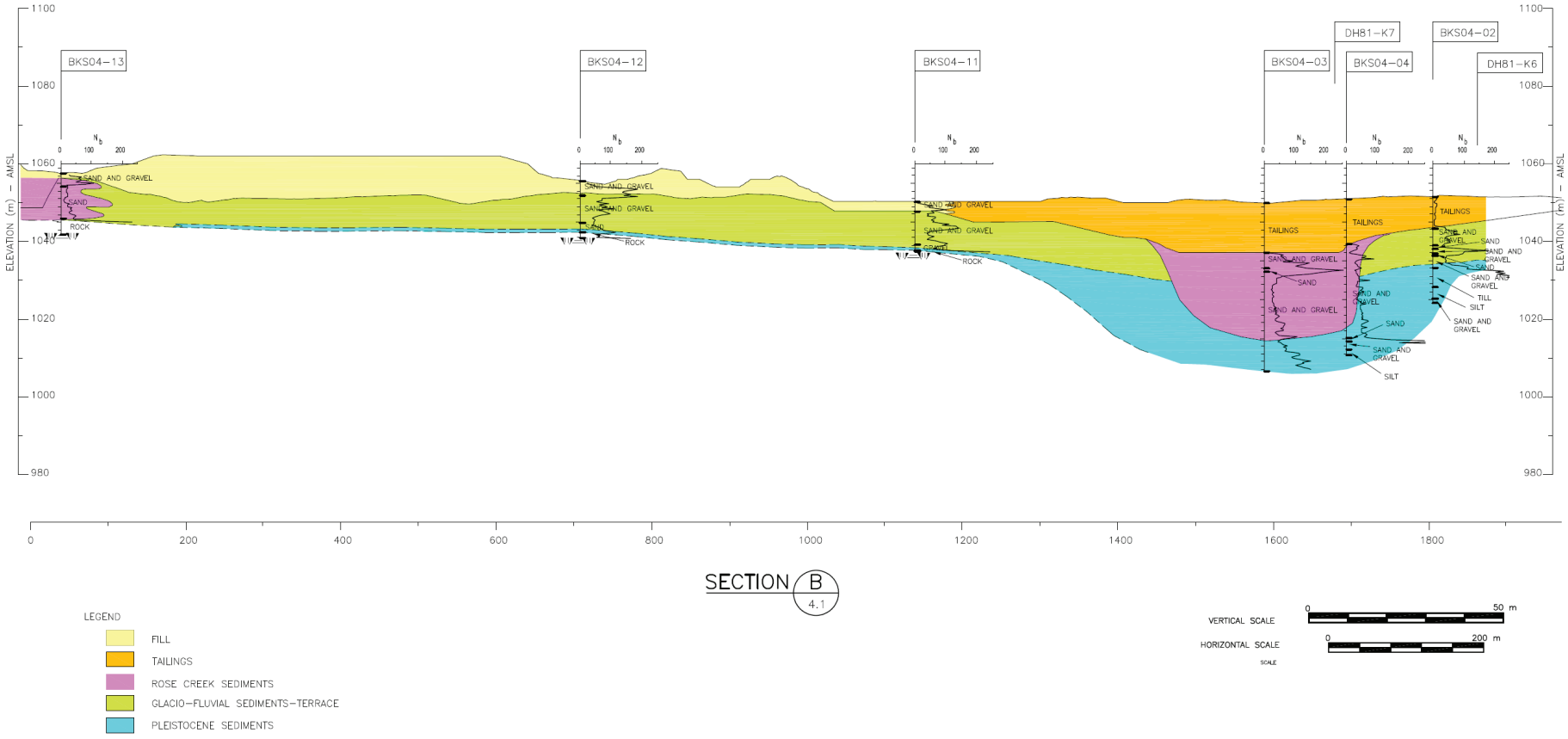


FIGURE 6C-23
Secondary Dam Foundation Stratigraphy
Faro Mine Interim Works

Source: Klohn Crippen Berger Ltd. (2006b); modified with the Government of Yukon's Permission

Attachment 6C-1
Seismic Stability Preliminary Analysis
Secondary Dam, East Limb

Seismic Stability Analysis, Secondary Dam - East Limb Faro Mine Complex

PREPARED BY: Michael Eller/CVO

DATE: October 25, 2013

PROJECT NUMBER: 472645.08.PT.EA.01

Introduction

This technical memorandum details the evaluation of liquefaction potential and slope stability of the East Limb of the Secondary Dam (SD). Ground motions associated with a 500-year seismic event were considered in the analysis.

The East Limb of the SD runs parallel with the Rose Creek Diversion and has a maximum height of approximately 5 metres (m). The dam was constructed with compacted tailings sand, and capped with a granular outer shell along the downstream slope. The downstream slope is 2H:1V. Figure 6C-1-1 shows the location of the SD.

Background

Seismicity

In 2013, Atkinson and Assatourians updated the seismic hazard assessment for the Faro Mine Complex (FMC) (Atkinson and Assatourians, 2013), resulting in significantly lower motions than those presented by Atkinson's previous seismic hazard assessment (2004). The main reasons for this re-evaluation of ground motions were insights gained during studies performed since 2004.

A significant study evaluated the tectonic setting of the Tintina Fault, the controlling fault for the FMC. In a report by CH2M HILL Canada Limited (CH2M HILL, 2013), the most recent interpretation of the 30-kilometre (km)-wide fault zone is that it no longer accommodates significant seismic deformation as once thought. The fault is currently characterized by low slip rates and activity rates. The report concluded the fault is structured more as aerial source zone comprising several faults than a distinct linear active fault.

The most significant study warranting a re-evaluation is the improvement of ground motion prediction equations (GMPEs). GMPEs estimate ground shaking based on an earthquake's magnitude, its distance from site, and site conditions. The databases that house GMPEs are actively growing, promoting continual refinement to the models.

GMPEs were developed for the FMC based upon Site Class B/C site conditions ("Site Class B/C" denotes the boundary between rock and soil materials and is defined as material with average shear wave velocity of 760 metres per second [m/s] in upper 30 m of soil profile). This follows the recommendations by Atkinson and Adams (2013) for the 2015 National Building Code of Canada (NBCC) National Seismic Hazard Maps. Amplification factors that convert spectral accelerations from Site Class B/C to other site classes, such as Site Class C (450 m/s), can be applied to account for change in ground motions due to softer soil conditions.

Based on these studies, the ground motions are reduced significantly for the FMC, particularly for the design maximum credible earthquake (MCE) for the 10,000-year return period. Atkinson and Assatourians (2013) reduce the peak ground acceleration (PGA) for the FMC from 0.5 g (mean value from Atkinson, 2004) to 0.25 g at the B/C boundary, a 50 percent reduction.

Ground motions were also evaluated for the subduction zone bordering Alaska. Although the subduction zone is located approximately 500 km from the FMC, a magnitude M9 subduction event can produce high ground motions at low frequencies, affecting structures with larger natural periods.

The seismic hazard assessment for the FMC was originally prepared by Atkinson (2004). This report presented site-specific seismic hazards, identifying an MCE with a moment magnitude (Mw) of 7.0, a return period of 10,000 years, and that could produce a mean PGA at a rock site (Site Class B/C boundary) of 0.5 g.

For a 500-year recurrence interval (the return period of interest for this analysis), the mean PGAs at the Site Class B/C boundary and at Site Class C are 0.043 g and 0.052 g, respectively. A Site Class amplification factor of 1.21 is applied to the PGA, to convert soil conditions from Site Class B/C to Site Class C.

Previous Geotechnical Work

In earlier phases of the FMC closure process, the following stability evaluations took place for the East Limb of the SD, as well as several other dams across the FMC.

Golder Associates

Golder Associates (Golder) (2004) evaluated the liquefaction potential in the tailings across the FMC, including those behind the East Limb of the SD. Using CPT soundings and laboratory testing, Golder (2004) identified the tailings sand and slimes to be potentially liquefiable for the Atkinson (2004) MCE event. Residual strengths for the tailings sand and slime were determined using the methods by Idriss (2004) and Olson and Stark (2002), respectively.

Klohn Crippen Berger

Klohn Crippen Consultants (KCC) (2006a) performed a seismic stability analysis for the East Limb of the SD based on a 10,000 year seismic event, the MCE for the FMC. According to the analysis, the foundation soils of the SD, particularly along the eastern section near Rose Creek, consisted of liquefiable sands and silts for the given ground motions of the MCE. The residual strength of these soils was estimated based on standard penetration test (SPT) $(N_1)_{60}$ values converted from Becker hammer penetration tests (BPT) using the Sy (1993) method. The liquefaction potential was evaluated based on the simplified method by Youd et al. (2001). Following this method, the ground motions for determining the cyclic stress ratio (CSR) were established using a site-specific response analysis from the time histories Atkinson recommended (2004). After the analysis, several layers were identified as potentially liquefiable between elevations of 1,049.5 m and 1,053.0 m, and 1,042.0 m and 1,046.0 m (KCC, 2006b). This corresponded to layers with BPT-converted SPT $(N_1)_{60}$ values less than 10.

The residual strength of the liquefied sands was determined using methods by Idriss (2004). A slope stability evaluation accounting for the strength loss within these soils resulted in a post-seismic failure along the downstream slope in the SD, releasing tailings downstream. The post-liquefaction slope stability was evaluated using GeoStudio's Slope/W (2004) computer program, following the Morgenstern and Price (1967) method. The post-liquefaction factor of safety was 0.78. Slope deformation estimates were performed using Newmark (1965), Makdisi and Seed (1978), and Hynes and Franklin (1984) methods. However, Golder did not report displacements in the text of the report.

In their analysis, KCC carried Golder's (2004) conclusion that the tailings would liquefy. KCC (2006a) provided a conceptual remediation design to the SD that involved vibro-replacement to densify the loose sands.

In a similar study, KCB (2007) evaluated the stability of the Cross Valley Dam for a 500-year event. Based on the seismic loading provided in Atkinson (2004), they concluded the foundation soils would not liquefy and that displacements for such an event will be tolerable.

Liquefaction Evaluation

Based on the updated ground motions provided by Atkinson and Assatourians (2013) for a 500-year event, CH2M HILL Canada Limited (CH2M HILL) re-evaluated the liquefaction potential of the SD, East Limb profile. The following BPTs were evaluated: BPT05-07, BPT04-13, and BPT05-06B. These were the same explorations KCC evaluated in their analysis (2006a). Equivalent BPT-converted SPT $(N_1)_{60}$ values were measured manually from Atkinson and Assatourians (2013). The simplified procedure from Youd et al (2001) was used. The PGA

for rock was modified to account for the Site Class C conditions at the FMC, using a F_a factor of 1.21, as provided by Atkinson and Assatourians (2013). Soil properties, such as unit weight and fines content, were selected based KCC (2006a).

Liquefaction potential is a function of overburden stress. Therefore, profiles at the crest and the toe of the SD were evaluated for each BPT exploration. No liquefaction zones were identified in the six profiles.

Figures 6C-1-2 and 6C-1-3 summarize the results of the analysis, showing the factor of safety against liquefaction (FS_L) with elevations at the crest and toe of the SD, respectively. Tables 6C-1-3 to 6C-1-8 provide complete results of the liquefaction analysis.

Slope Stability Analysis

Following the liquefaction analysis, slope stability evaluations were performed to estimate the factor of safety for the static, pseudo-static, and post-seismic conditions. The computer program SLIDE, Version 6 (RocScience, 2012) was used for the slope stability analysis. The Morgenstern and Price (1967) method was used to calculate the factor of safety for each of the stability analyses.

Although no liquefaction occurred in the profiles for a 500-year event, a post-seismic stability evaluation was performed to assess stability, assuming the retained tailings liquefy. The liquefied tailings would exert lateral pressure on the dam, which would tend to increase sliding potential through a horizontal surface. For the liquefied tailings, the residual strength estimated by Golder (2004) was used. No other reduction in soil strengths are made for this condition.

The cross-section profile used for analysis was that used by KCC (2006a, 2006b), which focuses on the section on the southeast end of the SD near the Rose Creek Drainage (Figure 6C-1-1). Figure 6C-1-4 shows the cross-section used for the analysis.

Soil properties used in the analysis are from KCC (2006a) and Golder (2004), and are summarized in Table 6C-1-1.

Table 6C-1-2 summarizes the results of the slope stability analysis. Based on the analysis, all conditions meet or exceed the minimum required factor of safety of 1.5.

Full results of the slope stability analysis are included in Figure 6C-1-5 for the static analysis, Figure 6C-1-6 for the pseudo-static analysis, and Figure 6C-1-7 for the post-seismic analysis.

Conclusion

For the East Limb of the SD, CH2M HILL reached the following conclusion for a 500-year seismic event:

- No liquefaction was predicted for the foundation soils of the SD.
- The slope on the southeast section of the SD is stable, with factors of safety of 1.5 or greater. Static, pseudo-static, and post-seismic conditions were analyzed, which assumed the retained tailings would liquefy.

For a 500-year seismic event, it is anticipated that small deformations will occur. Such deformations are tolerable; therefore, the SD will not breach and release tailings. This evaluation only applies to the interim period, and it is recommended that detailed analyses be performed for final closure utilizing MCE motions.

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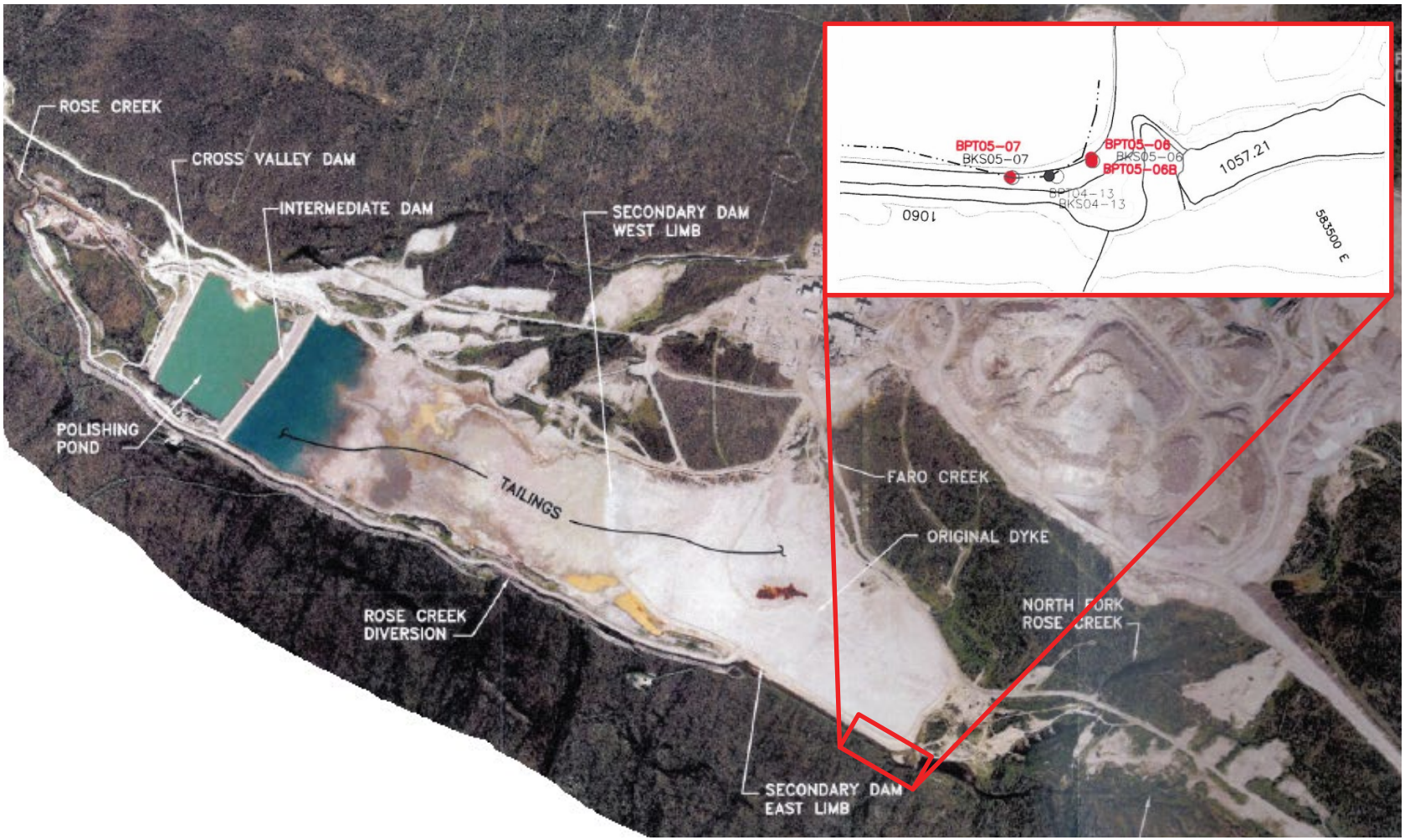
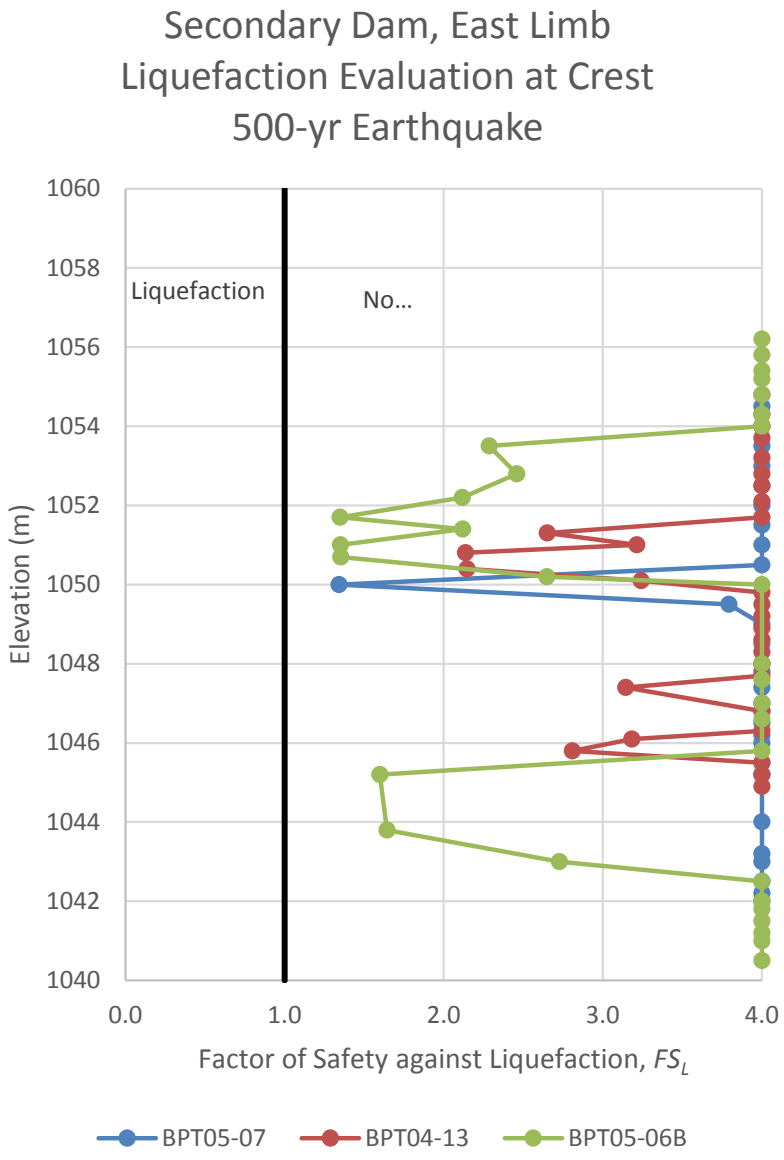


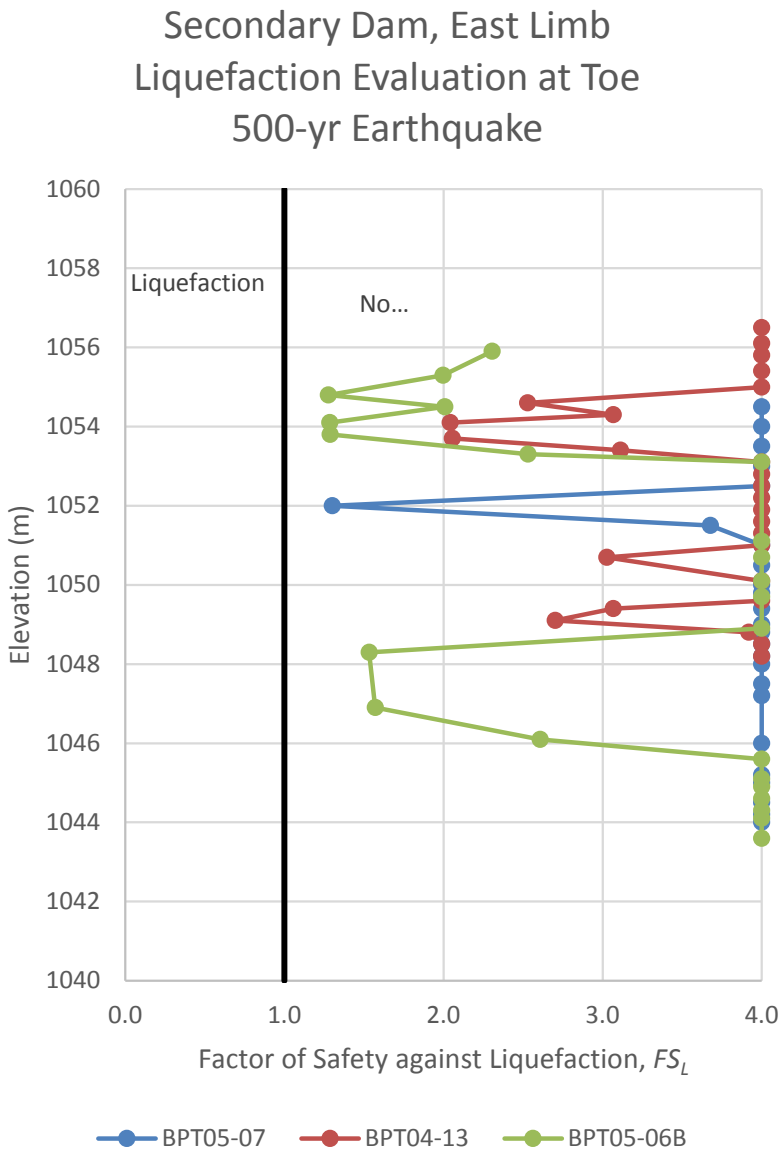
FIGURE 6C-1-1
Secondary Dam, East Limb of the Rose Creek Tailings Impoundment
Faro Mine Interim Works

Source: Klonn Crippen Berger Ltd. (2006b); modified with the Government of Yukon's Permission



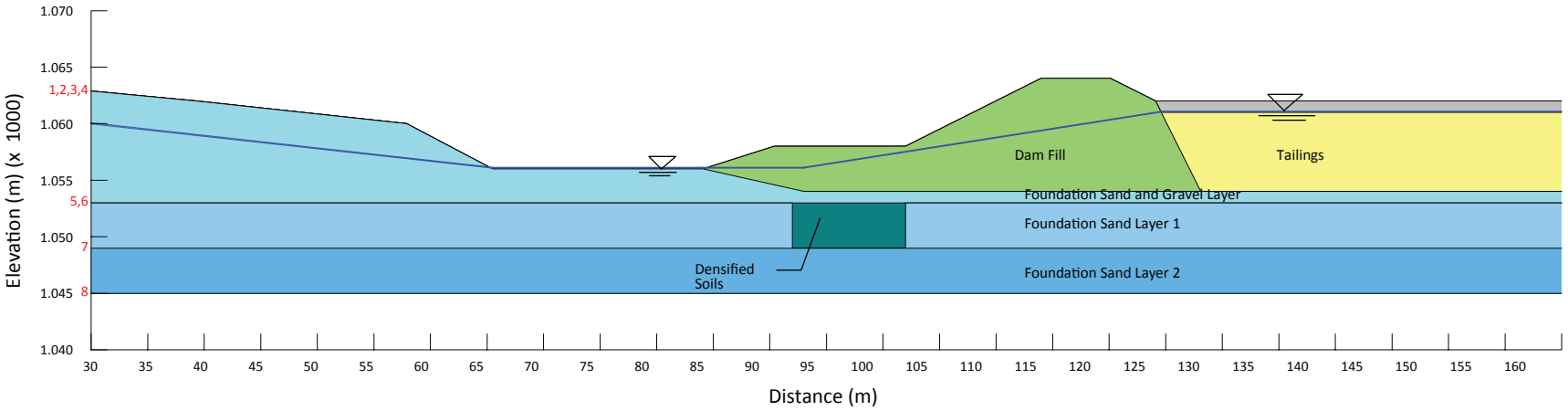
Note:
m = metres

FIGURE 6C-1-2
Liquefaction Evaluation at Dam Crest
Faro Mine Interim Works



Note:
m = metres

FIGURE 6C-1-3
Liquefaction Evaluation at Toe Dam
Faro Mine Interim Works



Note:
m = metres

Source: Klohn Crippen Berger Ltd. (2006a); modified with the Government of Yukon's Permission

FIGURE 6C-1-4
Cross Section of the Secondary Dam, East Limb, Used for Slope Stability Analysis
Faro Mine Interim Works

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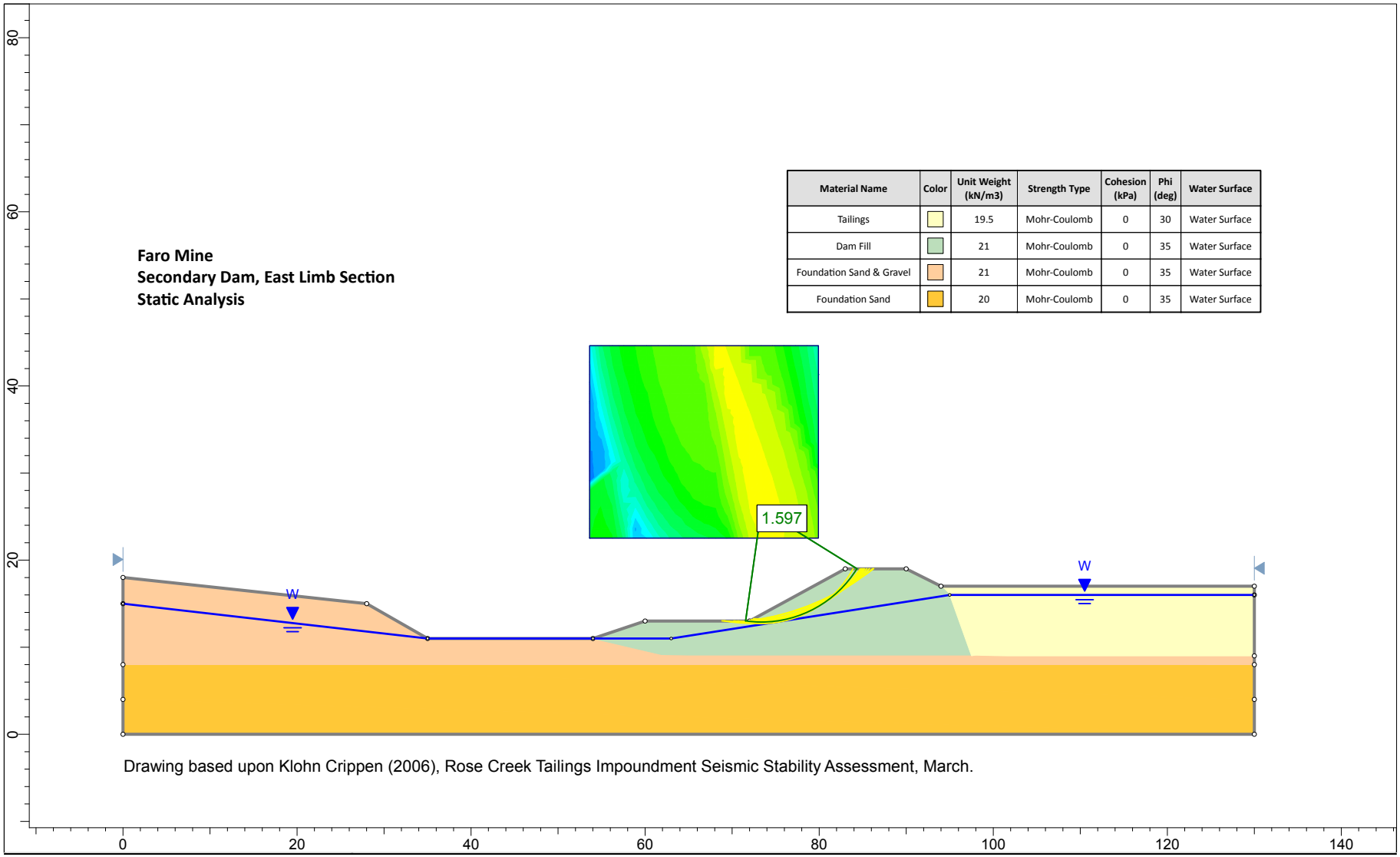

FIGURE 6C-1-5
Slope Stability Analysis – Static;
Secondary Dam, East Limb
Faro Mine Interim Works

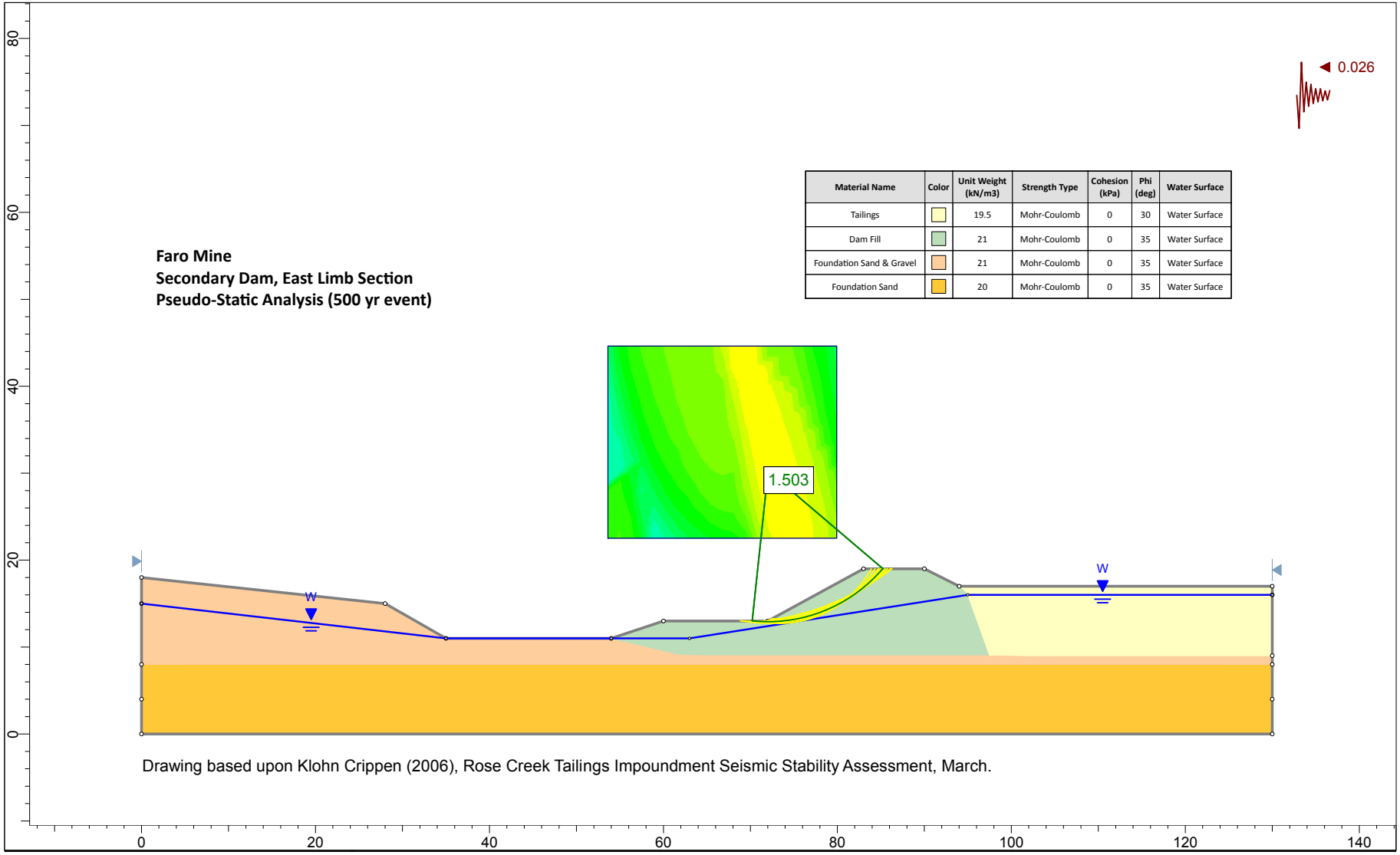

FIGURE 6C-1-6
Slope Stability Analysis – Pseudo-static; Secondary Dam, East Limb
Faro Mine Interim Works

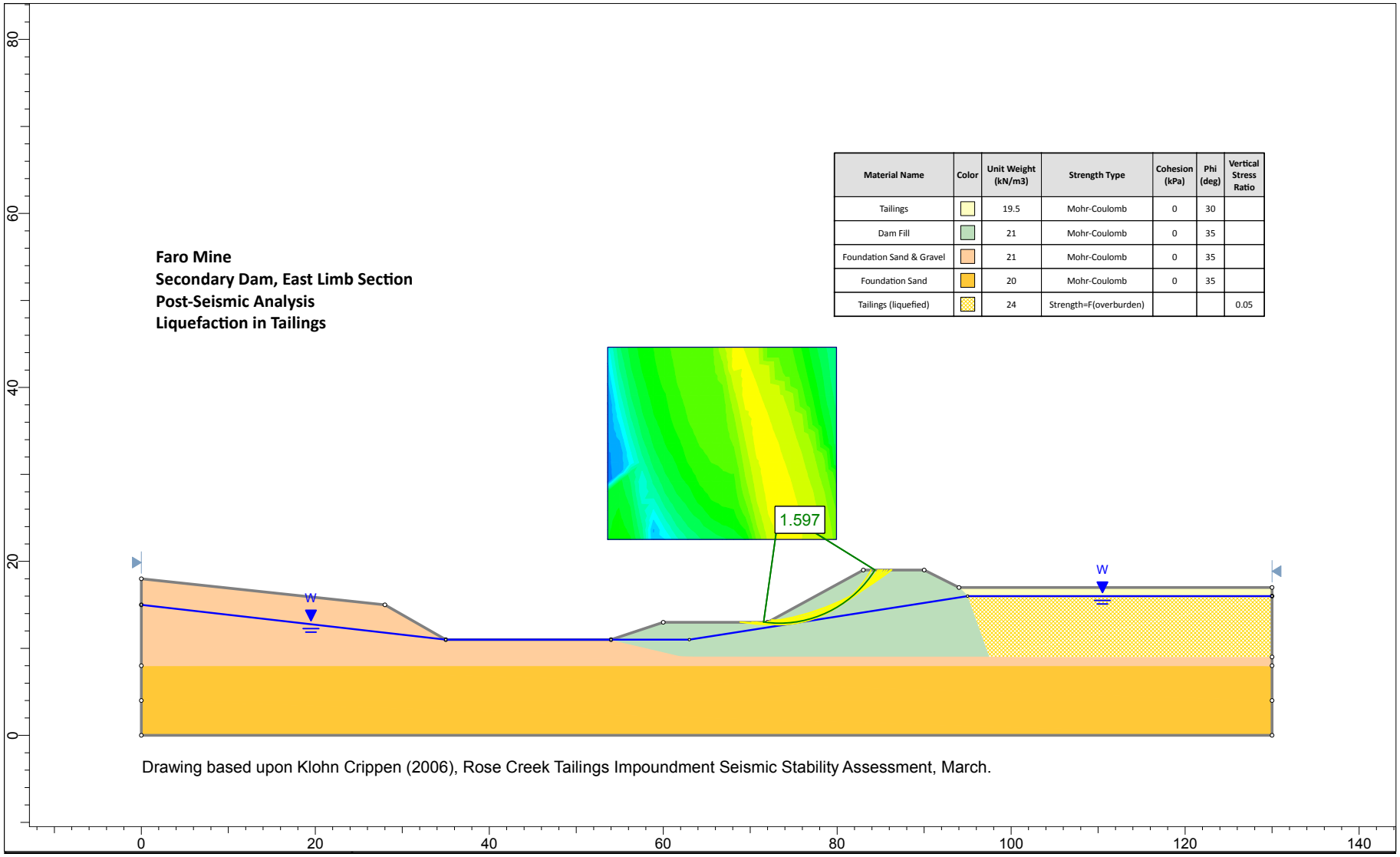

FIGURE 6C-1-7
Slope Stability Analysis – Post-seismic; Secondary Dam, East Limb
Faro Mine Interim Works



Note:
D50 is estimated as 1 metre.

Source: BCG Engineering Inc. (2006); modified with the Government of Yukon's Permission

FIGURE 6C-2-1
Construction Photo of Calc-silicate Rock Comprising the North Fork Rock Drain
Faro Mine Interim Works



VICINITY MAP



LEGEND

- Borehole Location
- Maximum Section of Haul Road
- Elevation Contour (10m Interval)
- Road Unpaved

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 37.5 75 112.5 150

Metres

Created by:
CRITIGEN

FIGURE 6C-2-2
Location of Maximum Section Selected for Stability Analysis
Faro Mine Interim Works

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CH2MHILL

TABLE 6C-1-1

Soil Properties used in Post-liquefaction Stability Analyses for the Secondary Dam East Limb Section*

Soil Unit	Unit Weight, (kN/m^3)	Friction Angle (deg)	Cohesion (kPa)	Post-Liquefaction Residual Strength Ratio, s_{ur}/σ'_{vo}
Dam Fill	21	35	0	-
Unsaturated Tailings	19.5	30	0	-
Liquefied Saturated Tailings	24	-	-	0.05
Foundation Sand and Gravel Layer 1 with $(N_1)_{60,cs} > 30$	21	35	0	-
Liquefied Foundation Sand Layer 1 with $(N_1)_{60,cs} \approx 10$	20	-	-	0.10
Foundation Sand Layer 1 with $(N_1)_{60,cs} > 22$	20	35	0	-

Notes

* From KCC (2006a, 2006b)

deg. – degree
kN/m^3 – kilonewton per cubic metre
kPa - kilopascal

TABLE 6C-1-2

Slope Stability Analysis Results for Secondary Dam, East Limb

Analysis Scenario	Factor of Safety
Static	1.60
Pseudo-Static (with $k_h = ½*F_a*PGA_{rock}$)	1.50
Post-Seismic	1.60

Notes:

$k_h = ½*F_a*PGA_{rock}$ – seismic coefficient

TABLE 6C-1-3

BPT-Converted SPT $(N^1)_{60}$ Liquefaction Analysis Using Simplified Procedure, Secondary Dam, East Limb, Boring BPT05-07, Crest of Dam

Project name (number):	Faro Mine, Secondary Dam East Limb
Engineer:	Michael Eller/CVO
Reviewer:	
Date:	10/10/13

Soil boring number:	**BPT05-07**	Evaluated at crest of dam
Soil boring ground surface elevation (m):	1055.0	
Groundwater depth during field exploration (m):	0.0	
Design groundwater depth (m):	0.0	
Peak horizontal ground acceleration (ξ_{max}/g):	0.05	$PGA = F_a * PGA_{rock}$, where F_a = 1.2 for Site Class C, and PGA_{rock} = 0.043 (after Atkinson and Assatourians, 2013)
Design earthquake magnitude (M):	7.1	
Magnitude Scaling Factor (MSF):	1.2	
Factor of safety criterion: {1.0 or higher}	1.1	

Interval Bottom Depth (m)	Interval Soil Type	Total Unit Weight (kN/m^3)	BPT-Converted SPT $(N_1)_{60}$ Value Note 1	Estimated Fines Content FC (%)	Estimated Relative Density DR (%)	Interval Bottom Elevation (m)	Average Layer Elevation (m)	Interval Thickness (m)	Effective Unit Weight (kN/m^3)	Average Layer Field Total Overburden (kPa)	Average Layer Design Total Overburden (kPa)	Average Layer Field Effective Overburden (kPa)	Average Layer Design Effective Overburden (kPa)	Stress Reduction Coefficient r_d	Cyclic Resistance Ratio $CRR_{7.5}$ Note 2	CRR Overburden Correction f	CRR Overburden Correction K_σ	CRR Static Shear Correction K_α	Cyclic Stress Ratio CSR	Factor of Safety FS	Limited Factor of Safety FS	Liquefaction Susceptibility	Comments
0.0	Dam Fill	21	100							0.0	0.0	0.0	0.0										
0.5	Dam Fill	21	85	10	85	1054.5	1054.8	0.5	11.19	5.3	5.3	2.8	2.8	1.00	1.000	0.60	1.00	1.00	0.063	18.3	> 4.0	NO	(N1)60 > 30
1.0	Dam Fill	21	70	10	85	1054.0	1054.3	0.5	11.19	15.8	15.8	8.4	8.4	0.99	1.000	0.60	1.00	1.00	0.062	18.4	> 4.0	NO	(N1)60 > 30
1.5	Dam Fill	21	58	10	85	1053.5	1053.8	0.5	11.19	26.3	26.3	14.0	14.0	0.99	1.000	0.60	1.00	1.00	0.062	18.5	> 4.0	NO	(N1)60 > 30
2.0	Gravel and Sand	21	42	9	75	1053.0	1053.3	0.5	11.19	36.8	36.8	19.6	19.6	0.98	1.000	0.63	1.00	1.00	0.062	18.6	> 4.0	NO	(N1)60 > 30
2.5	Gravel and Sand	21	80	9	85	1052.5	1052.8	0.5	11.19	47.3	47.3	25.2	25.2	0.98	1.000	0.60	1.00	1.00	0.062	18.6	> 4.0	NO	(N1)60 > 30
3.0	Sand	20	21	14	50	1052.0	1052.3	0.5	10.19	57.5	57.5	30.5	30.5	0.98	0.228	0.75	1.00	1.00	0.062	4.3	> 4.0	NO	
3.5	Sand	20	23	14	55	1051.5	1051.8	0.5	10.19	67.5	67.5	35.6	35.6	0.97	0.257	0.73	1.00	1.00	0.062	4.8	> 4.0	NO	
4.0	Sand	20	30	14	65	1051.0	1051.3	0.5	10.19	77.5	77.5	40.7	40.7	0.97	0.468	0.68	1.00	1.00	0.062	8.7	> 4.0	NO	
4.5	Sand	20	35	14	70	1050.5	1050.8	0.5	10.19	87.5	87.5	45.8	45.8	0.97	1.000	0.65	1.00	1.00	0.062	18.6	> 4.0	NO	(N1)60 > 30
5.0	Sand	20	5	14	20	1050.0	1050.3	0.5	10.19	97.5	97.5	50.9	50.9	0.96	0.072	0.80	1.00	1.00	0.062	1.3	1.3	NO	
5.5	Sand	20	19	14	50	1049.5	1049.8	0.5	10.19	107.5	107.5	56.0	56.0	0.96	0.203	0.75	1.00	1.00	0.062	3.8	3.8	NO	
6.0	Gravel and Sand	21	30	7	65	1049.0	1049.3	0.5	11.19	117.8	117.8	61.3	61.3	0.95	0.468	0.68	1.00	1.00	0.061	8.8	> 4.0	NO	
6.5	Gravel and Sand	21	36	7	70	1048.5	1048.8	0.5	11.19	128.3	128.3	66.9	66.9	0.95	1.000	0.65	1.00	1.00	0.061	18.8	> 4.0	NO	(N1)60 > 30
7.0	Gravel and Sand	21	23	7	55	1048.0	1048.3	0.5	11.19	138.8	138.8	72.5	72.5	0.95	0.257	0.73	1.00	1.00	0.061	4.9	> 4.0	NO	
7.2	Gravel and Sand	21	32	7	65	1047.8	1047.9	0.2	11.19	146.1	146.1	76.4	76.4	0.94	1.000	0.68	1.00	1.00	0.061	19.0	> 4.0	NO	(N1)60 > 30
7.6	Gravel and Sand	21	23	7	55	1047.4	1047.6	0.4	11.19	152.4	152.4	79.8	79.8	0.94	0.257	0.73	1.00	1.00	0.060	4.9	> 4.0	NO	
8.0	Gravel and Sand	21	30	7	65	1047.0	1047.2	0.4	11.19	160.8	160.8	84.3	84.3	0.94	0.468	0.68	1.00	1.00	0.060	9.0	> 4.0	NO	
8.2	Gravel and Sand	21	32	7	65	1046.8	1046.9	0.2	11.19	167.1	167.1	87.6	87.6	0.94	1.000	0.68	1.00	1.00	0.060	19.2	> 4.0	NO	(N1)60 > 30
8.5	Gravel and Sand	21	22	7	50	1046.5	1046.7	0.3	11.19	172.4	172.4	90.4	90.4	0.93	0.242	0.75	1.00	1.00	0.060	4.7	> 4.0	NO	
8.8	Gravel and Sand	21	22	7	50	1046.2	1046.4	0.3	11.19	178.7	178.7	93.8	93.8	0.93	0.242	0.75	1.00	1.00	0.060	4.7	> 4.0	NO	
9.0	Gravel and Sand	21	40	7	75	1046.0	1046.1	0.2	11.19	183.9	183.9	96.6	96.6	0.93	1.000	0.63	1.00	1.00	0.059	19.3	> 4.0	NO	(N1)60 > 30
9.5	Gravel and Sand	21	100	7	85	1045.5	1045.8	0.5	11.19	191.3	191.3	100.5	100.5	0.92	1.000	0.60	1.00	1.00	0.059	19.6	> 4.0	NO	(N1)60 > 30
9.8	Gravel and Sand	21	27	7	60	1045.2	1045.4	0.3	11.19	199.7	199.7	105.0	105.0	0.91	0.338	0.70	0.99	1.00	0.058	6.6	> 4.0	NO	
11.0	Gravel and Sand	21	100	7	85	1044.0	1044.6	1.2	11.19	215.4	215.4	113.4	113.4	0.88	1.000	0.60	0.96	1.00	0.056	19.6	> 4.0	NO	(N1)60 > 30
11.8	Gravel and Sand	21	100	7	85	1043.2	1043.6	0.8	11.19	236.4	236.4	124.6	124.6	0.86	1.000	0.60	0.92	1.00	0.055	19.4	> 4.0	NO	(N1)60 > 30
12.0	Weathered Rock	21	70	0	85	1043.0	1043.1	0.2	11.19	246.9	246.9	130.2	130.2	0.85	1.000	0.60	0.90	1.00	0.054	19.2	> 4.0	NO	(N1)60 > 30
12.5	Weathered Rock	21	48	0	80	1042.5	1042.8	0.5	11.19	254.3	254.3	134.1	134.1	0.84	1.000	0.60	0.89	1.00	0.053	19.2	> 4.0	NO	(N1)60 > 30
12.8	Weathered Rock	21	60	0	85	1042.2	1042.4	0.3	11.19	262.7	262.7	138.6	138.6	0.83	1.000	0.60	0.88	1.00	0.053	19.2	> 4.0	NO	(N1)60 > 30
13.0	Weathered Rock	21	100	0	85	1042.0	1042.1	0.2	11.19	267.9	267.9	141.4	141.4	0.83	1.000	0.60	0.88	1.00	0.053	19.2	> 4.0	NO	(N1)60 > 30

Notes:

[1] BPT-converted SPT $(N_1)_{60}$ values are interpreted from Klohn Crippen (2006b) report. It is assumed that the material is very few fines throughout the profile. Therefore, $(N_1)_{60}$ is equal to $(N_1)_{60,cs}$

[2] If BPT-converted SPT $(N_1)_{60}$ values are greater than 30, $CRR_{7.5}$ defaults to 1.0 for calculation.

TABLE 6C-1-4

BPT-Converted SPT $(N^1)^{60}$ Liquefaction Analysis Using Simplified Procedure, Secondary Dam, East Limb, Boring BPT05-07, Toe of Dam

Project name (number):	Faro Mine, Secondary Dam East Limb
Engineer:	Michael Eller/CVO
Reviewer:	
Date:	10/10/13

Soil boring number:	**BPT05-07**	Evaluated at toe of dam
Soil boring ground surface elevation (m):	1055.0	
Groundwater depth during field exploration (m):	0.0	
Design groundwater depth (m):	0.0	
Peak horizontal ground acceleration ($\acute{a}_{max}$/g):	0.05	$PGA = F_a * PGA_{rock}$, where F_a = 1.2 for Site Class C, and PGA_{rock} = 0.043 (after Atkinson and Assatourians, 2013)
Design earthquake magnitude (M):	7.1	
Magnitude Scaling Factor (MSF):	1.2	
Factor of safety criterion: {1.0 or higher}	1.1	

Interval Bottom Depth (m)	Interval Soil Type	Total Unit Weight (kN/m^3)	BPT-Converted SPT $(N_1)_{60}$ Value *Note 1*	Estimated Fines Content FC (%)	Estimated Relative Density DR (%)	Interval Bottom Elevation (m)	Average Layer Elevation (m)	Interval Thickness (m)	Effective Unit Weight (kN/m^3)	Average Layer Field Total Overburden (kPa)	Average Layer Design Total Overburden (kPa)	Average Layer Field Effective Overburden (kPa)	Average Layer Design Effective Overburden (kPa)	Stress Reduction Coefficient r_d	Cyclic Resistance Ratio $CRR_{7.5}$ *Note 2*	CRR Overburden Correction f	CRR Overburden Correction K_σ	CRR Static Shear Correction K_α	Cyclic Stress Ratio CSR	Factor of Safety FS	Limited Factor of Safety FS	Liquefaction Susceptibility	Comments
0.0	Gravel and Sand	21	42	9	75					0.0	0.0	0.0	0.0										
0.5	Gravel and Sand	21	80	9	85	1054.5	1054.8	0.5	11.19	5.3	5.3	2.8	2.8	1.00	1.000	0.60	1.00	1.00	0.063	18.3	> 4.0	NO	(N1)60 > 30
1.0	Sand	20	21	14	50	1054.0	1054.3	0.5	10.19	15.5	15.5	8.1	8.1	0.99	0.228	0.75	1.00	1.00	0.063	4.1	> 4.0	NO	
1.5	Sand	20	23	14	55	1053.5	1053.8	0.5	10.19	25.5	25.5	13.2	13.2	0.99	0.257	0.73	1.00	1.00	0.064	4.6	> 4.0	NO	
2.0	Sand	20	30	14	65	1053.0	1053.3	0.5	10.19	35.5	35.5	18.3	18.3	0.98	0.468	0.68	1.00	1.00	0.064	8.4	> 4.0	NO	
2.5	Sand	20	35	14	70	1052.5	1052.8	0.5	10.19	45.5	45.5	23.4	23.4	0.98	1.000	0.65	1.00	1.00	0.064	18.0	> 4.0	NO	(N1)60 > 30
3.0	Sand	20	5	14	20	1052.0	1052.3	0.5	10.19	55.5	55.5	28.5	28.5	0.98	0.072	0.80	1.00	1.00	0.064	1.3	1.3	NO	
3.5	Sand	20	19	14	50	1051.5	1051.8	0.5	10.19	65.5	65.5	33.6	33.6	0.97	0.203	0.75	1.00	1.00	0.064	3.7	3.7	NO	
4.0	Gravel and Sand	21	30	7	65	1051.0	1051.3	0.5	11.19	75.8	75.8	39.0	39.0	0.97	0.468	0.68	1.00	1.00	0.063	8.5	> 4.0	NO	
4.5	Gravel and Sand	21	36	7	70	1050.5	1050.8	0.5	11.19	86.3	86.3	44.6	44.6	0.97	1.000	0.65	1.00	1.00	0.063	18.3	> 4.0	NO	(N1)60 > 30
5.0	Gravel and Sand	21	23	7	55	1050.0	1050.3	0.5	11.19	96.8	96.8	50.2	50.2	0.96	0.257	0.73	1.00	1.00	0.062	4.7	> 4.0	NO	
5.2	Gravel and Sand	21	32	7	65	1049.8	1049.9	0.2	11.19	104.1	104.1	54.1	54.1	0.96	1.000	0.68	1.00	1.00	0.062	18.5	> 4.0	NO	(N1)60 > 30
5.6	Gravel and Sand	21	23	7	55	1049.4	1049.6	0.4	11.19	110.4	110.4	57.4	57.4	0.96	0.257	0.73	1.00	1.00	0.062	4.8	> 4.0	NO	
6.0	Gravel and Sand	21	30	7	65	1049.0	1049.2	0.4	11.19	118.8	118.8	61.9	61.9	0.95	0.468	0.68	1.00	1.00	0.061	8.8	> 4.0	NO	
6.2	Gravel and Sand	21	32	7	65	1048.8	1048.9	0.2	11.19	125.1	125.1	65.3	65.3	0.95	1.000	0.68	1.00	1.00	0.061	18.8	> 4.0	NO	(N1)60 > 30
6.5	Gravel and Sand	21	22	7	50	1048.5	1048.7	0.3	11.19	130.4	130.4	68.1	68.1	0.95	0.242	0.75	1.00	1.00	0.061	4.6	> 4.0	NO	
6.8	Gravel and Sand	21	22	7	50	1048.2	1048.4	0.3	11.19	136.7	136.7	71.4	71.4	0.95	0.242	0.75	1.00	1.00	0.061	4.6	> 4.0	NO	
7.0	Gravel and Sand	21	40	7	75	1048.0	1048.1	0.2	11.19	141.9	141.9	74.2	74.2	0.95	1.000	0.63	1.00	1.00	0.061	18.9	> 4.0	NO	(N1)60 > 30
7.5	Gravel and Sand	21	100	7	85	1047.5	1047.8	0.5	11.19	149.3	149.3	78.1	78.1	0.94	1.000	0.60	1.00	1.00	0.060	19.0	> 4.0	NO	(N1)60 > 30
7.8	Gravel and Sand	21	27	7	60	1047.2	1047.4	0.3	11.19	157.7	157.7	82.6	82.6	0.94	0.338	0.70	1.00	1.00	0.060	6.5	> 4.0	NO	
9.0	Gravel and Sand	21	100	7	85	1046.0	1046.6	1.2	11.19	173.4	173.4	91.0	91.0	0.93	1.000	0.60	1.00	1.00	0.060	19.3	> 4.0	NO	(N1)60 > 30
9.8	Gravel and Sand	21	100	7	85	1045.2	1045.6	0.8	11.19	194.4	194.4	102.2	102.2	0.91	1.000	0.60	1.00	1.00	0.058	19.7	> 4.0	NO	(N1)60 > 30
10.0	Weathered Rock	21	70	0	85	1045.0	1045.1	0.2	11.19	204.9	204.9	107.8	107.8	0.91	1.000	0.60	0.98	1.00	0.058	19.4	> 4.0	NO	(N1)60 > 30
10.5	Weathered Rock	21	48	0	80	1044.5	1044.8	0.5	11.19	212.3	212.3	111.7	111.7	0.89	1.000	0.60	0.96	1.00	0.057	19.4	> 4.0	NO	(N1)60 > 30
10.8	Weathered Rock	21	60	0	85	1044.2	1044.4	0.3	11.19	220.7	220.7	116.2	116.2	0.89	1.000	0.60	0.95	1.00	0.056	19.3	> 4.0	NO	(N1)60 > 30
11.0	Weathered Rock	21	100	0	85	1044.0	1044.1	0.2	11.19	225.9	225.9	119.0	119.0	0.88	1.000	0.60	0.94	1.00	0.056	19.2	> 4.0	NO	(N1)60 > 30

Notes:

[1] BPT-converted SPT $(N_1)_{60}$ values are interpreted from Klohn Crippen (2006b) report. It is assumed that the material is very few fines throughout the profile. Therefore, $(N_1)_{60}$ is equal to $(N_1)_{60,cs}$

[2] If BPT-converted SPT $(N_1)_{60}$ values are greater than 30, $CRR_{7.5}$ defaults to 1.0 for calculation.

TABLE 6C-1-5

BPT-Converted SPT $(N^1)_{60}$ Liquefaction Analysis Using Simplified Procedure, Secondary Dam, East Limb, Boring BPT04-13, Crest of Dam

Project name (number):	Faro Mine, Secondary Dam East Limb
Engineer:	Michael Eller/CVO
Reviewer:	
Date:	10/10/13

Soil boring number:	**BPT04-13**	Evaluated at crest of dam
Soil boring ground surface elevation (m):	1057.0	
Groundwater depth during field exploration (m):	0.0	
Design groundwater depth (m):	0.0	
Peak horizontal ground acceleration (a_{max}/g):	0.05	$PGA = F_a * PGA_{rock}$, where F_a = 1.2 for Site Class C, and PGA_{rock} = 0.043 (after Atkinson and Assatourians, 2013)
Design earthquake magnitude (M):	7.1	
Magnitude Scaling Factor (MSF):	1.2	
Factor of safety criterion: {1.0 or higher}	1.1	

Interval Bottom Depth (m)	Interval Soil Type	Total Unit Weight (kN/m^3)	BPT-Converted SPT $(N_1)_{60}$ Value *Note 1*	Estimated Fines Content FC (%)	Estimated Relative Density DR (%)	Interval Bottom Elevation (m)	Average Layer Elevation (m)	Interval Thickness (m)	Effective Unit Weight (kN/m^3)	Average Layer Field Total Overburden (kPa)	Average Layer Design Total Overburden (kPa)	Average Layer Field Effective Overburden (kPa)	Average Layer Design Effective Overburden (kPa)	Stress Reduction Coefficient r_d	Cyclic Resistance Ratio $CRR_{7.5}$ *Note 2*	CRR Overburden Correction f	CRR Overburden Correction K_σ	CRR Static Shear Correction K_α	Cyclic Stress Ratio CSR	Factor of Safety FS	Limited Factor of Safety FS	Liquefaction Susceptibility	Comments
0.0	Dam Fill	21	100							0.0	0.0	0.0	0.0										
2.2	Dam Fill	21	100	10	85	1054.8	1055.9	2.2	11.19	23.1	23.1	12.3	12.3	0.98	1.000	0.60	1.00	1.00	0.062	18.6	> 4.0	NO	(N1)60 > 30
2.7	Dam Fill	21	43	10	75	1054.3	1054.6	0.5	11.19	51.5	51.5	27.4	27.4	0.98	1.000	0.63	1.00	1.00	0.062	18.7	> 4.0	NO	(N1)60 > 30
3.0	Dam Fill	21	48	10	75	1054.0	1054.2	0.3	11.19	59.9	59.9	31.9	31.9	0.98	1.000	0.63	1.00	1.00	0.061	18.7	> 4.0	NO	(N1)60 > 30
3.3	Gravel and Sand	21	43	10	75	1053.7	1053.9	0.3	11.19	66.1	66.1	35.2	35.2	0.97	1.000	0.63	1.00	1.00	0.061	18.7	> 4.0	NO	(N1)60 > 30
3.8	Gravel and Sand	21	27	10	60	1053.2	1053.5	0.5	11.19	74.5	74.5	39.7	39.7	0.97	0.338	0.70	1.00	1.00	0.061	6.4	> 4.0	NO	
4.2	Sand	20	27	15	60	1052.8	1053.0	0.4	10.19	83.8	83.8	44.6	44.6	0.97	0.338	0.70	1.00	1.00	0.061	6.4	> 4.0	NO	
4.5	Sand	20	23	15	60	1052.5	1052.7	0.3	10.19	90.8	90.8	48.1	48.1	0.97	0.257	0.70	1.00	1.00	0.061	4.8	> 4.0	NO	
4.9	Sand	20	25	15	60	1052.1	1052.3	0.4	10.19	97.8	97.8	51.7	51.7	0.96	0.292	0.70	1.00	1.00	0.061	5.5	> 4.0	NO	
5.3	Sand	20	24	15	60	1051.7	1051.9	0.4	10.19	105.8	105.8	55.8	55.8	0.96	0.273	0.70	1.00	1.00	0.061	5.2	> 4.0	NO	
5.7	Sand	20	13	15	35	1051.3	1051.5	0.4	10.19	113.8	113.8	59.8	59.8	0.96	0.141	0.80	1.00	1.00	0.061	2.7	2.7	NO	
6.0	Sand	20	16	15	40	1051.0	1051.2	0.3	10.19	120.8	120.8	63.4	63.4	0.95	0.170	0.80	1.00	1.00	0.061	3.2	3.2	NO	
6.2	Gravel and Sand	21	10	10	35	1050.8	1050.9	0.2	11.19	125.9	125.9	66.1	66.1	0.95	0.113	0.80	1.00	1.00	0.061	2.1	2.1	NO	
6.6	Gravel and Sand	21	10	10	35	1050.4	1050.6	0.4	11.19	132.2	132.2	69.4	69.4	0.95	0.113	0.80	1.00	1.00	0.061	2.1	2.1	NO	
6.9	Gravel and Sand	21	16	10	40	1050.1	1050.3	0.3	11.19	139.6	139.6	73.3	73.3	0.95	0.170	0.80	1.00	1.00	0.060	3.2	3.2	NO	
7.2	Gravel and Sand	21	34	10	65	1049.8	1050.0	0.3	11.19	145.9	145.9	76.7	76.7	0.94	1.000	0.68	1.00	1.00	0.060	19.1	> 4.0	NO	(N1)60 > 30
7.5	Gravel and Sand	21	28	10	60	1049.5	1049.7	0.3	11.19	152.2	152.2	80.0	80.0	0.94	0.370	0.70	1.00	1.00	0.060	7.1	> 4.0	NO	
7.8	Gravel and Sand	21	30	10	65	1049.2	1049.4	0.3	11.19	158.4	158.4	83.4	83.4	0.94	0.468	0.68	1.00	1.00	0.060	9.0	> 4.0	NO	
8.1	Gravel and Sand	21	30	10	65	1048.9	1049.1	0.3	11.19	164.7	164.7	86.8	86.8	0.94	0.468	0.68	1.00	1.00	0.060	9.0	> 4.0	NO	
8.4	Gravel and Sand	21	53	10	85	1048.6	1048.8	0.3	11.19	171.1	171.1	90.1	90.1	0.94	1.000	0.60	1.00	1.00	0.060	19.3	> 4.0	NO	(N1)60 > 30
8.7	Gravel and Sand	21	39	10	75	1048.3	1048.5	0.3	11.19	177.4	177.4	93.5	93.5	0.93	1.000	0.63	1.00	1.00	0.059	19.4	> 4.0	NO	(N1)60 > 30
9.0	Gravel and Sand	21	39	10	75	1048.0	1048.2	0.3	11.19	183.7	183.7	96.8	96.8	0.93	1.000	0.63	1.00	1.00	0.059	19.4	> 4.0	NO	(N1)60 > 30
9.3	Gravel and Sand	21	30	10	65	1047.7	1047.9	0.3	11.19	189.9	189.9	100.2	100.2	0.93	0.468	0.68	1.00	1.00	0.059	9.1	> 4.0	NO	
9.6	Gravel and Sand	21	15	10	40	1047.4	1047.6	0.3	11.19	196.2	196.2	103.5	103.5	0.92	0.160	0.80	1.00	1.00	0.058	3.1	3.1	NO	
10.2	Gravel and Sand	21	31	10	65	1046.8	1047.1	0.6	11.19	205.7	205.7	108.6	108.6	0.90	1.000	0.68	0.98	1.00	0.057	19.6	> 4.0	NO	(N1)60 > 30
10.7	Gravel and Sand	21	31	10	65	1046.3	1046.6	0.5	11.19	217.3	217.3	114.7	114.7	0.89	1.000	0.68	0.96	1.00	0.056	19.6	> 4.0	NO	(N1)60 > 30
10.9	Gravel and Sand	21	15	10	40	1046.1	1046.2	0.2	11.19	224.6	224.6	118.7	118.7	0.88	0.160	0.80	0.97	1.00	0.056	3.2	3.2	NO	
11.2	Gravel and Sand	21	13	10	35	1045.8	1046.0	0.3	11.19	229.9	229.9	121.4	121.4	0.87	0.141	0.80	0.96	1.00	0.056	2.8	2.8	NO	
11.5	Weathered Rock	21	19	0	45	1045.5	1045.7	0.3	11.19	236.2	236.2	124.8	124.8	0.87	0.203	0.78	0.95	1.00	0.055	4.1	> 4.0	NO	
11.8	Weathered Rock	21	100	0	85	1045.2	1045.4	0.3	11.19	242.4	242.4	128.2	128.2	0.86	1.000	0.60	0.91	1.00	0.054	19.2	> 4.0	NO	(N1)60 > 30
12.1	Weathered Rock	21	100	0	85	1044.9	1045.1	0.3	11.19	248.7	248.7	131.5	131.5	0.85	1.000	0.60	0.90	1.00	0.054	19.2	> 4.0	NO	(N1)60 > 30

Notes:

[1] BPT-converted SPT $(N_1)_{60}$ values are interpreted from Klohn Crippen (2006b) report. It is assumed that the material is very few fines throughout the profile. Therefore, $(N)_{60}$ is equal to $(N_1)_{60,cs}$

[2] If BPT-converted SPT $(N_1)_{60}$ values are greater than 30, $CRR_{7.5}$ defaults to 1.0 for calculation.

TABLE 6C-1-6

BPT-Converted SPT $(N^1)_{60}$ Liquefaction Analysis Using Simplified Procedure, Secondary Dam, East Limb, Boring BPT04-13, Toe of Dam

Project name (number):	Faro Mine, Secondary Dam East Limb
Engineer:	Michael Eller/CVO
Reviewer:	
Date:	10/10/13

Soil boring number:	**BPT04-13**	Evaluated at toe of dam
Soil boring ground surface elevation (m):	1057.0	
Groundwater depth during field exploration (m):	0.0	
Design groundwater depth (m):	0.0	
Peak horizontal ground acceleration (a_{max}/g):	0.05	$PGA = F_a * PGA_{rock}$, where F_a = 1.2 for Site Class C, and PGA_{rock} = 0.043 (after Atkinson and Assatourians, 2013)
Design earthquake magnitude (M):	7.1	
Magnitude Scaling Factor (MSF):	1.2	
Factor of safety criterion: {1.0 or higher}	1.1	

Interval Bottom Depth (m)	Interval Soil Type	Total Unit Weight (kN/m^3)	BPT-Converted SPT $(N_1)_{60}$ Value *Note 1*	Estimated Fines Content FC (%)	Estimated Relative Density DR (%)	Interval Bottom Elevation (m)	Average Layer Elevation (m)	Interval Thickness (m)	Effective Unit Weight (kN/m^3)	Average Layer Field Total Overburden (kPa)	Average Layer Design Total Overburden (kPa)	Average Layer Field Effective Overburden (kPa)	Average Layer Design Effective Overburden (kPa)	Stress Reduction Coefficient r_d	Cyclic Resistance Ratio $CRR_{7.5}$ *Note 2*	CRR Overburden Correction f	CRR Overburden Correction K_σ	CRR Static Shear Correction K_α	Cyclic Stress Ratio CSR	Factor of Safety FS	Limited Factor of Safety FS	Liquefaction Susceptibility	Comments
0.0	Gravel and Sand	21	43							0.0	0.0	0.0	0.0										
0.5	Gravel and Sand	21	27	10	60	1056.5	1056.8	0.5	11.19	5.3	5.3	2.8	2.8	1.00	0.338	0.70	1.00	1.00	0.063	6.2	> 4.0	NO	
0.9	Sand	20	27	15	60	1056.1	1056.3	0.4	10.19	14.5	14.5	7.6	7.6	0.99	0.338	0.70	1.00	1.00	0.063	6.2	> 4.0	NO	
1.2	Sand	20	23	15	60	1055.8	1056.0	0.3	10.19	21.5	21.5	11.2	11.2	0.99	0.257	0.70	1.00	1.00	0.064	4.6	> 4.0	NO	
1.6	Sand	20	25	15	60	1055.4	1055.6	0.4	10.19	28.5	28.5	14.8	14.8	0.99	0.292	0.70	1.00	1.00	0.064	5.3	> 4.0	NO	
2.0	Sand	20	24	15	60	1055.0	1055.2	0.4	10.19	36.5	36.5	18.8	18.8	0.98	0.273	0.70	1.00	1.00	0.064	4.9	> 4.0	NO	
2.4	Sand	20	13	15	35	1054.6	1054.8	0.4	10.19	44.5	44.5	22.9	22.9	0.98	0.141	0.80	1.00	1.00	0.064	2.5	2.5	NO	
2.7	Sand	20	16	15	40	1054.3	1054.5	0.3	10.19	51.5	51.5	26.5	26.5	0.98	0.170	0.80	1.00	1.00	0.064	3.1	3.1	NO	
2.9	Gravel and Sand	21	10	10	35	1054.1	1054.2	0.2	11.19	56.6	56.6	29.1	29.1	0.98	0.113	0.80	1.00	1.00	0.064	2.0	2.0	NO	
3.3	Gravel and Sand	21	10	10	35	1053.7	1053.9	0.4	11.19	62.9	62.9	32.5	32.5	0.97	0.113	0.80	1.00	1.00	0.063	2.1	2.1	NO	
3.6	Gravel and Sand	21	16	10	40	1053.4	1053.6	0.3	11.19	70.3	70.3	36.4	36.4	0.97	0.170	0.80	1.00	1.00	0.063	3.1	3.1	NO	
3.9	Gravel and Sand	21	34	10	65	1053.1	1053.3	0.3	11.19	76.6	76.6	39.8	39.8	0.97	1.000	0.68	1.00	1.00	0.063	18.4	> 4.0	NO	(N1)60 > 30
4.2	Gravel and Sand	21	28	10	60	1052.8	1053.0	0.3	11.19	82.9	82.9	43.1	43.1	0.97	0.370	0.70	1.00	1.00	0.062	6.8	> 4.0	NO	
4.5	Gravel and Sand	21	30	10	65	1052.5	1052.7	0.3	11.19	89.2	89.2	46.5	46.5	0.97	0.468	0.68	1.00	1.00	0.062	8.7	> 4.0	NO	
4.8	Gravel and Sand	21	30	10	65	1052.2	1052.4	0.3	11.19	95.4	95.4	49.8	49.8	0.96	0.468	0.68	1.00	1.00	0.062	8.7	> 4.0	NO	
5.1	Gravel and Sand	21	53	10	85	1051.9	1052.1	0.3	11.19	101.8	101.8	53.2	53.2	0.96	1.000	0.60	1.00	1.00	0.062	18.7	> 4.0	NO	(N1)60 > 30
5.4	Gravel and Sand	21	39	10	75	1051.6	1051.8	0.3	11.19	108.1	108.1	56.5	56.5	0.96	1.000	0.63	1.00	1.00	0.061	18.7	> 4.0	NO	(N1)60 > 30
5.7	Gravel and Sand	21	39	10	75	1051.3	1051.5	0.3	11.19	114.4	114.4	59.9	59.9	0.96	1.000	0.63	1.00	1.00	0.061	18.8	> 4.0	NO	(N1)60 > 30
6.0	Gravel and Sand	21	30	10	65	1051.0	1051.2	0.3	11.19	120.7	120.7	63.3	63.3	0.95	0.468	0.68	1.00	1.00	0.061	8.8	> 4.0	NO	
6.3	Gravel and Sand	21	15	10	40	1050.7	1050.9	0.3	11.19	126.9	126.9	66.6	66.6	0.95	0.160	0.80	1.00	1.00	0.061	3.0	3.0	NO	
6.9	Gravel and Sand	21	31	10	65	1050.1	1050.4	0.6	11.19	136.4	136.4	71.7	71.7	0.95	1.000	0.68	1.00	1.00	0.060	19.0	> 4.0	NO	(N1)60 > 30
7.4	Gravel and Sand	21	31	10	65	1049.6	1049.9	0.5	11.19	148.0	148.0	77.8	77.8	0.94	1.000	0.68	1.00	1.00	0.060	19.1	> 4.0	NO	(N1)60 > 30
7.6	Gravel and Sand	21	15	10	40	1049.4	1049.5	0.2	11.19	155.3	155.3	81.7	81.7	0.94	0.160	0.80	1.00	1.00	0.060	3.1	3.1	NO	
7.9	Gravel and Sand	21	13	10	35	1049.1	1049.3	0.3	11.19	160.6	160.6	84.5	84.5	0.94	0.141	0.80	1.00	1.00	0.060	2.7	2.7	NO	
8.2	Weathered Rock	21	19	0	45	1048.8	1049.0	0.3	11.19	166.9	166.9	87.9	87.9	0.94	0.203	0.78	1.00	1.00	0.060	3.9	3.9	NO	
8.5	Weathered Rock	21	100	0	85	1048.5	1048.7	0.3	11.19	173.2	173.2	91.2	91.2	0.93	1.000	0.60	1.00	1.00	0.060	19.3	> 4.0	NO	(N1)60 > 30
8.8	Weathered Rock	21	100	0	85	1048.2	1048.4	0.3	11.19	179.4	179.4	94.6	94.6	0.93	1.000	0.60	1.00	1.00	0.059	19.4	> 4.0	NO	(N1)60 > 30

Notes:

[1] BPT-converted SPT $(N_1)_{60}$ values are interpreted from Klohn Crippen (2006b) report. It is assumed that the material is very few fines throughout the profile. Therefore, $(N_1)_{60}$ is equal to $(N_1)_{60,cs}$

[2] If BPT-converted SPT $(N_1)_{60}$ values are greater than 30, $CRR_{7.5}$ defaults to 1.0 for calculation.

TABLE 6C-1-7

BPT-Converted SPT $(N^1)_{60}$ Liquefaction Analysis Using Simplified Procedure, Secondary Dam, East Limb, Boring BPT05-06B, Crest of Dam

Project name (number):	Faro Mine, Secondary Dam East Limb
Engineer:	Michael Eller/CVO
Reviewer:	
Date:	10/10/13

Soil boring number:	**BPT05-06B**	Evaluated at crest of dam
Soil boring ground surface elevation (m):	1056.6	
Groundwater depth during field exploration (m):	0.0	
Design groundwater depth (m):	0.0	
Peak horizontal ground acceleration (a_{max}/g):	0.05	$PGA = F_a * PGA_{rock}$, where F_a = 1.2 for Site Class C, and PGA_{rock} = 0.043 (after Atkinson and Assatourians, 2013)
Design earthquake magnitude (M):	7.1	
Magnitude Scaling Factor (MSF):	1.2	
Factor of safety criterion: {1.0 or higher}	1.1	

Interval Bottom Depth (m)	Interval Soil Type	Total Unit Weight (kN/m^3)	BPT-Converted SPT $(N_1)_{60}$ Value *Note 1*	Estimated Fines Content FC (%)	Estimated Relative Density DR (%)	Interval Bottom Elevation (m)	Average Layer Elevation (m)	Interval Thickness (m)	Effective Unit Weight (kN/m^3)	Average Layer Field Total Overburden (kPa)	Average Layer Design Total Overburden (kPa)	Average Layer Field Effective Overburden (kPa)	Average Layer Design Effective Overburden (kPa)	Stress Reduction Coefficient r_d	Cyclic Resistance Ratio $CRR_{7.5}$ *Note 2*	CRR Overburden Correction f	CRR Overburden Correction K_σ	CRR Static Shear Correction K_α	Cyclic Stress Ratio CSR	Factor of Safety FS	Limited Factor of Safety FS	Liquefaction Susceptibility	Comments
0.0	Dam Fill	21	100							0.0	0.0	0.0	0.0										
0.4	Dam Fill	21	65	5	85	1056.2	1056.4	0.4	11.19	4.2	4.2	2.2	2.2	1.00	1.000	0.60	1.00	1.00	0.063	18.3	> 4.0	NO	(N1)60 > 30
0.8	Dam Fill	21	61	5	85	1055.8	1056.0	0.4	11.19	12.6	12.6	6.7	6.7	0.99	1.000	0.60	1.00	1.00	0.063	18.4	> 4.0	NO	(N1)60 > 30
1.2	Dam Fill	21	48	5	85	1055.4	1055.6	0.4	11.19	21.0	21.0	11.2	11.2	0.99	1.000	0.60	1.00	1.00	0.062	18.4	> 4.0	NO	(N1)60 > 30
1.4	Dam Fill	21	56	5	85	1055.2	1055.3	0.2	11.19	27.3	27.3	14.5	14.5	0.99	1.000	0.60	1.00	1.00	0.062	18.5	> 4.0	NO	(N1)60 > 30
1.8	Dam Fill	21	36	5	70	1054.8	1055.0	0.4	11.19	33.6	33.6	17.9	17.9	0.99	1.000	0.65	1.00	1.00	0.062	18.5	> 4.0	NO	(N1)60 > 30
2.3	Dam Fill	21	41	5	75	1054.3	1054.6	0.5	11.19	43.0	43.0	22.9	22.9	0.98	1.000	0.63	1.00	1.00	0.062	18.6	> 4.0	NO	(N1)60 > 30
2.6	Dam Fill	21	21	5	50	1054.0	1054.2	0.3	11.19	51.4	51.4	27.4	27.4	0.98	0.228	0.75	1.00	1.00	0.062	4.3	> 4.0	NO	
3.1	Gravel and Sand	21	11	5	35	1053.5	1053.8	0.5	11.19	59.8	59.8	31.9	31.9	0.98	0.122	0.80	1.00	1.00	0.061	2.3	2.3	NO	
3.8	Sand	20	12	5	35	1052.8	1053.2	0.7	10.19	72.1	72.1	38.3	38.3	0.97	0.131	0.80	1.00	1.00	0.061	2.5	2.5	NO	
4.4	Sand	20	10	5	35	1052.2	1052.5	0.6	10.19	85.1	85.1	44.9	44.9	0.97	0.113	0.80	1.00	1.00	0.061	2.1	2.1	NO	
4.9	Sand	20	5	5	20	1051.7	1052.0	0.5	10.19	96.1	96.1	50.5	50.5	0.96	0.072	0.80	1.00	1.00	0.061	1.3	1.3	NO	
5.2	Sand	20	10	5	35	1051.4	1051.6	0.3	10.19	104.1	104.1	54.6	54.6	0.96	0.113	0.80	1.00	1.00	0.061	2.1	2.1	NO	
5.6	Sand	20	5	5	20	1051.0	1051.2	0.4	10.19	111.1	111.1	58.1	58.1	0.96	0.072	0.80	1.00	1.00	0.061	1.4	1.4	NO	
5.9	Sand	20	5	5	20	1050.7	1050.9	0.3	10.19	118.1	118.1	61.7	61.7	0.95	0.072	0.80	1.00	1.00	0.061	1.4	1.4	NO	
6.4	Gravel and Sand	21	13	5	35	1050.2	1050.5	0.5	11.19	126.3	126.3	66.0	66.0	0.95	0.141	0.80	1.00	1.00	0.061	2.6	2.6	NO	
6.6	Gravel and Sand	21	100	5	85	1050.0	1050.1	0.2	11.19	133.7	133.7	69.9	69.9	0.95	1.000	0.60	1.00	1.00	0.061	18.9	> 4.0	NO	(N1)60 > 30
8.6	Gravel and Sand	21	100	5	85	1048.0	1049.0	2.0	11.19	156.8	156.8	82.2	82.2	0.93	1.000	0.60	1.00	1.00	0.060	19.3	> 4.0	NO	(N1)60 > 30
9.0	Gravel and Sand	21	65	5	85	1047.6	1047.8	0.4	11.19	182.0	182.0	95.7	95.7	0.93	1.000	0.60	1.00	1.00	0.059	19.4	> 4.0	NO	(N1)60 > 30
9.6	Gravel and Sand	21	59	5	85	1047.0	1047.3	0.6	11.19	192.5	192.5	101.3	101.3	0.92	1.000	0.60	1.00	1.00	0.059	19.7	> 4.0	NO	(N1)60 > 30
10.0	Gravel and Sand	21	64	5	85	1046.6	1046.8	0.4	11.19	203.0	203.0	106.9	106.9	0.91	1.000	0.60	0.98	1.00	0.058	19.5	> 4.0	NO	(N1)60 > 30
10.8	Gravel and Sand	21	26	5	55	1045.8	1046.2	0.8	11.19	215.6	215.6	113.6	113.6	0.89	0.313	0.73	0.97	1.00	0.056	6.2	> 4.0	NO	
11.4	Gravel and Sand	21	6	5	20	1045.2	1045.5	0.6	11.19	230.3	230.3	121.4	121.4	0.87	0.080	0.80	0.96	1.00	0.055	1.6	1.6	NO	
12.8	Weathered Rock	21	6	0	20	1043.8	1044.5	1.4	11.19	251.3	251.3	132.6	132.6	0.83	0.080	0.80	0.95	1.00	0.053	1.6	1.6	NO	
13.6	Weathered Rock	21	12	0	35	1043.0	1043.4	0.8	11.19	274.4	274.4	144.9	144.9	0.81	0.131	0.80	0.93	1.00	0.052	2.7	2.7	NO	
14.1	Weathered Rock	21	30	0	65	1042.5	1042.8	0.5	11.19	288.0	288.0	152.2	152.2	0.80	0.468	0.68	0.88	1.00	0.051	9.3	> 4.0	NO	
14.6	Weathered Rock	21	31	0	65	1042.0	1042.3	0.5	11.19	298.5	298.5	157.8	157.8	0.78	1.000	0.68	0.87	1.00	0.050	20.0	> 4.0	NO	(N1)60 > 30
14.8	Weathered Rock	21	50	0	85	1041.8	1041.9	0.2	11.19	305.9	305.9	161.7	161.7	0.78	1.000	0.60	0.83	1.00	0.049	19.3	> 4.0	NO	(N1)60 > 30
15.1	Weathered Rock	21	68	0	85	1041.5	1041.7	0.3	11.19	311.1	311.1	164.5	164.5	0.77	1.000	0.60	0.82	1.00	0.049	19.4	> 4.0	NO	(N1)60 > 30
15.4	Weathered Rock	21	62	0	85	1041.2	1041.4	0.3	11.19	317.4	317.4	167.8	167.8	0.76	1.000	0.60	0.82	1.00	0.048	19.4	> 4.0	NO	(N1)60 > 30
15.6	Weathered Rock	21	100	0	85	1041.0	1041.1	0.2	11.19	322.7	322.7	170.6	170.6	0.76	1.000	0.60	0.81	1.00	0.048	19.4	> 4.0	NO	(N1)60 > 30
16.1	Weathered Rock	21	100	0	85	1040.5	1040.8	0.5	11.19	330.0	330.0	174.6	174.6	0.74	1.000	0.60	0.80	1.00	0.047	19.6	> 4.0	NO	(N1)60 > 30

Notes:

[1] BPT-converted SPT $(N_1)_{60}$ values are interpreted from Klohn Crippen (2006b) report. It is assumed that the material is very few fines throughout the profile. Therefore, $(N_1)_{60}$ is equal to $(N_1)_{60,cs}$

[2] If BPT-converted SPT $(N_1)_{60}$ values are greater than 30, $CRR_{7.5}$ defaults to 1.0 for calculation.

TABLE 6C-1-8

BPT-Converted SPT $(N^1)_{60}$ Liquefaction Analysis Using Simplified Procedure, Secondary Dam, East Limb, Boring BPT05-06B, Toe of Dam

Project name (number):	Faro Mine, Secondary Dam East Limb
Engineer:	Michael Eller/CVO
Reviewer:	
Date:	10/10/13

Soil boring number:	**BPT05-06B**	Evaluated at crest of dam
Soil boring ground surface elevation (m):	1056.6	
Groundwater depth during field exploration (m):	0.0	
Design groundwater depth (m):	0.0	
Peak horizontal ground acceleration (ϵ_{max}/g):	0.05	$PGA = F_a * PGA_{rock}$, where F_a = 1.2 for Site Class C, and PGA_{rock} = 0.043 (after Atkinson and Assatourians, 2013)
Design earthquake magnitude (M):	7.1	
Magnitude Scaling Factor (MSF):	1.2	
Factor of safety criterion: {1.0 or higher}	1.1	

Interval Bottom Depth (m)	Interval Soil Type	Total Unit Weight (kN/m^3)	BPT-Converted SPT $(N_1)_{60}$ Value Note 1	Estimated Fines Content FC (%)	Estimated Relative Density DR (%)	Interval Bottom Elevation (m)	Average Layer Elevation (m)	Interval Thickness (m)	Effective Unit Weight (kN/m^3)	Average Layer Field Total Overburden (kPa)	Average Layer Design Total Overburden (kPa)	Average Layer Field Effective Overburden (kPa)	Average Layer Design Effective Overburden (kPa)	Stress Reduction Coefficient r_d	Cyclic Resistance Ratio $CRR_{7.5}$ Note 2	CRR Overburden Correction f	CRR Overburden Correction K_σ	CRR Static Shear Correction K_α	Cyclic Stress Ratio CSR	Factor of Safety FS	Limited Factor of Safety FS	Liquefaction Susceptibility	Comments
0.0	Gravel and Sand	21	11	5	35					0.0	0.0	0.0	0.0										
0.7	Sand	20	12	5	35	1055.9	1056.3	0.7	10.19	7.0	7.0	3.6	3.6	0.99	0.131	0.80	1.00	1.00	0.065	2.3	2.3	NO	
1.3	Sand	20	10	5	35	1055.3	1055.6	0.6	10.19	20.0	20.0	10.2	10.2	0.99	0.113	0.80	1.00	1.00	0.065	2.0	2.0	NO	
1.8	Sand	20	5	5	20	1054.8	1055.1	0.5	10.19	31.0	31.0	15.8	15.8	0.99	0.072	0.80	1.00	1.00	0.065	1.3	1.3	NO	
2.1	Sand	20	10	5	35	1054.5	1054.7	0.3	10.19	39.0	39.0	19.9	19.9	0.98	0.113	0.80	1.00	1.00	0.065	2.0	2.0	NO	
2.5	Sand	20	5	5	20	1054.1	1054.3	0.4	10.19	46.0	46.0	23.4	23.4	0.98	0.072	0.80	1.00	1.00	0.065	1.3	1.3	NO	
2.8	Sand	20	5	5	20	1053.8	1054.0	0.3	10.19	53.0	53.0	27.0	27.0	0.98	0.072	0.80	1.00	1.00	0.064	1.3	1.3	NO	
3.3	Gravel and Sand	21	13	5	35	1053.3	1053.6	0.5	11.19	61.2	61.2	31.3	31.3	0.97	0.141	0.80	1.00	1.00	0.064	2.5	2.5	NO	
3.5	Gravel and Sand	21	100	5	85	1053.1	1053.2	0.2	11.19	68.6	68.6	35.2	35.2	0.97	1.000	0.60	1.00	1.00	0.064	18.1	> 4.0	NO	(N1)60 > 30
5.5	Gravel and Sand	21	100	5	85	1051.1	1052.1	2.0	11.19	91.7	91.7	47.6	47.6	0.96	1.000	0.60	1.00	1.00	0.062	18.6	> 4.0	NO	(N1)60 > 30
5.9	Gravel and Sand	21	65	5	85	1050.7	1050.9	0.4	11.19	116.9	116.9	61.0	61.0	0.95	1.000	0.60	1.00	1.00	0.061	18.7	> 4.0	NO	(N1)60 > 30
6.5	Gravel and Sand	21	59	5	85	1050.1	1050.4	0.6	11.19	127.4	127.4	66.6	66.6	0.95	1.000	0.60	1.00	1.00	0.061	18.9	> 4.0	NO	(N1)60 > 30
6.9	Gravel and Sand	21	64	5	85	1049.7	1049.9	0.4	11.19	137.9	137.9	72.2	72.2	0.95	1.000	0.60	1.00	1.00	0.061	18.9	> 4.0	NO	(N1)60 > 30
7.7	Gravel and Sand	21	26	5	55	1048.9	1049.3	0.8	11.19	150.5	150.5	78.9	78.9	0.94	0.313	0.73	1.00	1.00	0.060	6.0	> 4.0	NO	
8.3	Gravel and Sand	21	6	5	20	1048.3	1048.6	0.6	11.19	165.2	165.2	86.7	86.7	0.94	0.080	0.80	1.00	1.00	0.060	1.5	1.5	NO	
9.7	Weathered Rock	21	6	0	20	1046.9	1047.6	1.4	11.19	186.2	186.2	97.9	97.9	0.92	0.080	0.80	1.00	1.00	0.058	1.6	1.6	NO	
10.5	Weathered Rock	21	12	0	35	1046.1	1046.5	0.8	11.19	209.3	209.3	110.2	110.2	0.89	0.131	0.80	0.98	1.00	0.057	2.6	2.6	NO	
11.0	Weathered Rock	21	30	0	65	1045.6	1045.9	0.5	11.19	223.0	223.0	117.5	117.5	0.88	0.468	0.68	0.95	1.00	0.056	9.2	> 4.0	NO	
11.5	Weathered Rock	21	31	0	65	1045.1	1045.4	0.5	11.19	233.5	233.5	123.1	123.1	0.87	1.000	0.68	0.94	1.00	0.055	19.6	> 4.0	NO	(N1)60 > 30
11.7	Weathered Rock	21	50	0	85	1044.9	1045.0	0.2	11.19	240.8	240.8	127.0	127.0	0.86	1.000	0.60	0.91	1.00	0.055	19.2	> 4.0	NO	(N1)60 > 30
12.0	Weathered Rock	21	68	0	85	1044.6	1044.8	0.3	11.19	246.1	246.1	129.8	129.8	0.85	1.000	0.60	0.91	1.00	0.054	19.2	> 4.0	NO	(N1)60 > 30
12.3	Weathered Rock	21	62	0	85	1044.3	1044.5	0.3	11.19	252.4	252.4	133.2	133.2	0.85	1.000	0.60	0.90	1.00	0.054	19.2	> 4.0	NO	(N1)60 > 30
12.5	Weathered Rock	21	100	0	85	1044.1	1044.2	0.2	11.19	257.6	257.6	136.0	136.0	0.84	1.000	0.60	0.89	1.00	0.053	19.2	> 4.0	NO	(N1)60 > 30
13.0	Weathered Rock	21	100	0	85	1043.6	1043.9	0.5	11.19	265.0	265.0	139.9	139.9	0.83	1.000	0.60	0.88	1.00	0.053	19.2	> 4.0	NO	(N1)60 > 30

Notes:

[1] BPT-converted SPT $(N_1)_{60}$ values are interpreted from Klohn Crippen (2006b) report. It is assumed that the material is very few fines throughout the profile. Therefore, $(N_1)_{60}$ is equal to $(N_1)_{60,cs}$

[2] If BPT-converted SPT $(N_1)_{60}$ values are greater than 30, $CRR_{7.5}$ defaults to 1.0 for calculation.

Appendix 6D
Climate Baseline Report

Draft

Climate Baseline Report
Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 6, 2014

CH2MHILL®

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Acronyms and Abbreviations

°	degrees
°C	degrees Celsius
AECOM	AECOM Canada Ltd.
AUT	Automated
cm	centimetre
FMC	Faro Mine Complex
ID	identification
km	kilometre
NHRI	National Hydrology Research Institute
m/s	metre per second
mm	millimetre
NA	not applicable
RH	relative humidity
Temp	temperature

SECTION 1

Introduction

This report presents a data summary and discussion of recent and historical climatic conditions in the vicinity of the Faro Mine Complex (FMC) to characterize baseline conditions for the Faro Mine Interim Works.

Climate parameters considered in this report include wind speed and directions, temperature, precipitation, humidity, solar radiation, evaporation and evapotranspiration.

The FMC is located in south-central Yukon. It is 22 kilometres (km) northeast of the Town of Faro and about 200 km northeast of the City of Whitehorse. The FMC is located in the Anvil Range Mountains within the Macmillan Highlands of the Yukon North-Plateau Eco region. The Yukon North-Plateau terrain is made up of rolling uplands, small mountain groups, and nearly level table lands dissected by deeply cut, generally broad, U-shaped valleys (Environment Canada, 1996).

The climate near the FMC is characterized as subarctic continental, which is typified by long, usually very cold winters, and short, cool to mild summers (Ritter, 2006). Historical monitoring data indicate a large annual range in temperature and relatively moderate amounts of annual precipitation. The area has strong terrain features that further accentuate the seasonal temperature differences and humidity levels. Winter temperatures can be 10 degrees (°) lower in valley bottoms as compared to higher elevations, because of temperature inversions. During the summer months, temperatures are closer to the environmental lapse rate with valley bottom temperatures higher than upland areas (Janowicz et al., 2005). Additional evaluations of climate data are presented in the Hydrology Baseline Report (CH2M HILL, 2013).

SECTION 2

Meteorological Data Sources

Meteorological monitoring data from Environment Canada's stations located in Faro area and onsite meteorological stations were used to provide the overall state of the regional and site-specific climate.

2.1 Environment Canada Stations

Three Environment Canada stations with hourly monitoring data were identified in Faro area. A summary of the station information is provided in Table 6D-1. The location of the stations are shown in Figure 6D-1. Faro A and Faro AUT Stations are located at the Faro Airport, approximately 145 metres apart. Faro station was located in the Town of Faro approximately 3 km from the other two stations. Considering data completion, data consistency, and length of monitoring periods, the two active Environment Canada stations, i.e. Faro A and Faro AUT Stations, are selected to define baseline regional climate conditions.

TABLE 6D-1
Environment Canada Meteorological Stations
Faro Mine Interim Works

Station Name	Climate ID/ WMO ID	Latitude	Longitude	Elevation (metres)	Hourly Data Available Periods	Parameters Measured
Faro	2100516/NA	62°14'N	133°21'W	694.3	1972 – 1977 04:00 – 22:00, even hours	Temperature, wind direction, wind speed, RH
Faro A	2100517/NA	62°12'25"N	133°22'24"W	716.3	1978 – present 05:00 to 17:00	Temperature, wind direction, wind speed, RH, cloud cover, total (daily) precipitation
Faro AUT	2100518/ 71949	62°12'27"N	133°22'33"W	716.6	1994 – present 00:00 – 23:00	Temperature, wind direction, wind speed, RH

Notes:

Total precipitation: includes total rainfall and total snowfall, reported separately.

AUT = automated
ID = identification
NA = not applicable
RH = Relative Humidity

2.2 Onsite Meteorological Stations

Two onsite meteorological stations were established at the FMC on the Faro Valley and Grum Waste Dump sites in December of 2003. The Faro Valley Dump meteorological station is located on the Faro Valley Waste Dump, at an elevation of 1,200 metres above sea level. The Grum Dump meteorological station was located on the Grum Waste Dump before June 2010 at an elevation of 1,250 metres above sea level. The station was moved on June 21, 2010, to a former gravel pit, located north of Grum overburden vegetation trials to accommodate the Grum sulphide cover project (Denison, 2011). When the Grum meteorological station was moved, efforts were made to verify that the station was installed at a similar location, elevation, and soil type, to where it had been previously. Soil temperature, moisture, and heat flux sensors were reinstalled at the same depths as where they had been. Data from the Grum climate station was reported as one continuous record, with the exception of wind data. A correction factor was applied to wind direction to adjust for the station move, until the wind direction sensor was recalibrated in January 2011. Snow depth sensor installation was evaluated after the move, and, based on preliminary evaluation, no correction factor was required (Denison, 2011). The locations of the onsite meteorological stations are shown in Figure 6D-2.

The Faro Valley Dump and Grum Dump meteorological stations sensors measure the following climate parameters:

- Temperature
- Relative humidity
- Wind speed
- Wind direction
- Soil moisture
- Soil temperature (at two depths)
- Soil heat flux
- Net radiation
- Albedo
- Solar radiation (incoming)
- Snow depth
- Precipitation

Averages of sensor measurements taken every 5 seconds were logged on an hourly basis and meteorological station data were downloaded on a monthly basis.

SECTION 3

Methods and Results

3.1 Temperature

3.1.1 Methods and Data Considerations

Since both Faro A and Faro AUT Stations are located in the Faro Airport at the same elevation and approximately 145 metres apart, consistency in temperature monitoring is expected.

AECOM Canada Ltd. (AECOM) has conducted a comparison between Faro A and Faro AUT Stations and the results show the temperatures at the two stations are generally consistent (AECOM, 2009).

At the completion of each decade, Environment Canada updates its climate normals for as many locations and as many climatic characteristics as possible. Based on data from Faro A Station, Environment Canada published the climate normals, averages, and extremes with at least 15 years of data from 1981 to 2010. These datasets were used to establish the temperature baseline for the region.

Hourly temperature data from the two onsite meteorological data stations were compared with Faro AUT Station data between December 2003 and December 2010. The Faro AUT Station was chosen for this comparison because the hourly records are more complete than the Faro A Station records.

3.1.2 Regional Temperature Normals and Extremes

The temperature normals and extremes published for the Faro A Station are presented in Table 6D-2 and Figure 6D-3. These data show the cold winters and warm summers typically observed in this region.

TABLE 6D-2
Environment Canada Regional Temperatures (1981 – 2010)
Faro Mine Interim Works

	Mean Temperature (°C)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Daily Mean Temp	-20.1	-15.5	-8.6	0.6	7.5	13.2	15.0	12.4	6.4	-2.0	-14.8	-17.9
Daily Average Min Temp	-24.6	-20.7	-15.0	-5.5	1.2	6.8	8.9	6.3	1.3	-5.7	-18.5	-22.3
Daily Average Max Temp	-16.0	-10.3	-2.1	6.8	13.8	19.6	21.0	18.4	11.5	1.7	-11.1	-13.8

Note:

°C = degrees Celsius

The daily average temperature is lowest in January at -20°C and highest in July at 15°C. This gap is further illustrated by an average daily minimum temperature in January of -24.6°C and an average daily maximum in July of 21.0°C. The average variation of temperature throughout the day is indicated by comparing the normal daily minimum and maximum. The change in temperature throughout the day is slightly more pronounced in the summer with an approximate 12°C difference between the minimum and maximum and less in the winter with an approximate 8°C difference.

A historical daily temperature trend from 1977 to 2011 is provided in Figure 6D-4.

3.1.3 Regional Long Term Temperature Trends

The annual average temperatures from 1981 to 2010 are shown in Figure 6D-5. The figure shows the annual average of daily means, annual average of daily minimum means, and annual average of daily maximum means as well as the extreme minimum and maximum observed each year. A linear regression analysis of the annual average data suggests a warming trend with a 0.7°C, 0.6°C and 1.0°C change in the mean daily maximum, mean

daily, and mean daily minimum, respectively. A warming trend is also observed in the extreme maximum and minimum of 0.3°C and 2.4°C, respectively.

3.1.4 Local Site Temperature Data

The monthly mean temperatures for the two onsite stations are summarized in Table 6D-3. The data indicate that the temperature at the two stations are consistent. The temperature data indicate that annual average temperatures ranged from about 12°C in summer to -16°C in winter.

TABLE 6D-3
Local Site Temperature (Dec 2003 – Dec 2010)
Faro Mine Interim Works

	Mean Temperature (°C)												
Station Name	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Faro Dump Station	-15.6	-12.1	-9.6	-1.1	5.8	11.3	12.3	10.3	4.2	-2.5	-10.7	-13.3	-1.8
Grum Dump Station	-15.5	-12.5	-9.8	-1.2	5.8	11.3	12.1	10.8	3.9	-2.6	-11.3	-12.5	-1.8
Faro AUT	-21.5	-15.8	-9.1	1.2	8.7	14.1	15.0	12.7	6.1	-1.6	-13.4	-18.6	-1.9

A comparison of the monthly average temperatures at the Faro Dump Station with those at the Faro AUT Station are presented in Figure 6D-6, which shows temperatures in the summer are generally cooler at the mine sites, as would be expected given the elevation difference. However, winter temperatures at the Faro AUT Station show a tendency to drop up to 10°C lower than at the Faro Dump Station, because of temperature inversions (Janowicz et al., 2005).

3.1.5 Expected Temperature Conditions at the Faro Mine Complex

While a long-term, complete dataset at the onsite stations does not exist, a strong correlation exists between the temperatures measured at the Faro AUT Station and those measured at the site stations. Plots of the temperatures at the two site stations with those at the Faro AUT Station and the resulting regression analysis and equations are shown in Figure 6D-6. With this correlation, the normals published for the Environment Canada Faro A Station can be adapted to the onsite stations using these equations.

3.2 Precipitation

Precipitation records at the local site stations have a short history (less than 10 years). Detailed discussions of these records can be found in the Hydrology Baseline Report (CH2M HILL, 2013). This section discusses the precipitation characteristics based on Environment Canada's 1981-2010 climate normal for the Faro A Station.

The average monthly precipitation, as recorded at the Faro A Station for 1981-2010, is shown in Figure 6D-7, and the annual total precipitation trend is shown in Figure 6D-8. The mean annual total precipitation ranges from 166 millimetres (mm) (1998) to 355 mm (1990), with an average of 320 mm.

Table 6D-4 summarized the monthly rainfall and snowfall in the same 1981-2010 period. On average, monthly rainfall amounts are higher from May to September. At the Faro A Station, the monthly snowfall amounts are greatest between in October and November, but generally snow covers the ground from October to March.

TABLE 6D-4
Rainfall, Snowfall, and Total Precipitation (1981 – 2010) – Faro A
Faro Mine Interim Works

Component	Monthly Average												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rainfall (mm)	0	0.01	0.12	2.6	27.3	36.7	56.1	47.5	38.4	9.4	0.16	0.13	218.4
Snowfall (cm)	16.7	14.6	13.1	6.3	0.63	0	0	0.65	2.4	20.4	21.7	17.6	114.0
Total precipitation[a] (mm)	14.6	12.3	12.3	8.7	27.9	36.7	56.1	48.2	41.0	27.3	19.4	15.2	319.7

Note:
cm = centimetre

[a]: Total precipitation is the water equivalent of all types of precipitation, including rainfall, snowfall, drizzle, freezing rain, freezing drizzle and hail.

3.3 Wind

3.3.1 Data Sources and Considerations

Environment Canada's Faro AUT Station and site-specific meteorological stations, as described previously, were used to assess surface winds for the 5-year period between 2006 and 2010. Wind speed, wind class frequency data, and wind direction were assessed and are presented below in a series of wind roses (Figures 6D-9A to 6D-11C).

The seasonal analysis of the wind data is defined as:

- Summer: May, June, July, August, September
- Winter: October, November, December, January, February, March, April

The description of winds has been presented in summary for both total and seasonal wind speed, wind direction and wind class frequency for the Faro AUT Station, Faro Dump Station, and Grum Dump Station in Sections 3.3.2 and 3.3.3.

3.3.2 Total and Seasonal Wind Speed and Frequency

Summaries of the total and seasonal wind speed, and wind class frequency for the Faro AUT Station, Faro Dump Station, and Grum Dump Station are presented in Table 6D-5. Figures 6D-9A, 6D-9B, and 6D-9C are the wind roses that show the total wind speed distribution at the above three stations. Figures 6D-10A, 6D-10B and 6D-10C show the wind rose for summer, and Figures 6D-11A, 6D-11B and 6D-11C for winter for the three stations, respectively.

Total wind speeds average 2.21 metres per second (m/s) for Faro AUT Station, 2.13 m/s for the Faro Dump Station, and 2.49 m/s for the Grum Dump Station. Across data sets, calm winds occur at lower frequencies (Faro AUT <5.5 percent, Faro Dump Station <4 percent, Grum Dump Station <1 percent). Table 6D-5 and Figures 6D-9A, 6D-9B, and 6D-9C also suggest that the data has a higher percentage of wind class frequencies across calmer wind classes (0.5 to 2.1 m/s).

Summer wind speeds average 2.21 m/s for the Faro AUT Station, 2.35 m/s for the Faro Dump Station, and 2.38 m/s for the Grum Dump Station. Winter wind speeds average 2.21 m/s for the Faro AUT Station, 1.96 m/s for the Faro Dump Station, and 2.57 m/s for the Grum Dump Station.

TABLE 6D-5
Wind Class Frequency Distribution
Faro Mine Interim Works

Time Period	Station Name	Wind Class (m/s) 0.5 - 2.1	2.1 - 3.6	3.6 - 5.7	5.7 - 8.8	8.8 -11.1	>= 11.1	Calms	Missing	Total
	Faro AUT	56%	17%	19%	3.16%	0.08%	0.01%	5.33%		100%
Total	Faro Dump Station	62%	14%	18%	2.65%	0.21%	0.02%	3.95%		100%
	Grum Dump Station	48%	27%	20%	1.81%	0.01%	0.00%	0.84%	2%	100%
	Faro AUT	59%	18%	19%	1.85%	0.04%	0.01%	2.60%		100%
Summer	Faro Dump Station	57%	18%	23%	1.41%	0.07%	0.01%	0.40%		100%
	Grum Dump Station	49%	32%	15%	0.25%	0.00%	0.00%	0.03%	4%	100%
	Faro AUT	54%	16%	18%	4.11%	0.11%	0.01%	7.29%		100%
Winter	Faro Dump Station	65%	10%	14%	3.60%	0.32%	0.02%	6.67%		100%
	Grum Dump Station	47%	23%	23%	2.89%	0.02%	0.00%	1.40%	3%	100%

3.3.3 Total and Seasonal Wind Direction

Summaries of total and seasonal wind direction and frequency distribution for the Faro AUT Station, Faro Dump Station, and Grum Dump Station are presented in Table 6D-6. The wind roses Figures 6D-9A, 9B, 9C, 10A, 10B, 10C, 11A, 11B and 11C also show the total, summer, and winter wind direction distributions for the three stations.

On an annual basis, the winds at Faro AUT Station and Grum Dump are predominantly from the southeast and northwest. Winds at the Faro Dump Station are predominantly from the southeast and northeast.

In summer , all three stations show a predominant wind from the west and northwest, while Faro Valley Dump also shows a smaller northeasterly component.

In winter, all three stations show a strong southeasterly component while Faro AUT shows an easterly component and Grum Dump station shows a strong northeasterly component.

TABLE 6D-6
Wind Direction Frequency Distribution
Faro Mine Interim Works

Wind Direction (Blow from)	Total			Summer			Winter		
	Faro AUT	Faro Dump Station	Grum Dump Station	Faro AUT	Faro Dump Station	Grum Dump Station	Faro AUT	Faro Dump Station	Grum Dump Station
N	3%	4%	3%	4%	5%	5%	2%	3%	2%
NE	9%	21%	5%	11%	21%	7%	7%	21%	4%
E	13%	6%	5%	9%	4%	5%	15%	8%	5%
SE	30%	23%	29%	20%	16%	20%	36%	29%	34%
S	3%	6%	5%	4%	7%	4%	3%	6%	6%
SW	8%	15%	10%	10%	21%	12%	6%	11%	8%
W	11%	8%	4%	16%	12%	6%	7%	5%	3%
NW	19%	12%	36%	23%	15%	37%	16%	10%	34%
Calms	5%	4%	1%	3%	0%	0%	7%	7%	1%
Missing/incomplete			2%			4%			3%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

3.4 Solar Radiation

3.4.1 Data Sources and Considerations

A record of solar radiation is not published for the Environment Canada Faro stations. The meteorological stations at the two onsite stations measure solar radiation and the data were recorded from December 2003 to July 2009. Five complete years of data (2004 to 2008) were used in this analysis. The average daily solar radiation is presented in Figure 6D-12. Table 6D-7 summarizes the monthly data with the calculated monthly average and the average monthly solar radiation is presented in Figure 6D-13.

TABLE 6D-7
Monthly Average Solar Radiation
Faro Mine Interim Works

		Average Daily Solar Radiation (kilowatts)					
	Station	**2004**	**2005**	**2006**	**2007**	**2008**	**Average**
January	Grum Dump Station	0.27	0.21	0.22	0.28	0.3	0.264
	Faro Dump Station	0.21	0.25	0.22	0.28	0.4	
February	Grum Dump Station	0.91	0.86	1.11	0.56	0.95	0.868
	Faro Dump Station	0.88	0.87	1.09	0.61	0.84	
March	Grum Dump Station	2.31	2.55	2.54	2.44	2.63	2.46
	Faro Dump Station	2.15	2.57	2.51	2.31	2.59	
April	Grum Dump Station	4.73	4.38	3.95	4.39	4.33	4.357
	Faro Dump Station	4.65	4.43	3.92	4.38	4.41	
May	Grum Dump Station	5.21	5.45	4.64	5.25	5.12	5.177
	Faro Dump Station	5.41	5.31	4.75	5.39	5.24	
June	Grum Dump Station	5.89	5.7	6.09	5.42	5.45	5.599
	Faro Dump Station	5.52	5.71	5.9	5.15	5.16	
July	Grum Dump Station	4.72	4.61	5.32	4.92	4.53	4.703
	Faro Dump Station	4.47	4.15	5.02	4.76	4.53	
August	Grum Dump Station	4.12	3.81	3.66	4.22	3.57	3.794
	Faro Dump Station	3.95	3.72	3.54	3.97	3.38	
September	Grum Dump Station	2.17	2.21	2.25	2.12	2.22	2.136
	Faro Dump Station	2.06	2.08	2.21	1.95	2.09	
October	Grum Dump Station	1.13	1.16	1.13	1.06	0.94	1.07
	Faro Dump Station	1.09	1.07	1.09	1.08	0.95	
November	Grum Dump Station	0.45	0.28	0.23	0.43	0.4	0.36
	Faro Dump Station	0.44	0.24	0.31	0.42	0.4	
December	Grum Dump Station	0.08	0.17	0.1	0.14	0.15	0.129
	Faro Dump Station	0.1	0.17	0.11	0.13	0.14	

3.5 Evaporation and Evapotranspiration

Evaporation is measured as the loss of water from free water surfaces and is usually represented as a rate of water loss in monthly or annual mm of depth. Evapotranspiration is the loss of water from land surfaces. It is also normally expressed in terms of monthly or annual mm, and represents a combination of evaporation from the

ground surface and transpiration by vegetation. Estimates of evaporation and evapotranspiration rates for the FMC have been calculated from meteorological data collected at onsite climate stations, and from regional climate stations, using the Environment Canada National Hydrology Research Institute (NHRI) WREVAP Model (NHRI, 1985).

WREVAP is a semi-empirical, semi-physical model that estimates evaporation from meteorological data (humidity, air temperature and sunshine duration or solar radiation). The two onsite dump weather stations monitor the necessary input data for the evaporation model. Accordingly, the WREVAP model was applied by AECOM to the data sets provided by these two stations (AECOM, 2009). The computed mean annual evapotranspiration rates for the Faro Dump and Grum Dump weather stations are 229 mm and 246 mm, respectively. The computed mean annual lake evaporation rates for the Faro Dump and Grum Dump are 472 mm and 484 mm, respectively, or roughly double the corresponding mean annual evapotranspiration rates. The monthly evapotranspiration values for the FMC are shown in Table 6D-8.

TABLE 6D-8
Monthly Evapotranspiration Data
Faro Mine Interim Works

Month	Faro Dump Station Evapotranspiration (mm)	Grum Dump Station Evapotranspiration (mm)
January	0	0
February	0	0
March	10	10
April	30	32
May	48	47
June	50	56
July	48	57
August	26	30
September	20	20
October	5	4
November	0	0
December	0	0

Source: AECOM (2009)

3.6 Relative Humidity

The RH at Faro A Station is generally recorded twice per day in summer months (April through October) at 06:00 and 15:00, and once per day at 15:00 during the rest of the year. The annual average RH, as recorded at 15:00 for 1981-2010, is 62.69 percent. The RH is generally higher in the morning and lower in the afternoon. Table 6D-9 shows the 1981 – 2010 Climate Normal data of RH recorded at Faro A.

TABLE 6D-9
Monthly Relative Humidity at Faro A Station (1981-2010)
Faro Mine Interim Works

Month	RH (%) at 06:00	RH (%) at 15:00
January		79.18
February		71.89
March		54.76
April	78.5	
May	74.6	
June	75.11	41.44
July	80.77	47.9
August	88.23	50.41
September	89.99	55.4
October	86.27	63.68
November		81.17
December		81.03
Annual	**81.92**	**62.69**

SECTION 4

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Figures



VICINITY MAP



LEGEND

- Climate Station
- Major Road
- Minor Road

Note:
1. Aerial Source: Copyright © 2013 Google

N

0 250 500 750 1,000
Metres

Created by:
CRITIGEN

FIGURE 6D-1
Location of Environment Canada Climate Stations
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

- Meteorological Station
- Major Road
- Minor Road

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 1,000 2,000 3,000 4,000
Metres

Created by:
CRITIGEN

FIGURE 6D-2
Location of the On-site Meteorological Stations
Faro Mine Interim Works

CH2MHILL

R:\FAROMINE_20000342\MAPFILES\TAR08\6D_CLIMATE\FIG6D-2.MXD TMCBROOME 2/6/2014 9:04:20 AM

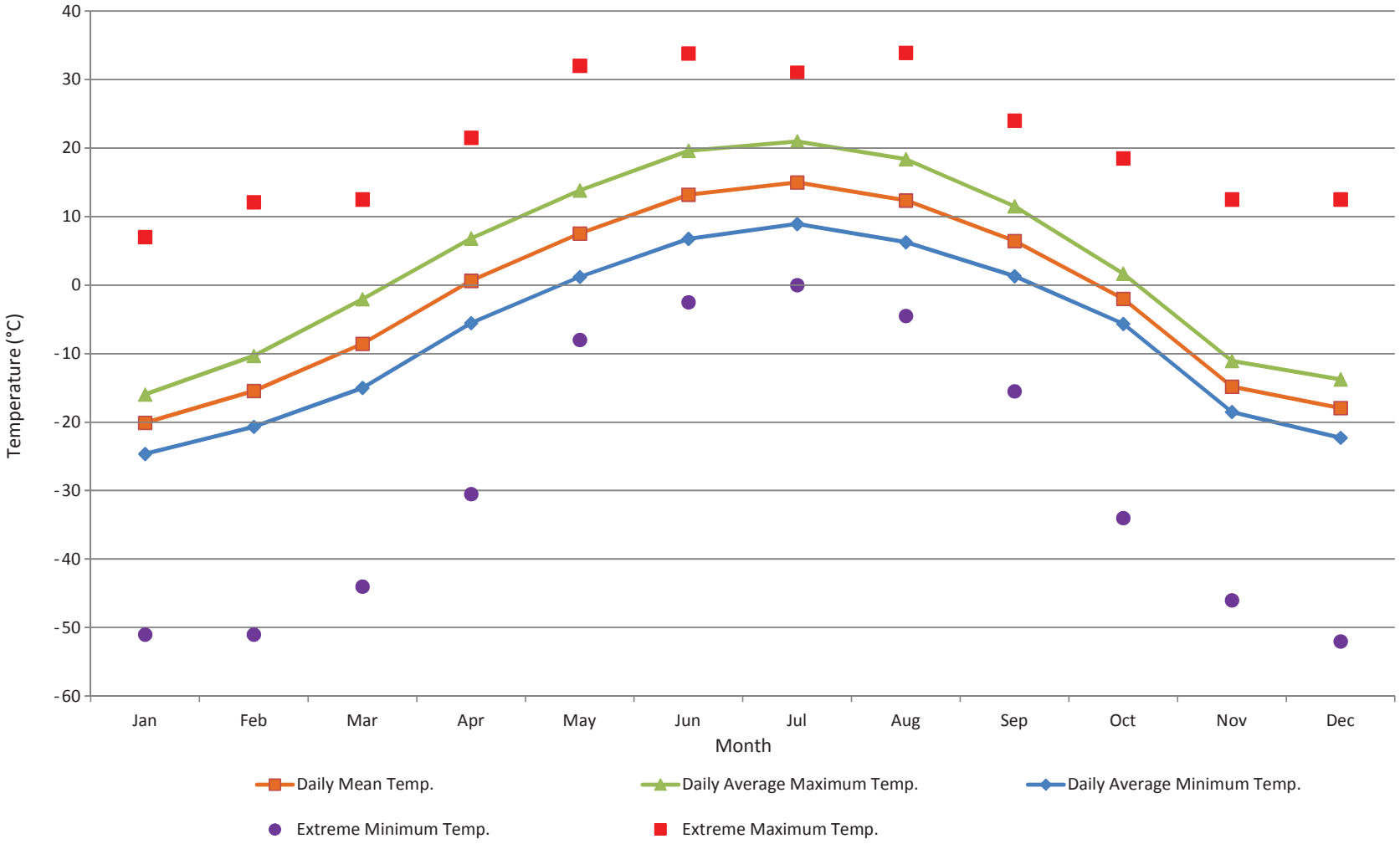


FIGURE 6D-3
Monthly Temperature Normals and Extremes (1981–2010) – Faro A
Faro Mine Interim Works

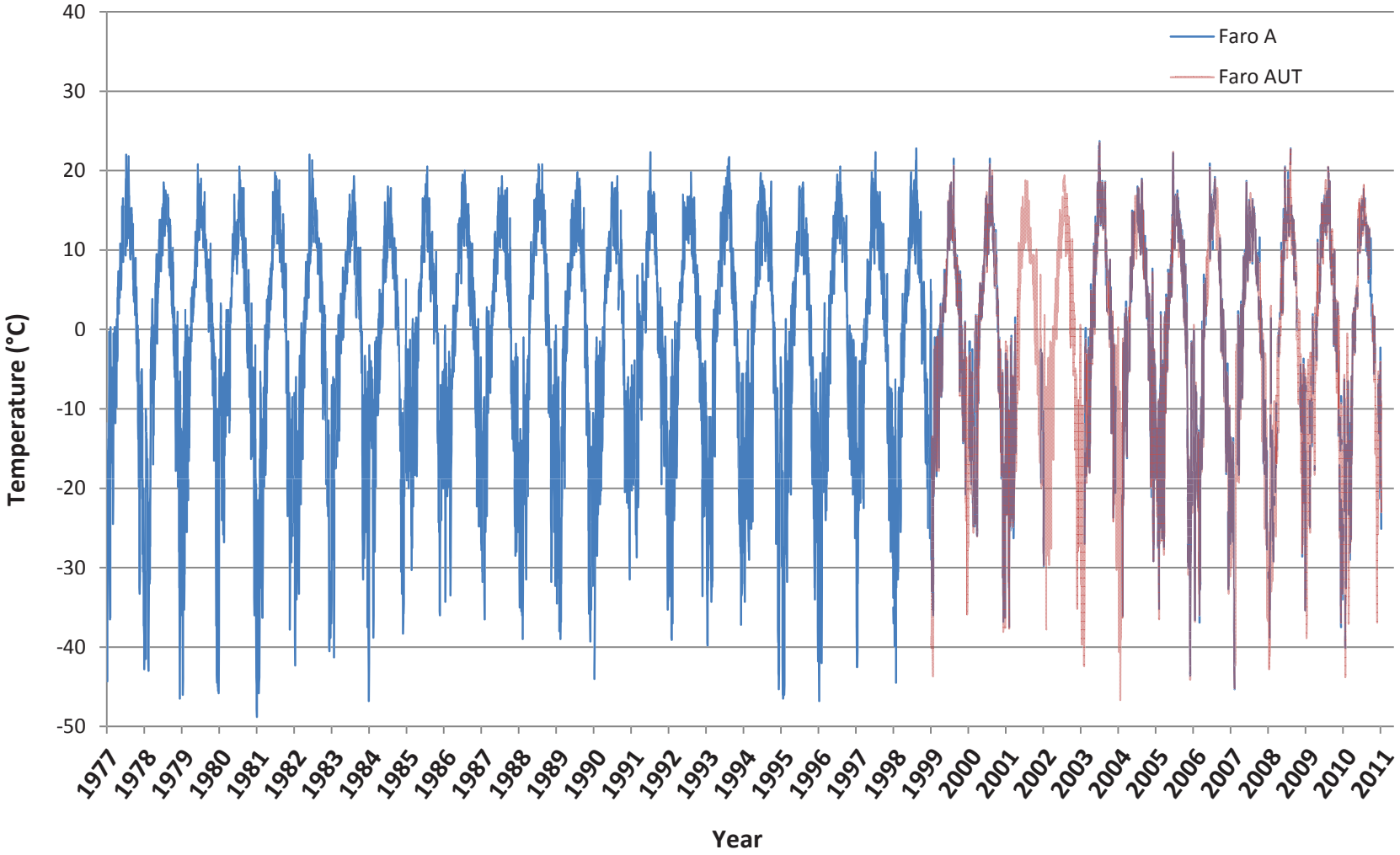


FIGURE 6D-4
Historical Daily Temperature (1977–2011)
Faro Mine Interim Works

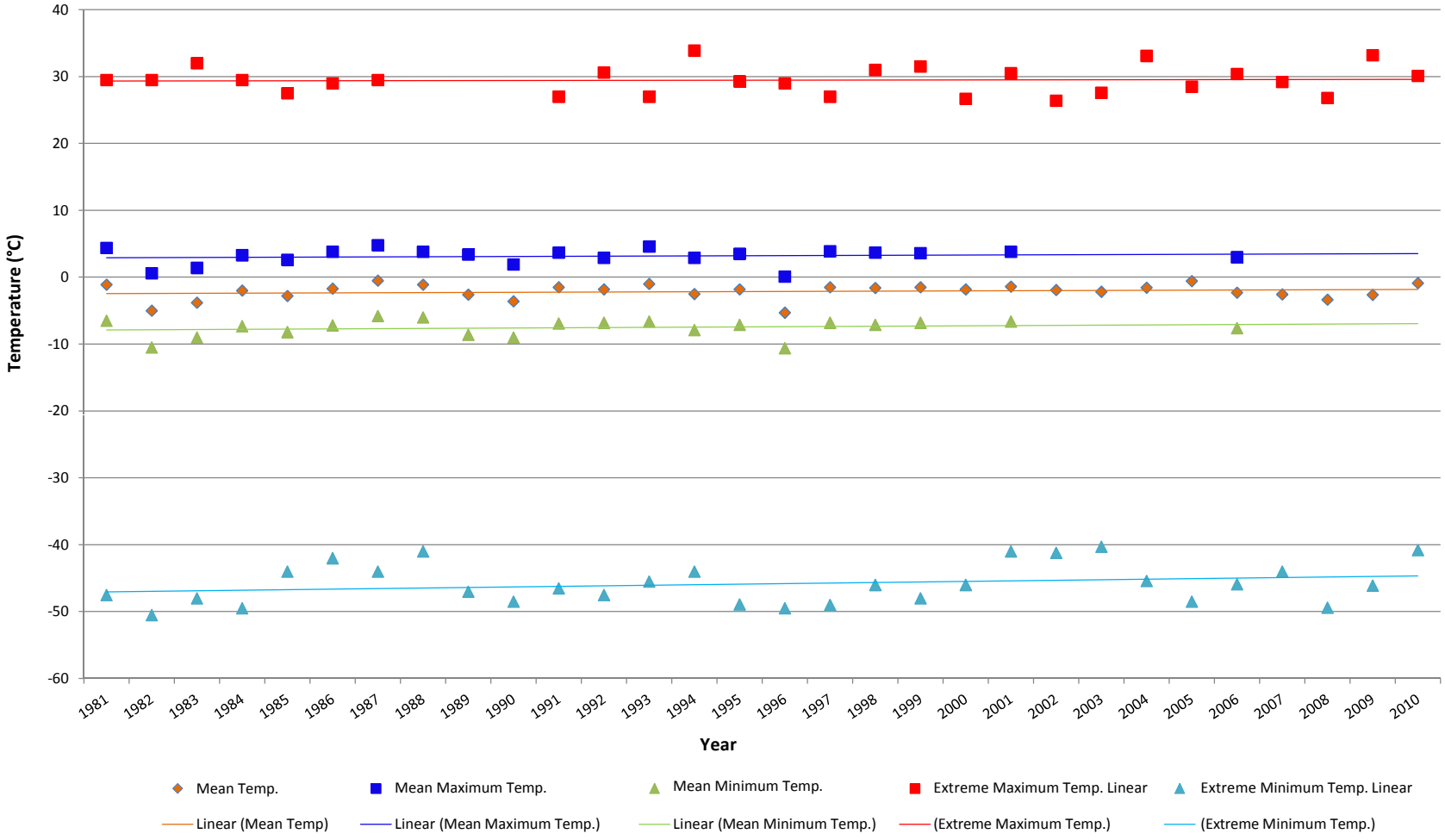


FIGURE 6D-5
Mean Annual Temperature Trend (1981–2010) – Faro A and Faro AUT
Faro Mine Interim Works

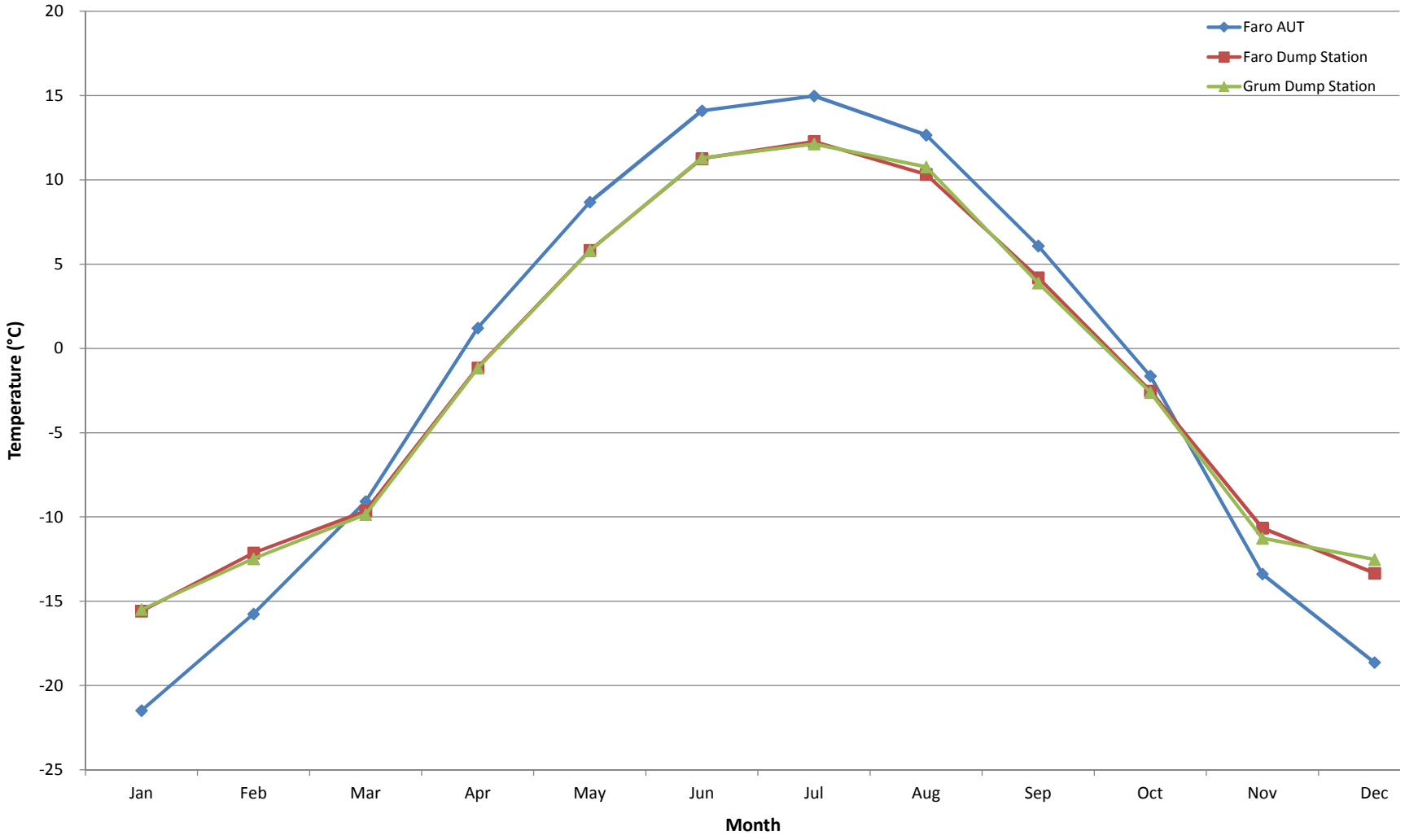


FIGURE 6D-6
Comparison of Monthly Average Temperature
Faro Mine Interim Works

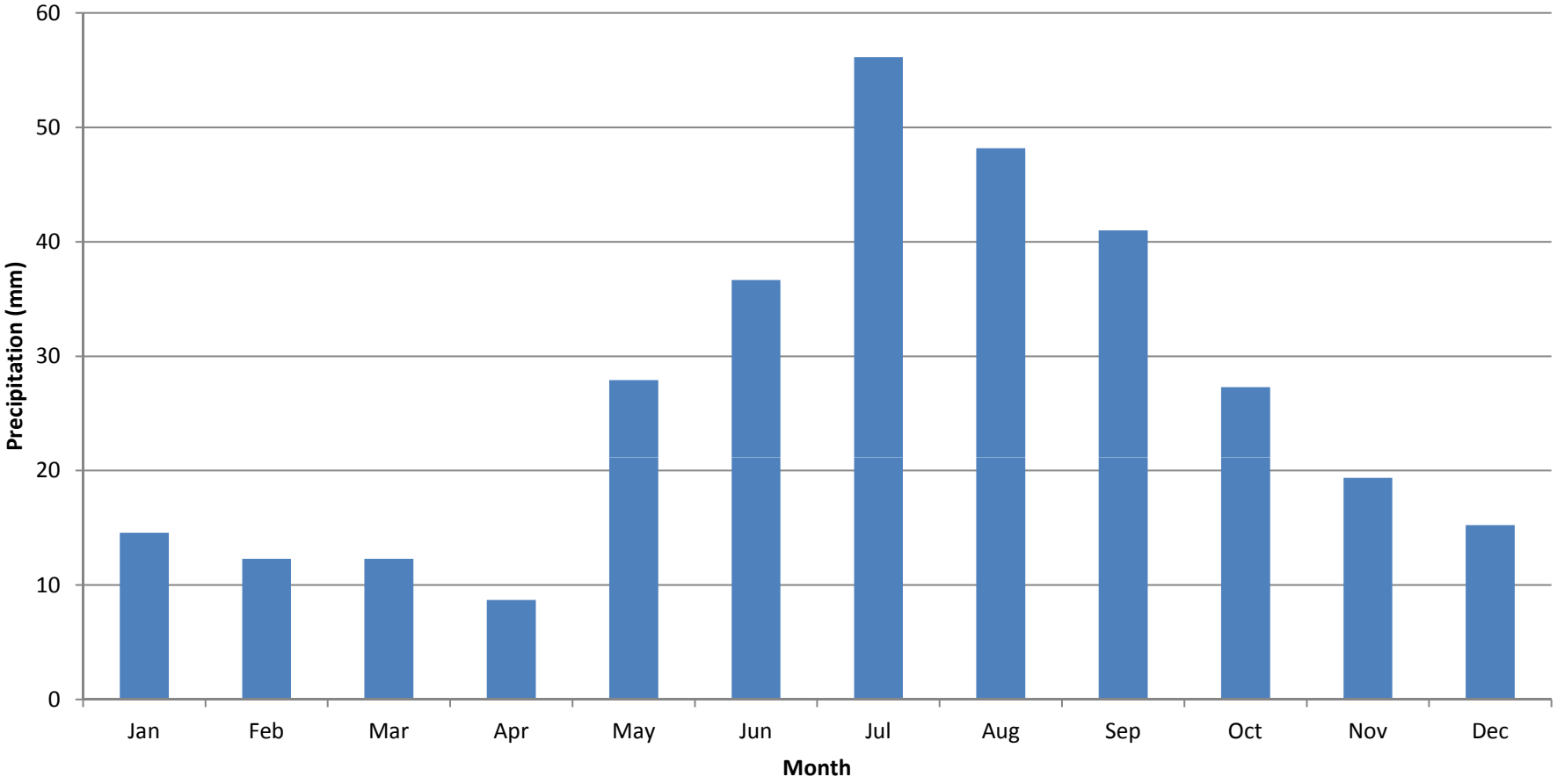


FIGURE 6D-7
Monthly Precipitation (1981–2010) – Faro A
Faro Mine Interim Works

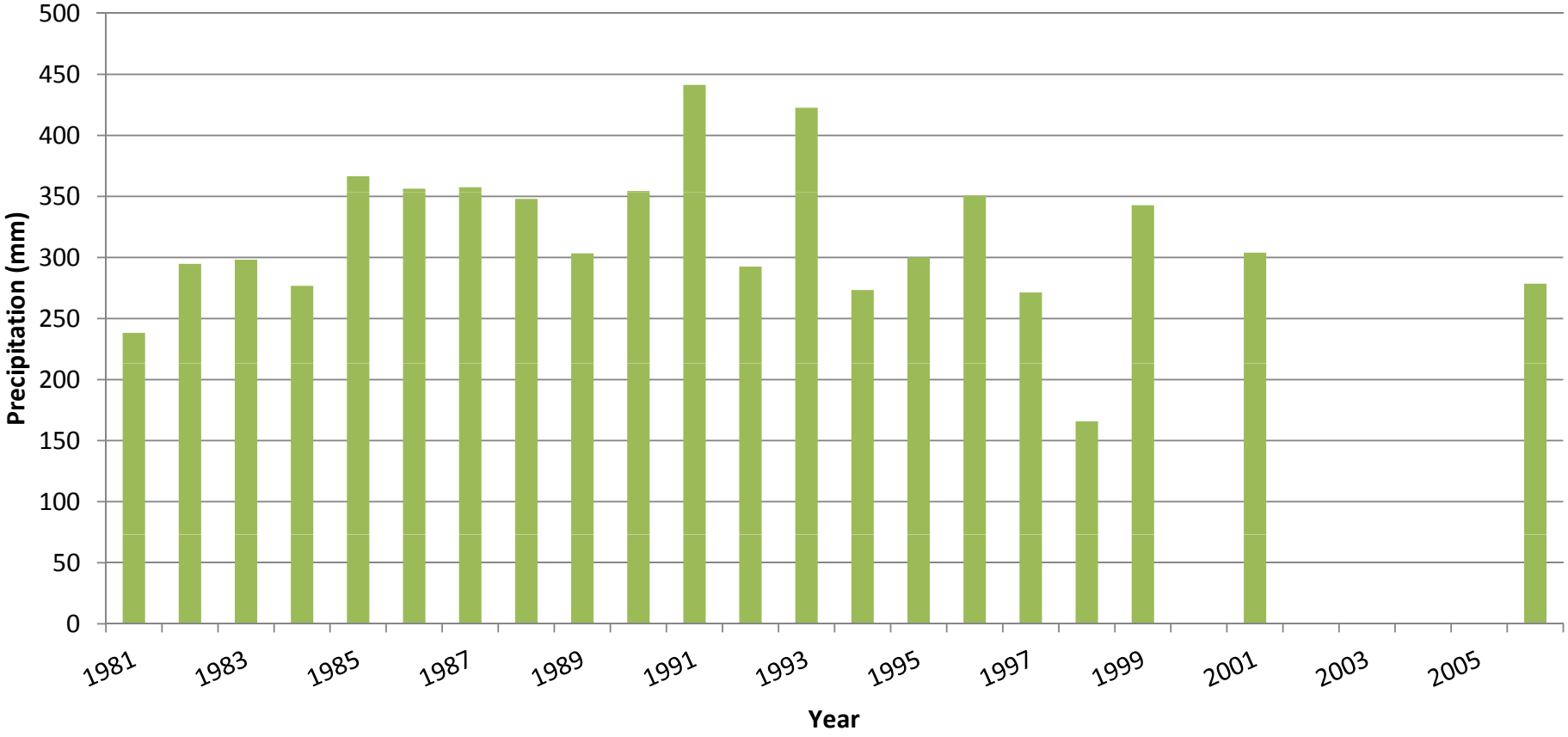
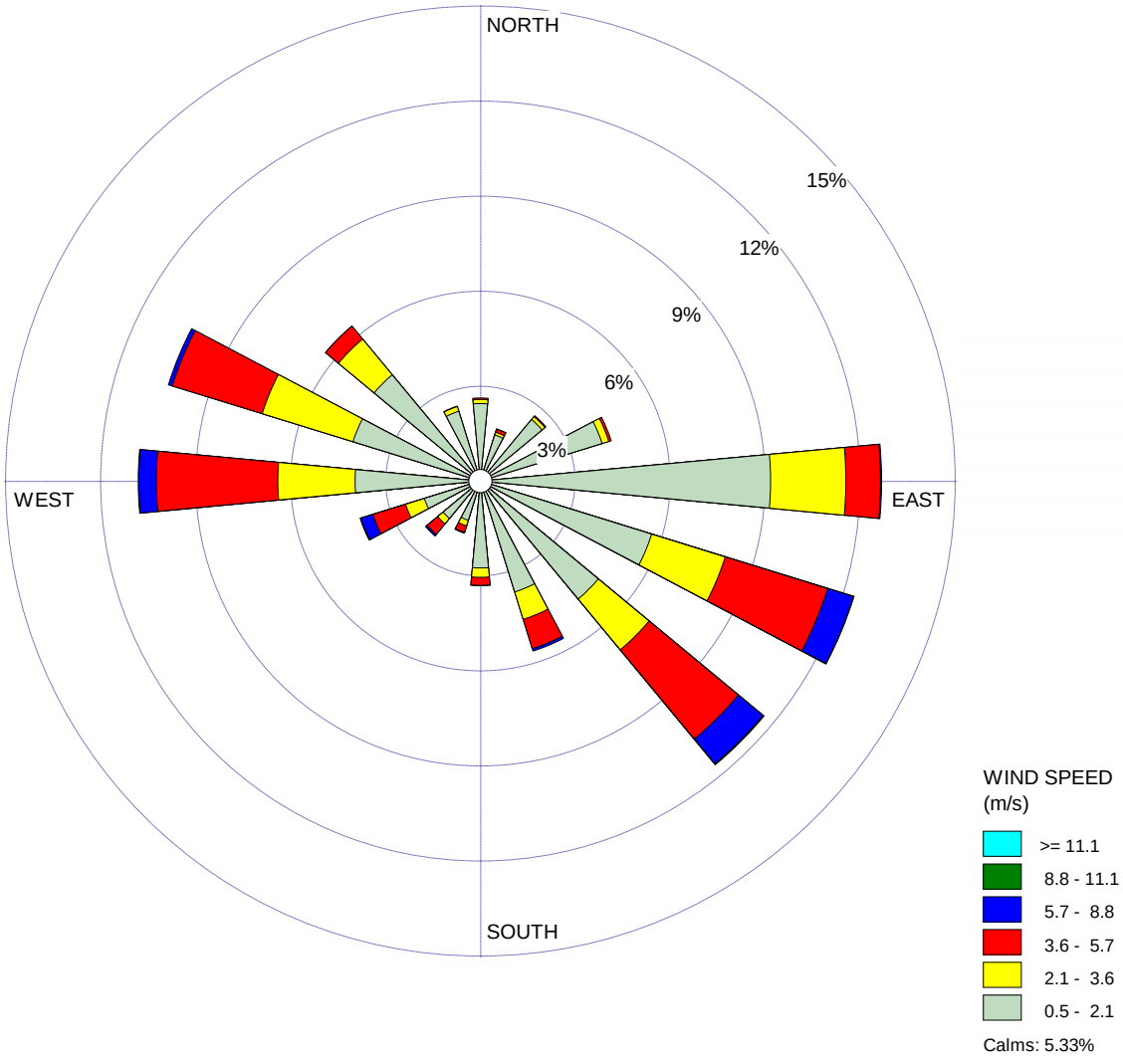


FIGURE 6D-8
Annual Precipitation (1981–2010) – Faro A
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)

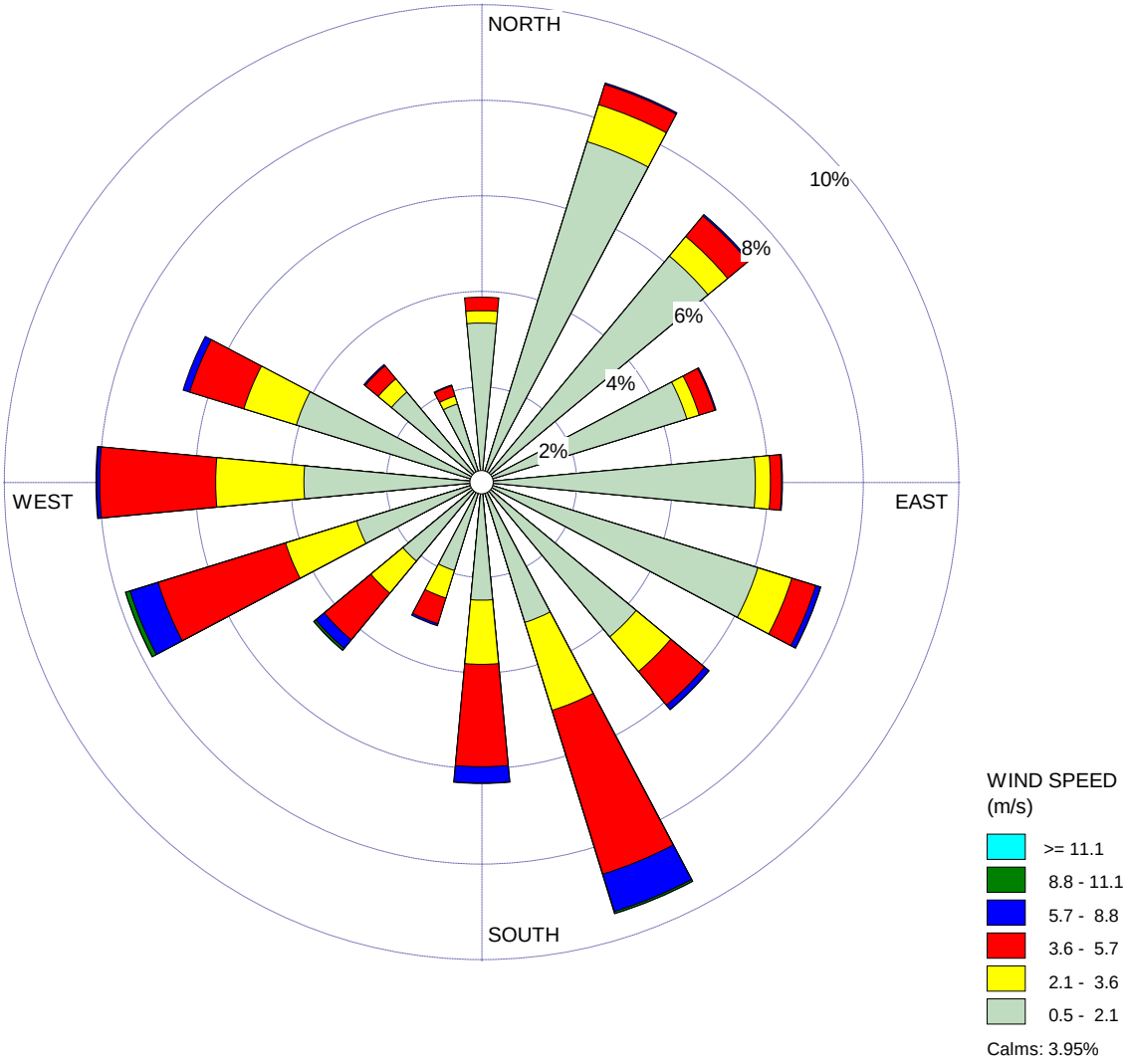


COMMENTS:	DATA PERIOD:	COMPANY NAME:	
Faro AUT Station	**Start Date: 1/1/2006 - 00:00** **End Date: 12/31/2010 - 23:00**	**CH2M HILL**	
		MODELER:	
	CALM WINDS: **5.33%**	TOTAL COUNT: **43824 hrs.**	
	AVG. WIND SPEED: **2.21 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-9A
Wind Rose 2006–2010 – Faro AUT Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)

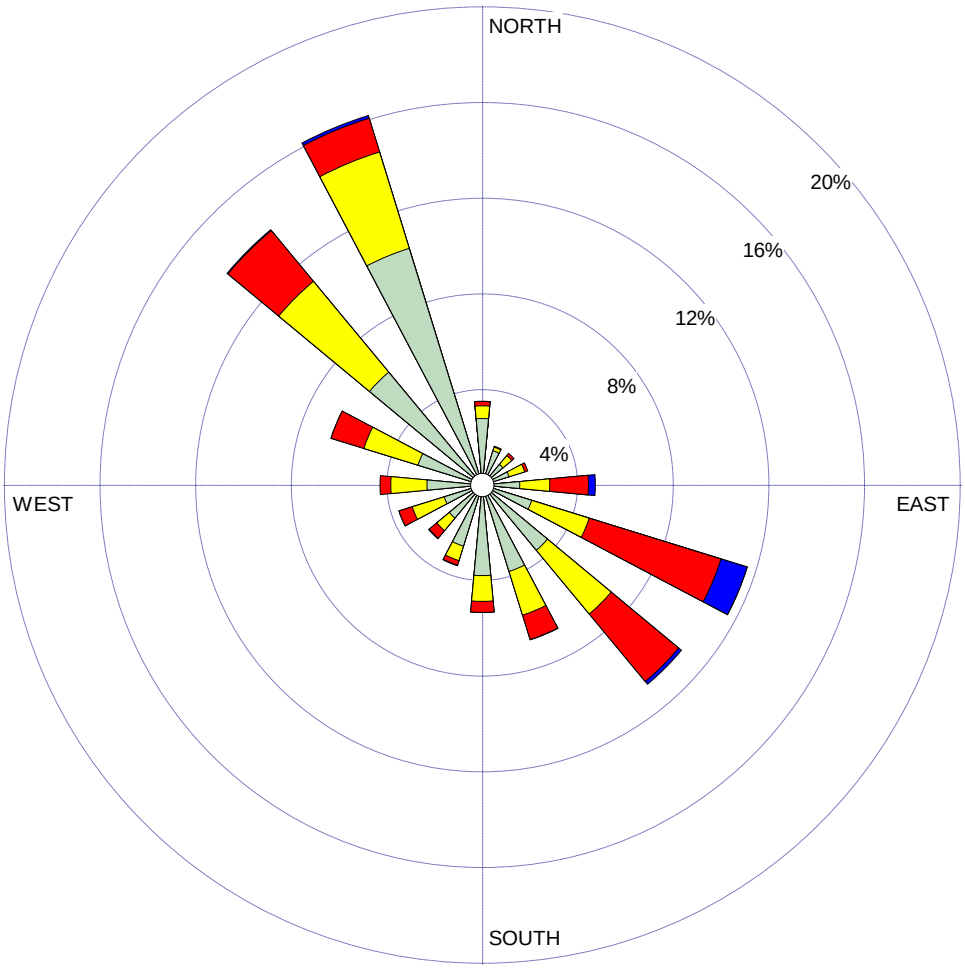


COMMENTS: Faro Dump Station	DATA PERIOD: **Start Date: 1/1/2006 - 00:00** **End Date: 12/31/2010 - 23:00**	COMPANY NAME: **CH2M HILL**	
		MODELER:	
	CALM WINDS: **3.95%**	TOTAL COUNT: **41043 hrs.**	
	AVG. WIND SPEED: **2.13 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-9B
Wind Rose 2006–2010 – Faro Dump Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)



WIND SPEED
(m/s)

- >= 11.1
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1

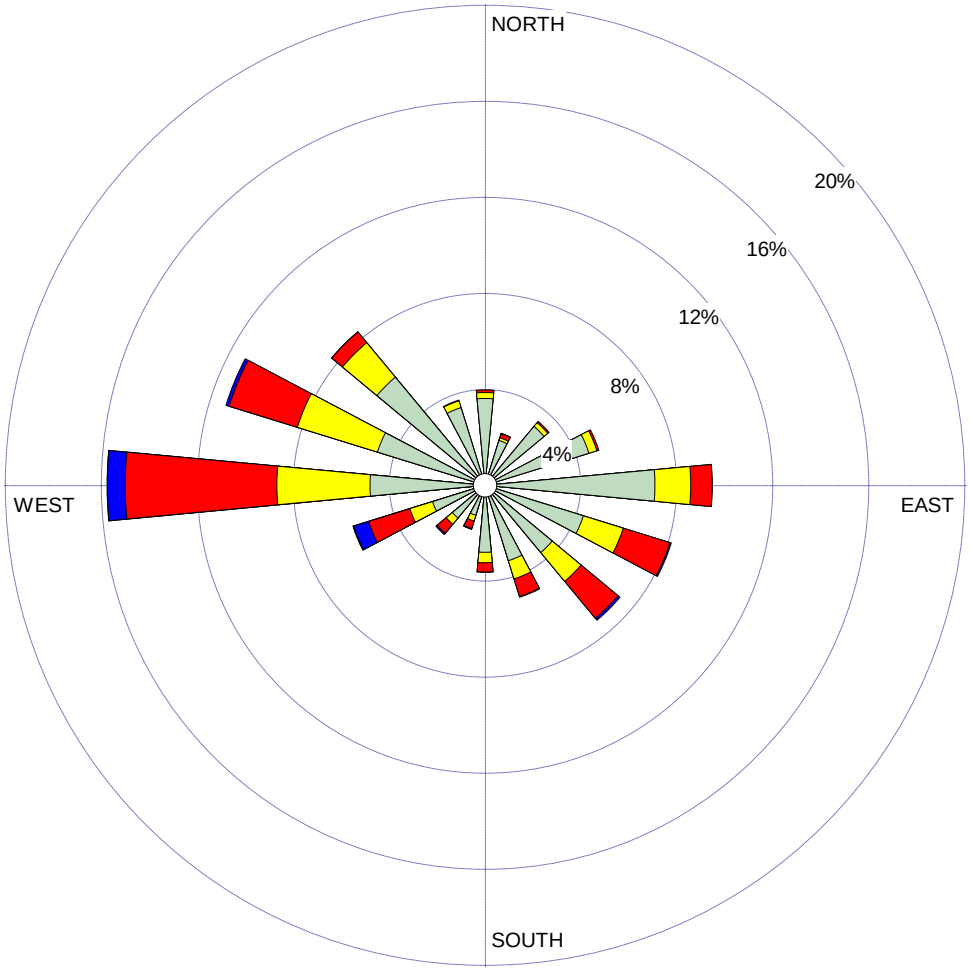
Calms: 0.84%

COMMENTS:	DATA PERIOD:	COMPANY NAME:	
Grum Dump Station	**Start Date: 1/1/2006 - 00:00** **End Date: 12/31/2010 - 23:00**	**CH2M HILL**	
		MODELER:	
	CALM WINDS: **0.84%**	TOTAL COUNT: **34070 hrs.**	
	AVG. WIND SPEED: **2.49 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-9C
Wind Rose 2006–2010 – Grum Dump Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)



WIND SPEED
(m/s)

- >= 11.1
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1

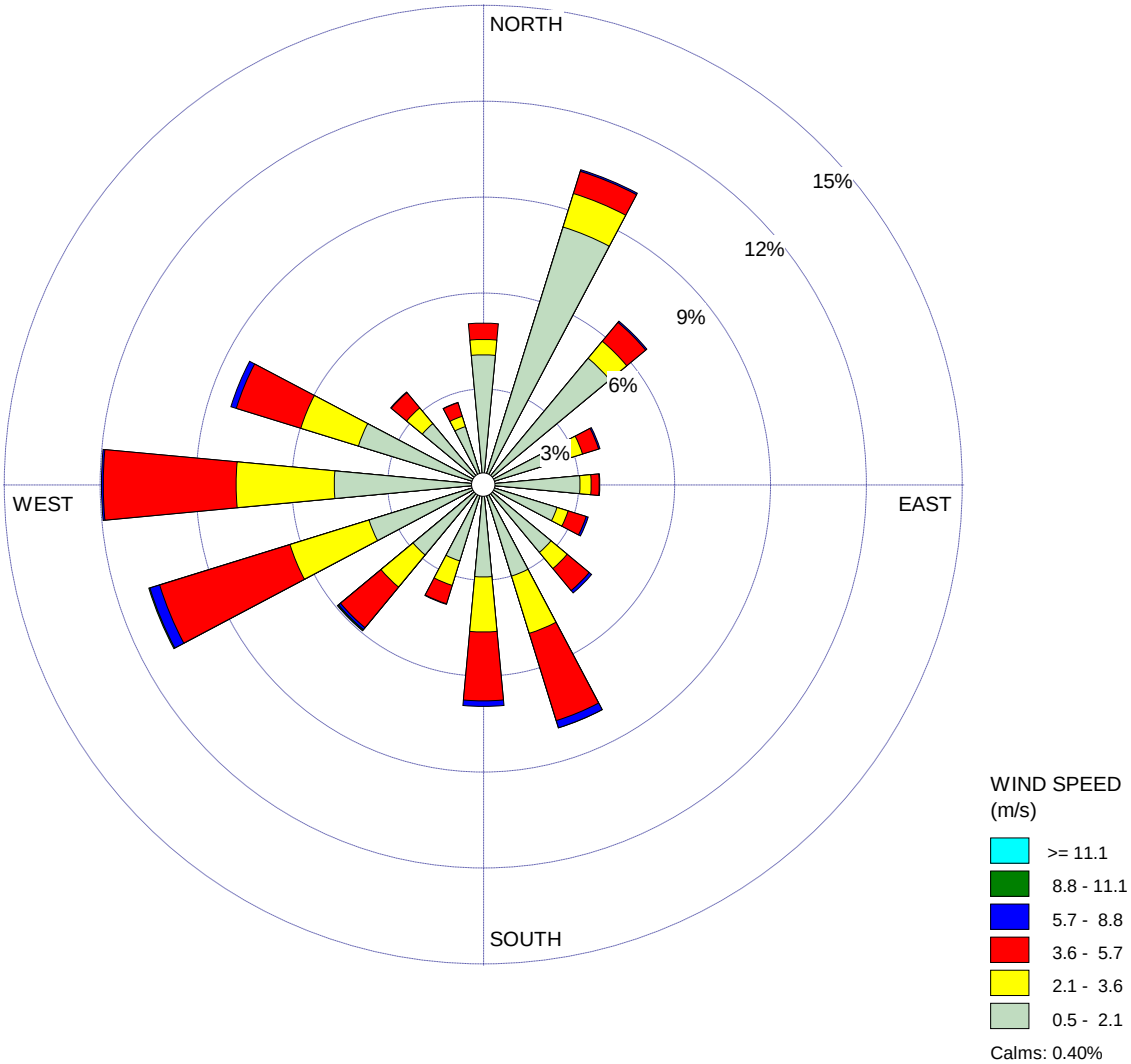
Calms: 2.60%

COMMENTS: Faro AUT Station May 1 - September 30		COMPANY NAME: **CH2M HILL**	
		MODELER:	
	CALM WINDS: **2.60%**	TOTAL COUNT: **18360 hrs.**	
	AVG. WIND SPEED: **2.21 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-10A
Wind Rose 2006–2010, Summer – Faro AUT Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)

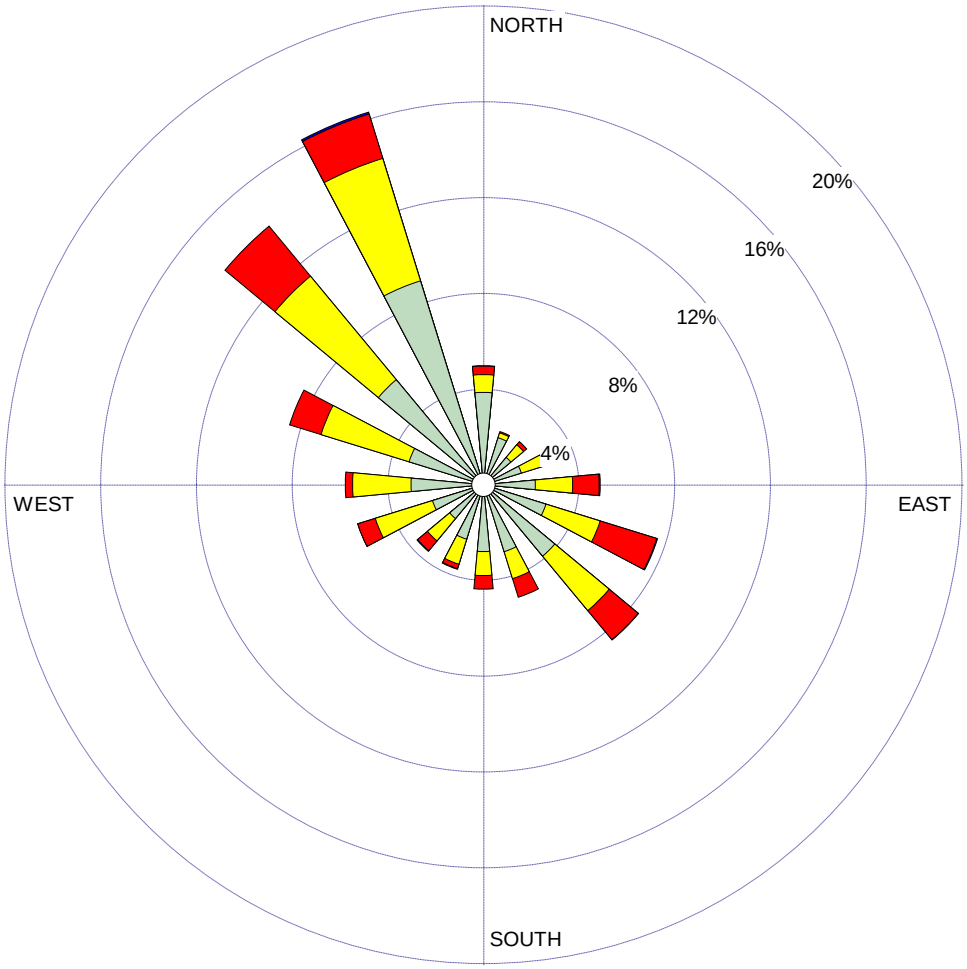


COMMENTS: Faro Dump Station May 1 - September 30		COMPANY NAME: **CH2M HILL**	
		MODELER:	
	CALM WINDS: **0.40%**	TOTAL COUNT: **17788 hrs.**	
	AVG. WIND SPEED: **2.35 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-10B
Wind Rose 2006–2010, Summer – Faro Dump Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)



WIND SPEED
(m/s)

- >= 11.1
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1

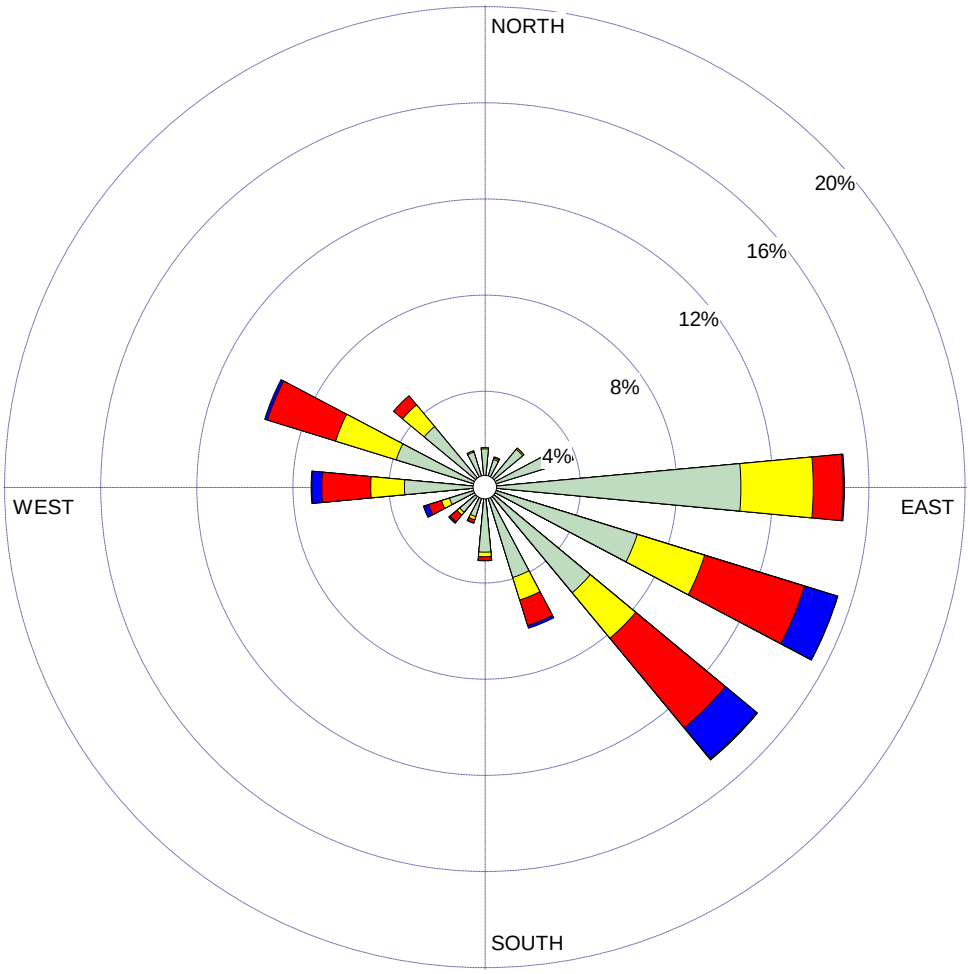
Calms: 0.03%

COMMENTS: Grum Dump Station May 1 - September 30		COMPANY NAME: **CH2M HILL**	
		MODELER:	
	CALM WINDS: **0.03%**	TOTAL COUNT: **14125 hrs.**	
	AVG. WIND SPEED: **2.38 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-10C
Wind Rose 2006–2010, Summer – Grum Dump Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)



WIND SPEED
(m/s)

- >= 11.1
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1

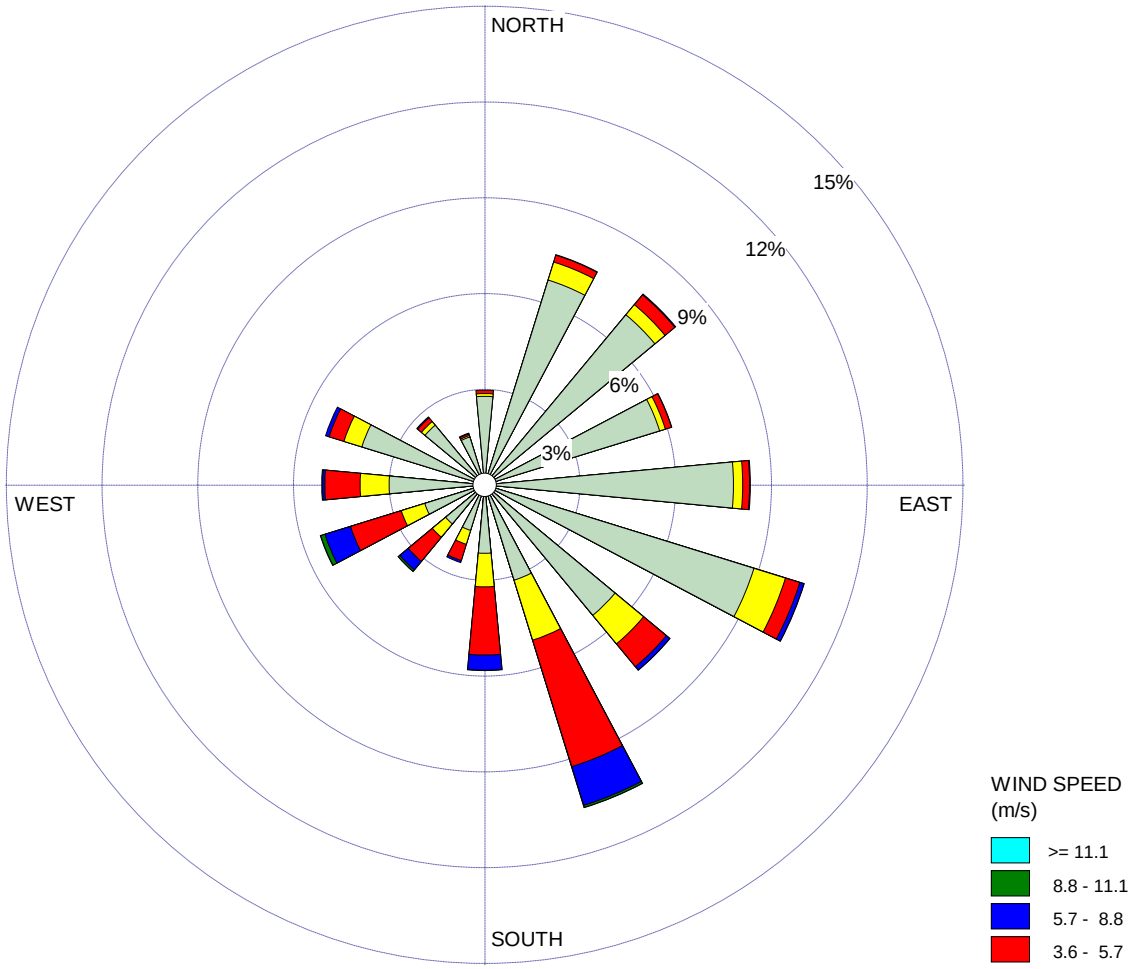
Calms: 7.29%

COMMENTS: Faro AUT Station October 1 - April 30		COMPANY NAME: **CH2M HILL**	
		MODELER:	
	CALM WINDS: **7.29%**	TOTAL COUNT: **25464 hrs.**	
	AVG. WIND SPEED: **2.21 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-11A
Wind Rose 2006–2010, Winter – Faro AUT Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)

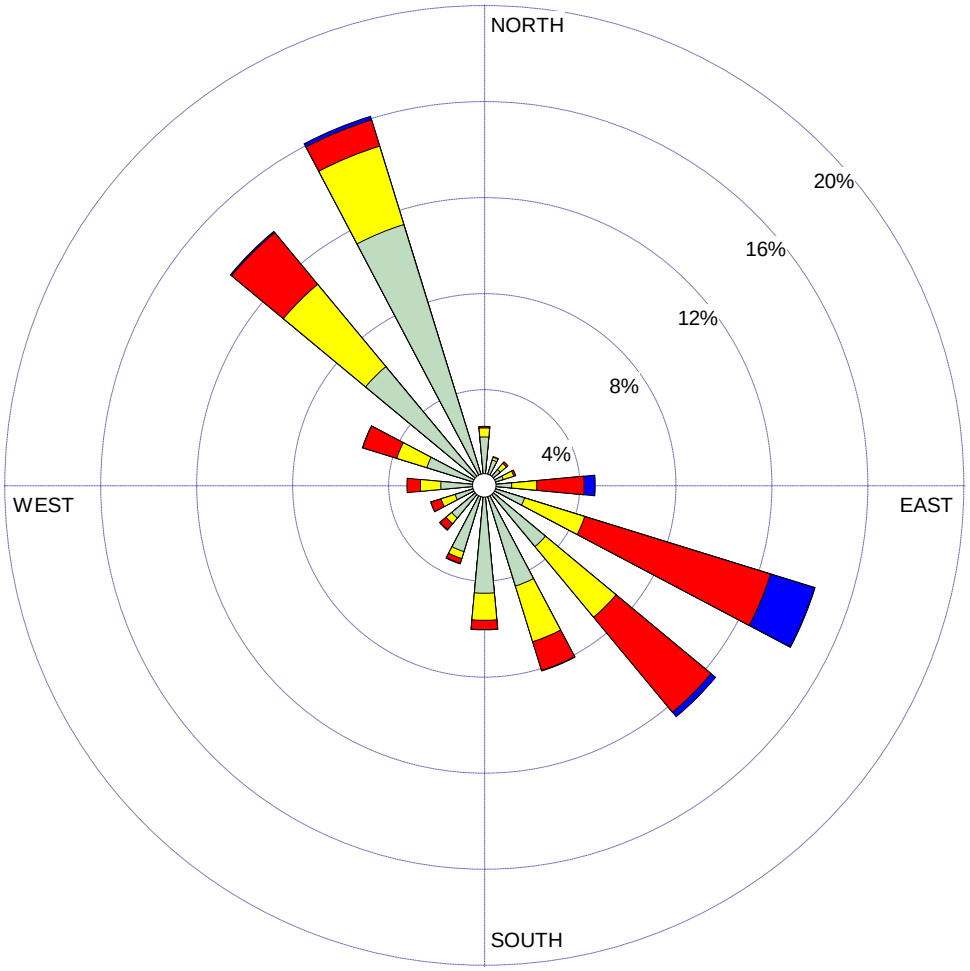


COMMENTS: Faro Dump Station October 1 - April 30		COMPANY NAME: **CH2M HILL**	
		MODELER:	
	CALM WINDS: **6.67%**	TOTAL COUNT: **23255 hrs.**	
	AVG. WIND SPEED: **1.96 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-11B
Wind Rose 2006–2010, Winter – Faro Dump Station
Faro Mine Interim Works

DISPLAY:
Wind Speed
Direction (blowing from)



WIND SPEED
(m/s)

- >= 11.1
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1

Calms: 1.40%

COMMENTS: Grum Dump Station October 1 - April 30		COMPANY NAME: **CH2M HILL**	
		MODELER:	
	CALM WINDS: **1.40%**	TOTAL COUNT: **19945 hrs.**	
	AVG. WIND SPEED: **2.57 m/s**	DATE: **9/19/2013**	PROJECT NO.: **472645**

WRPLOT View - Lakes Environmental Software

FIGURE 6D-11C
Wind Rose 2006–2010, Winter – Grum Dump Station
Faro Mine Interim Works

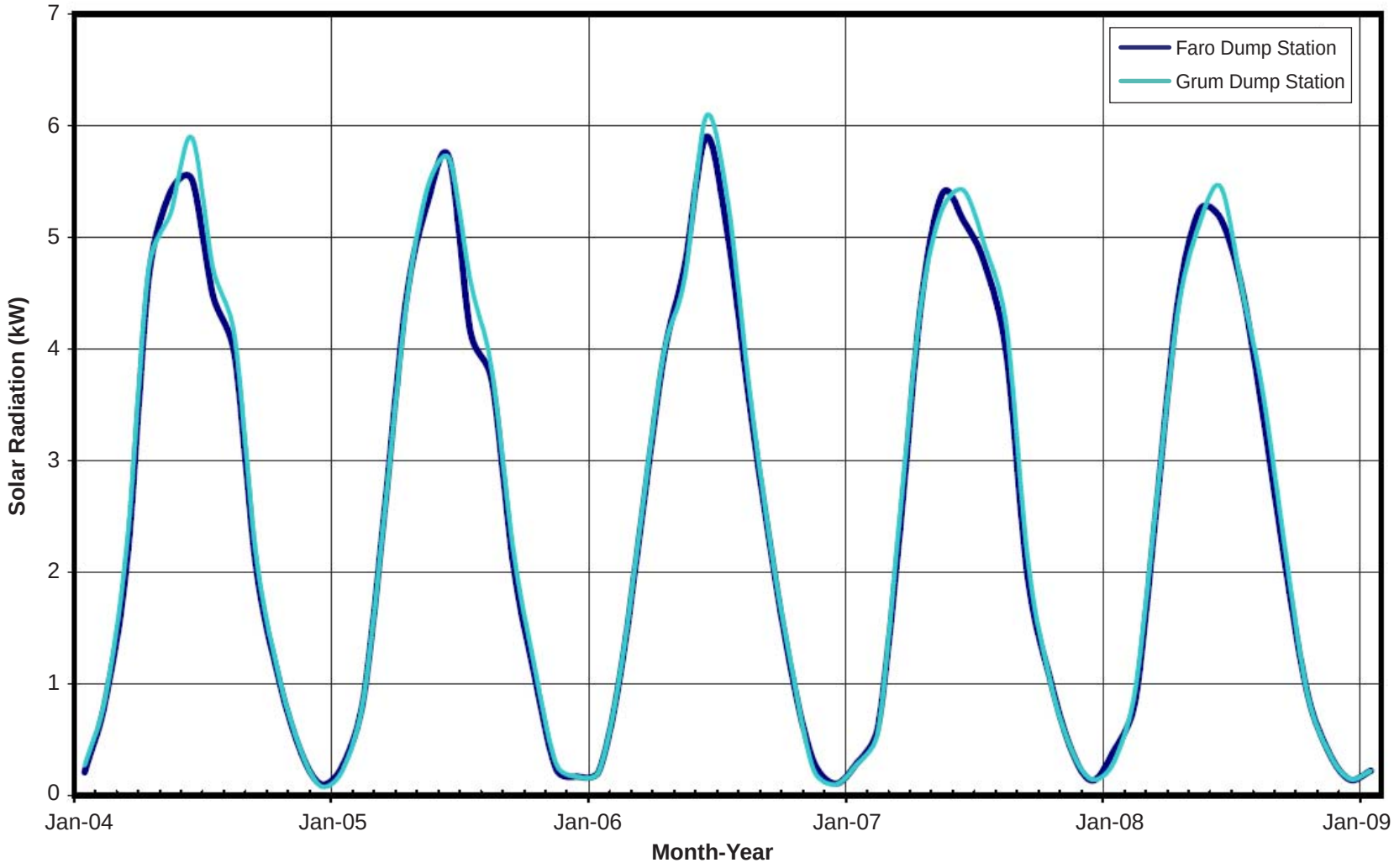


FIGURE 6D-12
Average Daily Solar Radiation
Faro Mine Interim Works

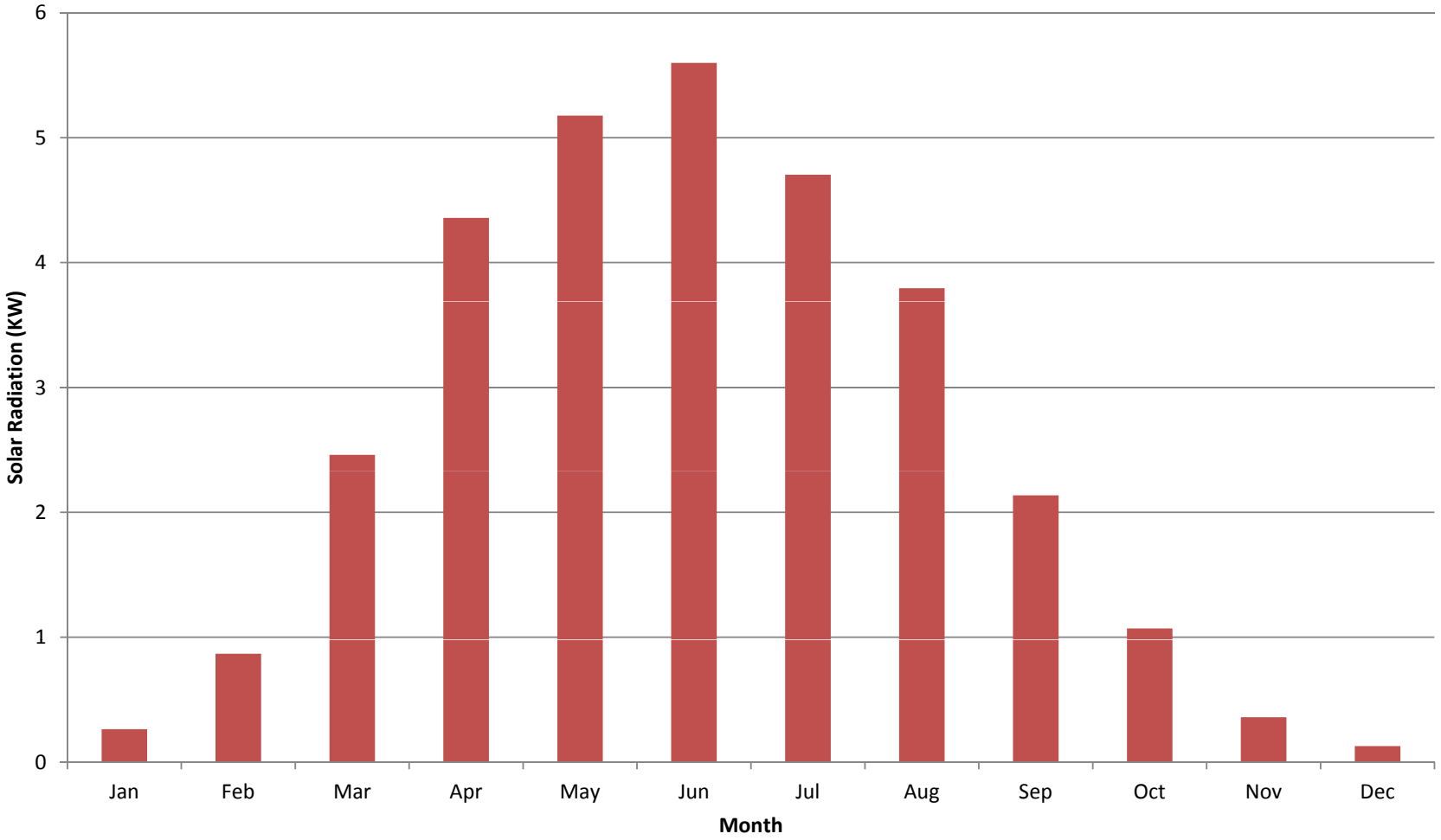


FIGURE 6D-13
Average Monthly Solar Radiation
Faro Mine Interim Works

Appendix 6E
Air Quality Baseline Report

Draft

Air Quality Baseline Report, Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon Y1A 2J9

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Attachment

1 2008 Baseline Air Quality Monitoring Assessment – SENES Consultants Ltd.

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Acronyms and Abbreviations

µg/m^3	micrograms per cubic metre
AAQO	ambient air quality objectives
AAQS	ambient air quality standards
CO	carbon monoxide
FMC	Faro Mine Complex
FMRP	Faro Mine Remediation Project
GHG	greenhouse gas
IW	Interim Works
km	kilometre
MDL	method detection limit
MOE	[Ontario] Ministry of the Environment
NAAQS	[USEPA] National Ambient Air Quality Standards
NAPS	National Air Pollution Surveillance
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NPRI	National Pollution Release Inventory
NWT	Northwest Territory
O_3	ozone
PM_{10}	particulate matter with aerodynamic diameter less than 10 microns
$PM_{2.5}$	particulate matter with aerodynamic diameter less than 2.5 microns
ppb	parts per billion
ppbv	parts per billion, volumetric
ppm	parts per million
QA	quality assurance
QC	quality control
SO_2	sulphur dioxide
TEOM	Tapered Element Oscillating Microbalance
TSP	total suspended particulates
VC	valued component
VOC	volatile organic compound
YG	Government of Yukon
YT	Yukon Territory
USEPA	U.S. Environmental Protection Agency

SECTION 1

Introduction

Air quality is considered to be an important consideration and a primary goal for the Faro Mine Interim Works (IW) project. Air quality is characterized by ambient concentrations of key air quality indicators including nitrogen oxides (NO_x), sulphur dioxide (SO_2), particulate matter (including metals), carbon monoxide (CO), ozone (O_3), and other pollutants. This document describes the baseline air quality conditions of the area on and around the Faro Mine Complex (FMC) site. The purpose of this baseline air quality analysis is to quantitatively define the existing or baseline ambient air quality conditions near the FMC, which is used in part to assess the air quality effects of the IW project as described in the *Air Quality Effects Report, Faro Mine Interim Works* (CH2M HILL, 2014).

Existing air quality conditions were characterized using recent air quality data obtained from previous onsite monitoring studies, as well as by air quality monitoring data obtained from offsite Environment Canada monitoring stations.

This report summarizes the air quality data used for the baseline assessment and discusses the representativeness of those data used to characterize ambient air concentrations in the vicinity of the project site.

SECTION 2

Methods

This section describes the air quality study area, data sources, and data analysis methods. In general, site monitoring data were used as the primary source of baseline air quality data. For parameters that were not monitored on the site, the nearest National Air Pollution Surveillance (NAPS) monitoring stations operated by Environment Canada were used to obtain representative data. The following sections provide additional details about the study area, data sources, and analysis methods.

2.1 Study Area

The study area for the ambient air quality analysis at the FMC site includes the areal extent of any likely air quality impacts attributable to IW project-related emissions. This area was assumed to be comprised of a 100-kilometre (km) -by-100-km square area approximately centred on the project site. The extent of the study area is considered to be sufficient to assess air quality parameters such as secondary particulate matter formation.

Figure 6E-1 shows the baseline air quality analysis study area.

2.2 Analysis Parameters

Air quality was described by characterizing ambient concentrations of key air quality indicators including NO_x, SO_2, particulate matter, CO, O_3, and particulate based metals. This baseline analysis did not characterize greenhouse gases (GHGs) because the IW is scheduled for completion within 10 years. As a result, the project is not expected to contribute measurably to global climate conditions.

Only those emissions that will be associated with current site operations and proposed IW activities were quantified for the baseline and effects determination, respectively.

2.3 Sources of Data and Information

The following databases and reports were reviewed for use in establishing the baseline ambient air quality for the FMC site:

- Environment Canada NAPS, http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=8BA86647-1, Accessed September 5, 2013 (Environment Canada, 2013)
- Yukon State of the Environment Interim Report, An Update for Environmental Indicators, Government of Yukon (YG), Yukon Environment (YG, 2013)
- AECOM Canada Ltd. (AECOM). 2009. *Faro Mine Closure Complex Closure and Reclamation* – Current Environmental Conditions Supporting Document (AECOM, 2009)
- 2008 Baseline Air Quality Monitoring Assessment – Faro Mine Complex. February 24, 2009. (SENES, 2009)

Results from onsite sampling conducted by SENES Consultants Ltd. (SENES) in 2008 were the data source for contaminants that were measured in that program. Data from the nearest NAPS monitoring stations (Whitehorse in the Yukon Territory [YT] and Norman Wells in the Northwest Territories [NWT]) were used as the primary data source for characterizing ambient air quality for those contaminants that were not monitored at the FMC site.

2.4 Data Analysis Methods

The proposed project activities will result in emissions that have the potential to affect criteria air contaminants as a result of construction and maintenance activities. The effects assessment (CH2M HILL, 2014) required a comprehensive understanding of the current state of air quality in the site area, so that an assessment of effect of the project on baseline air quality could be made.

An evaluation of existing ambient air quality will serve as a benchmark for evaluating effects of project related emissions on existing air quality. Current ongoing projects at the FMC have been considered in characterizing

baseline ambient air quality. The effects primarily result from airborne dust from vehicle traffic on unpaved roads, fugitive emissions from construction and material handling, wind-blown dust emissions from the tailings storage facilities, and the combustion of diesel and other fuels in onsite and mobile equipment.

A review of local air quality literature and information sources shows that only limited ambient air quality monitoring has been performed on or near the FMC site. This includes data from onsite monitoring stations, as well as data from nearby monitoring stations operated by Environment Canada as part of the NAPS network.

2.4.1 Criteria Air Contaminants (Other Than Particulate Matter)

For criteria contaminants other than particulate matter, the ambient air quality characterization relied on Environment Canada NAPS data from the nearest stations. Apart from SO_2, the baseline characterization relied on data collected at Whitehorse, about 200 km from the FMC. Ambient SO_2 was not measured at Whitehorse; therefore, the FMC characterization used data collected at Norman Wells, NWT, approximately 460 km from the FMC, which is the nearest NAPS station measuring SO_2. Although Norman Wells is a significant distance from the FMC, the nature and quantities of SO_2 emissions near the monitor were deemed similar to those expected for the FMC; therefore, these data were used as an SO_2 concentration indicator.

The NAPS network was established in 1969 as a joint program of the federal and provincial governments to monitor and assess ambient air quality in Canadian urban centres. The goal of the NAPS program is to provide accurate and long-term air quality data of a uniform standard across Canada. Air quality data for criteria air pollutants such as SO_2, CO, nitrogen dioxide (NO_2), O_3, and particulate matter are measured at most stations. For smog assessments (ground-level ozone), data for NO_x and volatile organic compounds (VOCs) are being collected at selected stations. Trace contaminants are also monitored at several stations.

NAPS data are validated using automated and manual procedures; data from network agencies are converted to a compatible format and then entered into the NAPS database. Though the NAPS data base is a reliable source for establishing ambient air quality baselines, the monitoring data best indicate pollution levels at sampling sites and may not necessarily represent community-wide air quality. Environment Canada suggests that community-wide comparisons can only be made by using data from all available sampling stations in a region and interpreting them on the basis of specific monitoring site characteristics. The NAPS data are used in this fashion by stating the concentrations from the station along with (1) an accompanying discussion regarding how those values may differ at the FMC and (2) an indication of magnitude of the difference.

The available NAPS hourly monitoring results from Whitehorse and Norman Wells for two recent years (2010 and 2011) for criteria air pollutants (including O_3, SO_2, CO, NO_x, NO_2, and particulate matter with aerodynamic diameter less than 2.5 microns [$PM_{2.5}$]) were downloaded from the NAPS database. In addition, annual mean concentrations for O_3, SO_2, CO, NO_x, NO_2, and $PM_{2.5}$ were obtained from the NAPS database (Environment Canada, 2013).

The Yukon Ambient Air Quality Standards (Yukon Standard) (YG, 2010, and provided in Table 6E-1) were used to select concentration averaging time periods of the applicable air pollutants to establish the ambient air quality baselines for the current air quality analysis. As Yukon does not have a standard for PM_{10}, the BC Ambient Air Quality Objective for PM_{10} was used, as listed in Table 6E-1. These concentrations were also used as background air concentrations in the Air Quality Effects Report (CH2M HILL, 2014).

The United States Environmental Protection Agency (USEPA) provides guidance on which percentile concentrations from a time series of hourly or daily monitored concentrations should be used to characterize ambient air background concentrations when conducting an ambient air quality analysis for permitting purposes. As there is no Canadian guidance available for establishing background concentration from monitoring data sets, the USEPA guidance was followed as a reference. Specifically, maximum, minimum, and average values, as well as 90th, 98th, and 99th percentile values, are presented consistent with that guidance except where noted.

TABLE 6E-1
Yukon Ambient Air Quality Standards
Faro Mine Interim Works

Parameter	Standard (µg/m^3)	Standard (ppm)	Standard (ppbv)
Sulphur Dioxide (SO_2)			
1-hour average			172
24-hour average			57
Annual arithmetic mean			11
Ground Level Ozone (O_3)			
8-hour running average			65
Total Suspended Particulate (TSP)			
24-hour average	120		
Annual geometric mean	60		
Carbon Monoxide (CO)			
1-hour average		13	
8-hour average		5	
Fine Particulate Matter ($PM_{2.5}$)			
24-hour average	30		
Nitrogen Dioxide (NO_2)			
1-hour average			213
24-hour average			106
Annual arithmetic mean			32
Particulate Matter (PM_{10})[a]			
24-hour average	50		

Notes:

[a] BC Ambient Air Quality Objectives

The above standards are the maximum concentrations of pollutants acceptable in ambient air throughout the Yukon Territory. These standards are used in the effects assessment to help determine the significance of emissions from proposed and existing developments.
µg/m^3 = micrograms per cubic metre
ppm = parts per million
ppbv = parts per billion by volume
All ambient air quality measurements have been referenced to standard conditions of 25 degrees Celsius and 101.3 kilopascals.
Source: Yukon Ambient Air Quality Standards, April 22, 2010

2.4.2 Particulate Matter and Metals

For particulate matter other than $PM_{2.5}$ and metals, the characterization of baseline air quality was based on onsite data. The SENES 2008 monitoring program report indicated the program was successfully completed, with data recovery of TSP samples ranging from 54 percent to 77 percent for 8 of the 9 sampling sites (and 24 percent at the "A1" site near the Faro Pit) and data recovery of PM_{10} samples ranged from 39 percent to 69 percent (SENES, 2009).

AECOM (2009) conducted a further QA/QC analysis on the SENES 2008 sampling results, including (1) a gap analysis to assess the representativeness of results with consideration of the weather conditions during the sampling periods and (2) an additional data recovery analysis following the regulatory sampling procedure outlined by British Columbia, Ontario, and the federal government (NAPS).

Based on these previous assessments by AECOM and SENES, although the SENES 2008 monitoring program had limited results, it did provide representative data that may be used as a primary source to establish a representative ambient air quality baseline for particulate matter and metals. Attachment 6E-1 describes the SENES 2008 program.

SECTION 3

Monitoring Results

3.1 NAPS Monitoring Network

3.1.1 Monitoring Stations

Table 6E-2 lists the NAPS stations that were active in 2010 and 2011 and used in the baseline air quality characterization for the FMC site, including stations in Whitehorse and in Norman Wells, NWT. Figure 6E-2 shows the location of the selected NAPS stations relative to the Faro Mine Area.

TABLE 6E-2
NAPS stations in the Yukon and NWT
Faro Mine Interim Works

NAPS ID	Station Name	Type	City	Address	Time Zone	Latitude	Longitude	Elevation (m)
119004[a]	Steele Street	Residential	Whitehorse	410 STEELE STREET, YT	-8	60.71972	-135.059	640
119003	NAPS House	Commercial	Whitehorse	1091 - 1ST AVENUE, YT	-8	60.71861	-135.049	643
129102	Norman Wells	Residential	Norman Wells	#7 Forestry Road, NWT	-7	65.27914	-126.812	60

[a] New station added in October 2011

Source: NAPS Network, http://www.etc-cte.ec.gc.ca/napsdata/Default.aspx, accessed on September 5, 2013

3.1.2 Monitoring Results

Hourly concentrations of criteria air contaminants (with exception of SO_2 and PM_{10}) were monitored at the NAPS stations in Whitehorse. Monitoring data from 2010 and 2011 from the NAPS stations in Table 6E-2 were compiled and reviewed and the statistical summary results are provided in Table 6E-3. Please note that NO_x monitoring data were only available for 2011 at station 119004 in Whitehorse.

SO_2 was not monitored at either Yukon NAPS station or in historical ambient air quality monitoring programs conducted onsite, and therefore the monitoring results from the nearest NAPS Station that measured SO_2 (located in Norman Wells, NWT) were used as an ambient concentration representative of the FMC site.

The 2010 and 2011 monitoring results were generally consistent with one another, with only a small variation. The average of the two years of data was used to establish FMC site baseline concentrations. Table 6E-3 shows the contaminants that were used to characterize the baseline concentrations and the station where they were measured (for instance CO concentrations from the Norman Wells station are not shown since the baseline is from the Whitehorse station, which is considered more representative of the FMC).

TABLE 6E-3
NAPS Ambient Air Quality Monitoring Data
Faro Mine Interim Works

Contaminant	Averaging Time	Maximum	Mean	99th percentile	98th percentile	90th percentile	Station ID	Available Data Year	Data percent Complete
NOx (ppb)	1-hour	43		35	31	20	119004	2011	26%
	24-hour	29		26	24	16	119004	2011	25%
	Annual		12.4[a]				119004	2011	26%

TABLE 6E-3
NAPS Ambient Air Quality Monitoring Data
Faro Mine Interim Works

Contaminant	Averaging Time	Maximum	Mean	99th percentile	98th percentile	90th percentile	Station ID	Available Data Year	Data percent Complete
CO (ppm)	1-hour	1.2		0.7	0.6	0.5	119003	2011	51%
		1.1		0.8	0.8	0.7		2010	41%
	8-hour	0.8		0.6	0.6	0.5	119003	2011	51%
		0.8		0.8	0.8	0.7		2010	41%
CO (ppm)	1-hour	2.4		1.5	1.3	1	119004	2011	26%
	8-hour	1.9		1.5	1.3	1	119004	2011	25%
$PM_{2.5}$	24-hour	17		9	7	5	119003	2011	90%
(TEOM)		10		8	7	4		2010	100%
($\mu g/m^3$)	annual		2[a]				119003	2011	89%
			2					2010	99%
SO_2 (ppb)	1-hour	2		1	1	1	129102	2011	83%
		2		2	2	1		2010	92%
	24-hour	1		1	1	1	129102	2011	86%
		2		2	2	1		2010	95%
	Annual		0[a]				129102	2011	83%
			0					2010	92%
O_3 (ppb)	8-hour	49		47	46	41	11903	2011	40%
		49		47	46	42		2010	41%
	8-hour	39		36	35	34	11904	2011	26%

[a] Average hourly concentration over available data
Source: NAPS Network, http://www.etc-cte.ec.gc.ca/napsdata/Default.aspx, accessed on September 5, 2013
Notes:
TEOM = Tapered Element Oscillating Microbalance

3.2 Baseline Air Quality Monitoring at Faro Mine

3.2.1 Description of the Monitoring Program

Samples of TSP and respirable PM_{10} were collected by SENES at nine sites in 2008. Eight sites were located on the FMC site and one site was located in the Town of Faro. The locations of the eight environmental effects air monitoring stations at FMC were distributed widely among the three main areas, the Faro Mine Area, the Vangorda/Grum Area, and the Tailings Area.

Five sampling sites were established in the vicinity of the Faro Mine and Tailings areas. Three sampling sites were located in the vicinity of the Vangorda/Grum Area. One site was located in the Town of Faro. Each of these three regions is separated by a minimum of 8 km. The locations of the sampling sites are presented in Figure 6E-3 and described in Table 6E-4.

The monitoring program consisted of thirteen 24-hour sampling periods in July, August, September, and October 2008. The ambient air monitoring program was designed to measure particulate matter and 30 metals contained in the particulate matter.

TABLE 6E-4
Onsite Ambient Air Quality Monitoring Sites
Faro Mine Interim Works

Station	Location	Description
TL1	South of Intermediate Tailings area	Located south of the Intermediate Impoundment, near the unpaved road between the tailings area and Rose Creek, where trace metals concentrations were expected to be elevated.
TL2	South of Intermediate Dam	Located south of the Intermediate Impoundment, near the Intermediate Dam and the unpaved road between the Tailings Area and Rose Creek, where trace metals concentrations were expected to be elevated.
TL3	Mill Area Road	Located southwest of the Mill area, west of the emergency tailing area on a slope beside the main road to the mine administration buildings.
RC1	Rose Creek	Located northwest of the Cross Valley Pond and Existing Emergency Spillways, near Rose Creek, where previous soil sampling indicated the potential for transport of trace metals (Gartner Lee Limited, 2006).
A1	Northwest of Faro Pit	Located northwest of the Faro Pit. The site is beside a road that is no longer in use, in the creek hollow beside an area of exposed soil, and would thus be subject to some potential fugitive dust from the west and southwest.
VG1	Northwest of Ore Transfer Pad and Grum Pit	Located northwest of the Grum Pit beside the Ore Transfer Pad.
VG2	Northwest of Ore Transfer Pad and Grum Pit	Located on the breach dam beside the effluent discharge pond between the Vangorda and Grum pits.
G1	Northwest of Ore Transfer Pad and Grum Pit	Located above and to the east of the Vangorda Pit along a road reported to be used by one family in the Town of Faro, for traditional purposes.

Source: Table 1.2-4, AECOM, 2009

3.2.2 Monitoring Results

A summary of the sampling results for TSP, PM_{10}, and metals (contained in particulate) concentrations are presented in Table 6E-5. Results are grouped into three areas: the Faro Mine and Tailings Area, the Grum and Vangorda Area, and the Town of Faro.

TABLE 6E-5
Summary of Ambient Air Quality Results for Particulate Matter and Metals
Faro Mine Interim Works

Parameter	Sampling Area	Sampling Sites Included	24-hour max (µg/m³)	24-hour average (µg/m³)	24-hour 99th percentile (µg/m³)	24-hour 75th percentile (µg/m³)
TSP	TSP-all site	All nine sites	95.5	12.6	75.6	11.7
	Faro Mine and Tailings Areas	TL1, TL2, TL-3 RC1,A1	70.6	11.3	56.7	11.4
	Vangorda/Grum Area	V01, V02, G1	95.5	14.6	78.5	13.9
	Town of Faro	FA1	17.2	10.8	16.9	10.7
PM_{10}	PM_{10}-all site	All nine sites	19.3	6.6	17.3	7.1
	Faro Mine and Tailings Areas	TL1, TL2, TL-3 RC1,A1	17.3	6.5	15.6	6.3
	Vangorda/Grum Area	V01, V02, G1	19.3	6.6	17.4	7.6

TABLE 6E-5
Summary of Ambient Air Quality Results for Particulate Matter and Metals
Faro Mine Interim Works

Parameter	Sampling Area	Sampling Sites Included	24-hour max (µg/m³)	24-hour average (µg/m³)	24-hour 99th percentile (µg/m³)	24-hour 75th percentile (µg/m³)
	Town of Faro	FA1	12.1	7.4	12.0	10.0
Aluminum	All site	All nine sites	6.59E-01	5.92E-02	4.90E-01	5.64E-02
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**6.59E-01**	5.72E-02	4.67E-01	5.30E-02
	Vangorda/Grum Area	V01, V02, G1	5.61E-01	6.20E-02	4.09E-01	5.62E-02
	Town of Faro	FA1	1.34E-01	6.07E-02	1.29E-01	7.24E-02
Antimony	All site	All nine sites	MDL	MDL	MDL	MDL
Arsenic	All site	All nine sites	4.92E-03	1.74E-03	4.67E-03	2.38E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**4.92E-03**	1.71E-03	4.73E-03	2.31E-03
	Vangorda/Grum Area	V01, V02, G1	3.39E-03	1.75E-03	3.32E-03	2.46E-03
	Town of Faro	FA1	2.97E-03	1.96E-03	2.97E-03	2.63E-03
Barium	All site	All nine sites	4.56E-02	3.74E-03	3.76E-02	3.63E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**4.56E-02**	4.08E-03	4.13E-02	3.53E-03
	Vangorda/Grum Area	V01, V02, G1	2.76E-02	3.12E-03	2.05E-02	3.03E-03
	Town of Faro	FA1	1.75E-02	4.50E-03	1.64E-02	5.32E-03
Beryllium	All site	All nine sites	MDL	MDL	MDL	MDL
Boron	All site	All nine sites	MDL	MDL	MDL	MDL
Cadmium	All site	All nine sites	2.46E-03	2.15E-04	1.70E-03	2.50E-04
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**2.46E-03**	2.31E-04	1.80E-03	2.43E-04
	Vangorda/Grum Area	V01, V02, G1	1.70E-03	1.99E-04	1.06E-03	2.51E-04
	Town of Faro	FA1	5.00E-04	1.77E-04	4.90E-04	1.76E-04
Calcium	All site	All nine sites	9.75E-01	1.27E-01	6.30E-01	1.44E-01
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**9.75E-01**	1.28E-01	6.59E-01	1.37E-01
	Vangorda/Grum Area	V01, V02, G1	6.51E-01	1.22E-01	4.71E-01	1.49E-01
	Town of Faro	FA1	2.25E-01	1.52E-01	2.25E-01	2.01E-01
Chromium	All site	All nine sites	2.61E-01	7.09E-02	1.26E-01	7.74E-02
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	1.27E-01	7.10E-02	1.26E-01	7.62E-02
	Vangorda/Grum Area	V01, V02, G1	**2.61E-01**	7.14E-02	1.75E-01	7.88E-02
	Town of Faro	FA1	8.55E-02	6.76E-02	8.50E-02	7.44E-02
Cobalt	All site	All nine sites	MDL	MDL	MDL	MDL
Copper	All site	All nine sites	4.77E-01	7.66E-03	7.82E-02	3.60E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**4.77E-01**	1.07E-02	1.50E-01	3.60E-03

TABLE 6E-5
Summary of Ambient Air Quality Results for Particulate Matter and Metals
Faro Mine Interim Works

Parameter	Sampling Area	Sampling Sites Included	24-hour max (µg/m³)	24-hour average (µg/m³)	24-hour 99th percentile (µg/m³)	24-hour 75th percentile (µg/m³)
	Vangorda/Grum Area	V01, V02, G1	6.04E-02	3.85E-03	3.37E-02	3.55E-03
	Town of Faro	FA1	1.51E-02	4.29E-03	1.45E-02	5.85E-03
Iron	All site	All nine sites	1.39E+00	1.43E-01	1.10E+00	1.45E-01
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**1.39E+00**	1.48E-01	1.09E+00	1.37E-01
	Vangorda/Grum Area	V01, V02, G1	1.18E+00	1.36E-01	8.87E-01	1.36E-01
	Town of Faro	FA1	2.89E-01	1.48E-01	2.88E-01	2.05E-01
Lead	All site	All nine sites	8.39E-02	3.93E-03	5.93E-02	2.80E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**8.39E-02**	5.27E-03	7.49E-02	2.90E-03
	Vangorda/Grum Area	V01, V02, G1	2.38E-02	2.37E-03	1.68E-02	2.48E-03
	Town of Faro	FA1	5.40E-03	1.95E-03	5.28E-03	3.10E-03
Magnesium	All site	All nine sites	6.26E-01	5.48E-02	4.89E-01	3.68E-02
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	4.94E-01	4.77E-02	4.28E-01	3.19E-02
	Vangorda/Grum Area	V01, V02, G1	**6.26E-01**	6.70E-02	5.41E-01	3.74E-02
	Town of Faro	FA1	8.60E-02	4.33E-02	8.36E-02	4.98E-02
Manganese	All site	All nine sites	2.10E-02	2.03E-03	1.64E-02	2.00E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**2.10E-02**	1.95E-03	1.70E-02	1.95E-03
	Vangorda/Grum Area	V01, V02, G1	1.63E-02	2.10E-03	1.35E-02	2.00E-03
	Town of Faro	FA1	6.10E-03	2.30E-03	5.99E-03	3.50E-03
Molybdenum	All site	All nine sites	1.10E-03	3.16E-04	6.17E-04	3.00E-04
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**1.10E-03**	3.16E-04	4.84E-04	3.00E-04
	Vangorda/Grum Area	V01, V02, G1	8.00E-04	3.18E-04	6.17E-04	3.00E-04
	Town of Faro	FA1	4.00E-04	3.09E-04	3.90E-04	3.00E-04
Nickel	All site	All nine sites	8.50E-03	1.58E-03	5.43E-03	2.48E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**8.50E-03**	1.58E-03	6.12E-03	2.40E-03
	Vangorda/Grum Area	V01, V02, G1	5.20E-03	1.54E-03	5.02E-03	2.35E-03
	Town of Faro	FA1	4.80E-03	1.82E-03	4.66E-03	3.10E-03
Phosphorus	All site	All nine sites	1.71E-01	1.09E-01	1.56E-01	1.24E-01
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**1.71E-01**	1.08E-01	1.57E-01	1.22E-01
	Vangorda/Grum Area	V01, V02, G1	1.56E-01	1.10E-01	1.50E-01	1.25E-01
	Town of Faro	FA1	1.25E-01	1.05E-01	1.25E-01	1.18E-01
Potassium	All site	All nine sites	4.39E-01	7.82E-02	1.74E-01	7.77E-02
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**4.39E-01**	7.99E-02	2.05E-01	7.76E-02

TABLE 6E-5
Summary of Ambient Air Quality Results for Particulate Matter and Metals
Faro Mine Interim Works

Parameter	Sampling Area	Sampling Sites Included	24-hour max (µg/m³)	24-hour average (µg/m³)	24-hour 99th percentile (µg/m³)	24-hour 75th percentile (µg/m³)
	Vangorda/Grum Area	V01, V02, G1	1.75E-01	7.50E-02	1.68E-01	7.40E-02
	Town of Faro	FA1	1.49E-01	8.22E-02	1.47E-01	9.93E-02
Selenium	All site	All nine sites	MDL	MDL	MDL	MDL
Silver	All site	All nine sites	9.00E-04	2.16E-04	6.39E-04	2.00E-04
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	4.00E-04	1.98E-04	2.24E-04	2.00E-04
	Vangorda/Grum Area	V01, V02, G1	7.00E-04	2.31E-04	6.39E-04	2.00E-04
	Town of Faro	FA1	**9.00E-04**	2.73E-04	8.50E-04	2.00E-04
Sodium	All site	All nine sites	9.42E+00	2.25E+00	8.81E+00	5.95E+00
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	8.64E+00	2.13E+00	8.59E+00	6.09E+00
	Vangorda/Grum Area	V01, V02, G1	**9.42E+00**	2.44E+00	9.07E+00	5.64E+00
	Town of Faro	FA1	7.67E+00	2.09E+00	7.66E+00	3.61E+00
Strontium	All site	All nine sites	4.20E-03	7.02E-04	2.99E-03	6.00E-04
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**4.20E-03**	7.22E-04	2.97E-03	6.00E-04
	Vangorda/Grum Area	V01, V02, G1	3.30E-03	6.89E-04	2.08E-03	6.00E-04
	Town of Faro	FA1	7.00E-04	6.18E-04	7.00E-04	6.00E-04
Tellurium	All site	All nine sites	MDL	MDL	MDL	MDL
Thallium	All site	All nine sites	9.00E-04	1.10E-04	3.39E-04	1.00E-04
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	4.00E-04	1.08E-04	3.12E-04	1.00E-04
	Vangorda/Grum Area	V01, V02, G1	**9.00E-04**	1.15E-04	4.73E-04	1.00E-04
	Town of Faro	FA1	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Tin	All site	All nine sites	1.48E-02	1.63E-03	1.08E-02	1.68E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**1.48E-02**	1.54E-03	1.01E-02	1.60E-03
	Vangorda/Grum Area	V01, V02, G1	1.08E-02	1.64E-03	8.36E-03	1.85E-03
	Town of Faro	FA1	1.08E-02	2.25E-03	1.01E-02	2.55E-03
Titanium	All site	All nine sites	2.71E-02	5.60E-03	2.01E-02	5.70E-03
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**2.71E-02**	5.59E-03	2.11E-02	5.50E-03
	Vangorda/Grum Area	V01, V02, G1	2.00E-02	5.60E-03	1.99E-02	5.78E-03
	Town of Faro	FA1	7.70E-03	5.76E-03	7.68E-03	6.65E-03
Vanadium	All site	All nine sites	MDL	MDL	MDL	MDL
Zinc	All site	All nine sites	1.01E-01	1.12E-02	8.51E-02	1.28E-02
	Faro Mine Area	TL1, TL2, TL-3 RC1,A1	**1.01E-01**	1.11E-02	9.37E-02	1.13E-02
	Vangorda/Grum Area	V01, V02, G1	8.02E-02	1.13E-02	5.67E-02	1.51E-02

TABLE 6E-5
Summary of Ambient Air Quality Results for Particulate Matter and Metals
Faro Mine Interim Works

Parameter	Sampling Area	Sampling Sites Included	24-hour max (µg/m³)	24-hour average (µg/m³)	24-hour 99th percentile (µg/m³)	24-hour 75th percentile (µg/m³)
	Town of Faro	FA1	3.39E-02	1.12E-02	3.24E-02	1.24E-02
Zirconium	All site	All nine sites	MDL	MDL	MDL	MDL

Source: Tables 1.2-5 and 1.2-6 (AECOM, 2009)
Notes:
For each parameter, the maximum concentration is in red to highlight the measurement area in which it occurred.
MDL = below Method Detection Limit (MDL) for > 98% of samples.

3.2.3 Analysis of Data Recovery

The acceptability of data recovery for the 2008 air monitoring program was assessed by SENES (2009) and a further analysis by AECOM (2009) using the following sampling procedures:

- British Columbia Field Sampling Manual, HiVol Particulate Sampling Procedure (BC MOE, 2003)
- British Columbia Air Monitoring Guidelines: Volume 1 Particulate Non-Continuous (BC MOE, 1996)
- British Columbia Environmental Laboratory Manual (BC MOE, 2009)
- Operations Manual for Air Quality Monitoring in Ontario (MOE, 2005)
- NAPS network schedule (Environment Canada and Health Canada, 1998, “National Ambient Air Quality Objectives for Particulate Matter”)

SENES concluded that there was a low data recovery rate that may have been as a result of technical issues during the original field surveys and monitoring data periods. The lower data recovery ratio than what is typical of best practices suggested a level of uncertainty in the monitored data. However, despite the data quality issues and concerns, the data do provide an indication of the ambient air quality in the area. As the best available local monitoring data, they were used as primary sources of baseline ambient air pollutant concentrations for this analysis.

3.3 Ambient Air Quality Summary

To select the most representative values for background ambient air concentrations, USEPA guidance for National Ambient Air Quality Standards (NAAQS) compliance was used as a reference for criteria air contaminants. This guidance indicates what percentile concentrations should be used from an ambient air dataset in order to characterize a background value for each contaminant and averaging period. Table 6E-6 summarizes the baseline concentration estimates of criteria air pollutants in the project area. The concentrations shown are consistent with the form of the USEPA standards for each of the Criteria Air Contaminants monitored at NAPS. A 75th percentile of the 24-hour average concentrations of TSP and PM_{10} from the FMC site monitoring program were used as an ambient background concentration for those contaminants. For metals, the maximum observed 24-hour concentration from all nine onsite stations was conservatively used to represent the ambient background of the FMC site.

TABLE 6E-6
Summary of Ambient Air Quality Monitoring Data for the FMC Site Region
Faro Mine Interim Works

Contaminant	Averaging Time	Monitoring Results	Data Description	Station ID	Data Source	AAQS	AAQS Sources
NOx	1-hour	31 (ppb)	98th percentile of 1-hour averages	119004 - Whitehorse	NAPS	213 (ppbv)	Yukon AAQS
	24-hour	26 (ppb)	99th percentile of 24-hour averages			106 (ppbv)	Yukon AAQS
	Annual	12.4 (ppb)	Annual average for the monitoring period			32 (ppbv)	Yukon AAQS
CO	1-hour	1.1 (ppm)	High 2nd high of 1-hour averages	119003 - Whitehorse	NAPS	13 (ppm)	Yukon AAQS
	8-hour	0.8 (ppm)	High 2nd high of rolling 8-hour averages			5 (ppm)	Yukon AAQS
$PM_{2.5}$ (TEOM)	24-hour	7 ($\mu g/m^3$)	98th percentile of 24-hour averages	119003 - Whitehorse	NAPS	30 ($\mu g/m^3$)	Yukon AAQS
	annual	2 ($\mu g/m^3$)	Annual mean				
PM_{10}	24-hour	7.1 ($\mu g/m^3$)	75th percentile of 24-hour averages	All 9 Onsite Stations	SENES 2008	50 ($\mu g/m^3$)[a]	BC AAQO
TSP	24-hour	11.7 ($\mu g/m^3$)	75th percentile of 24-hour averages	All 9 Onsite Stations	SENES 2008	120 ($\mu g/m^3$)	Yukon AAQS
SO_2	1-hour	1.5 (ppb)	99th percentile of 1-hour daily maximum averages	129102 Normal Wells	NAPS	172 (ppbv)	Yukon AAQS
	24-hour	1 (ppb)	High 2nd high of 24-hour averages	129102 Norman Wells	NAPS	57 (ppbv)	Yukon AAQS
	annual	0 (ppb)	Annual mean	129102 Norman Wells	NAPS	11 (ppbv)	Yukon AAQS
O_3	8-hour	47 (ppb)	Annual 4th-highest daily maximum 8-hour average	119003 Whitehorse	NAPS	65 (ppbv)	Yukon AAQS
Antimony	24-hour	MDL	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	25 ($\mu g/m^3$)	Ontario Standard [b]
Arsenic	24-hour	0.0049 ($\mu g/m^3$)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	5 ($\mu g/m^3$)	Ontario Standard
Barium	24-hour	0.046 ($\mu g/m^3$)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	10 ($\mu g/m^3$)	Ontario Guideline [b]
Beryllium	24-hour	MDL	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	0.01 ($\mu g/m^3$)	Ontario Standard
Boron	24-hour	MDL	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	120 ($\mu g/m^3$)	Ontario Standard
Cadmium	24-hour	0.0025 ($\mu g/m^3$)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	0.025 ($\mu g/m^3$)	Ontario Standard
Chromium	24-hour	0.26 ($\mu g/m^3$)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	1.5 ($\mu g/m^3$)	Ontario Guideline

TABLE 6E-6
Summary of Ambient Air Quality Monitoring Data for the FMC Site Region
Faro Mine Interim Works

Contaminant	Averaging Time	Monitoring Results	Data Description	Station ID	Data Source	AAQS	AAQS Sources
Cobalt	24-hour	MDL	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	0.1 (µg/m^3)	Ontario Guideline
Copper	24-hour	0.48 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	50 (µg/m^3)	Ontario Standard
Iron	24-hour	1.39 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	4 (µg/m^3)	Ontario Standard
Lead	24-hour	0.084 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	0.5 (µg/m^3)	Ontario Standard
Manganese	24-hour	0.021 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	2.5 (µg/m^3)	Ontario Guideline
Molybdenum	24-hour	0.0011 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	120 (µg/m^3)	Ontario Guideline
Nickel	24-hour	0.009 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	2 (µg/m^3)	Ontario Standard
Selenium	24-hour	MDL	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	10 (µg/m^3)	Ontario Guideline
Silver	24-hour	0.0009 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	1 (µg/m^3)	Ontario Standard
Strontium	24-hour	0.0042 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	120 (µg/m^3)	Ontario Guideline
Tellurium	24-hour	MDL	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	10 (µg/m^3)	Ontario Standard
Tin	24-hour	0.015 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	10 (µg/m^3)	Ontario Standard
Titanium	24-hour	0.027 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	120 (µg/m^3)	Ontario Standard
Vanadium	24-hour	MDL	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	2 (µg/m^3)	Ontario Standard
Zinc	24-hour	0.1 (µg/m^3)	Maximum Observed 24-hour concentration	All 9 onsite stations	SENES 2008	120 (µg/m^3)	Ontario Standard

Notes:

AAQO = ambient air quality objectives
AAQS = ambient air quality standards
MDL = below Method Detection Limit for > 98% of samples.

SECTION 4

Baseline Ambient Air Quality

Table 6E-7 summarizes the available monitoring data used to represent baseline air quality concentrations of criteria air contaminants and ozone in the study area. The table also shows the Yukon Standard and BC Ambient Air Quality Objectives for applicable contaminants.

Table 6E-8 summarizes the available monitoring data used to represent baseline ambient air quality concentrations for metals. As the Yukon Standard does not include ambient standards for metals, and neither BC nor Alberta has a 24-hour average metal standard or objective, the table provides Ontario Ministry of the Environment (MOE) 24-hour standards or guidelines for metals for comparison. These also help to gauge the magnitude of the concentrations.

Data for many of the contaminants in Table 6E-8 (except PM_{10} and TSP) were derived from the nearest NAPS stations, which were 200 km and 460 km from the site for the Whitehorse and Normal Wells stations, respectively. These stations are in residential or light industrial areas, where there may have been significant anthropogenic contributions to the measured concentrations from sources such as residential wood burning, and combustion gases from nearby traffic arteries and mobile vehicles and equipment. Also, Whitehorse is subject to occasional elevated smog concentrations because of winter inversions, leading to higher concentrations of $PM_{2.5}$, ozone, and nitrogen oxides than would be expected at the FMC site. However, baseline Faro ambient air measurements would be expected to capture emissions from vehicular traffic (tailpipe and road dust re-suspension) and combustion products from heavy equipment, power generation, and heating systems for on-going care and maintenance activities at the FMC site. Therefore, although contaminants other than TSP, PM_{10}, and metals were not measured at the FMC site, conservative estimates can be obtained from NAPS stations where sources that influence the ambient concentrations are likely to be similar in nature and magnitude.

The criteria contaminant concentrations from the NAPS stations are likely higher than those at the FMC site. This is because anthropogenic influence and occasional meteorological effects are more likely to affect measured concentrations in the NAPS station areas than at the FMC site. However, as mentioned, these concentrations are useful for estimating concentration indicators, given the lack of ambient measurements in the FMC site area.

The *Air Quality Effects Report, Faro Mine Interim Works* (CH2M HILL, 2014) quantified the potential effects of IW activities by estimating emissions from those activities and using a comprehensive air dispersion model to estimate the effects. These effects were then added to the background concentrations as determined in this report to determine the effects of IW activities on regional air quality levels. The conservative nature of the background concentrations is expected to lead to conservative conclusions regarding the effects of IW activities on regional air quality.

TABLE 6E-7
Proposed Ambient Air Quality Baseline Levels – Criteria Air Contaminants
Faro Mine Interim Works

Contaminant	Averaging Time	Baseline Concentration	Yukon AAQS
NOx	1-hour	31 (ppb)	213 (ppbv)
	24-hour	26 (ppb)	106 (ppbv)
	Annual	12.4 (ppb)	32 (ppbv)
CO	1-hour	1.1 (ppm)	13 (ppm)
	8-hour	0.8 (ppm)	5 (ppm)
$PM_{2.5}$ (TEOM)	24-hour	7 ($\mu g/m^3$)	30 ($\mu g/m^3$)
PM_{10}	24-hour	7.1 (µg/m3)	50 ($\mu g/m^3$)[a]

TABLE 6E-7
Proposed Ambient Air Quality Baseline Levels – Criteria Air Contaminants
Faro Mine Interim Works

TSP	24-hour	11.7 (µg/m^3)	120 (µg/m^3)
SO_2	1-hour	1.5 (ppb)	172 (ppbv)
	24-hour	1 (ppb)	57 (ppbv)
	annual	0.00 (ppb)	11 (ppbv)
O_3	8-hour	47 (ppb)	65 (ppbv)

Notes:
ppbv = parts per billion, volumetric
[a]: BC Ambient Air Quality Objectives

TABLE 6E-8
Proposed Ambient Air Quality Baseline Levels – Metals Contained in Particulate Matter
Faro Mine Interim Works

Element	Baseline Concentration 24-hour Average (µg/m^3)	AAQC[a] 24-hour Average (µg/m^3)	Jurisdiction
Antimony	MDL	25	Ontario Standard
Arsenic	0.0049	5	Ontario Standard
Barium	0.046	10	Ontario Guideline
Beryllium	MDL	0.01	Ontario Standard
Boron	MDL	120	Ontario Standard
Cadmium	0.0025	0.025	Ontario Standard
Chromium	0.26	1.5	Ontario Guideline
Cobalt	MDL	0.1	Ontario Guideline
Copper	0.48	50	Ontario Standard
Iron	1.39	4	Ontario Standard
Lead	0.084	0.5	Ontario Standard
Manganese	0.021	2.5	Ontario Guideline
Molybdenum	0.0011	120	Ontario Guideline
Nickel	0.009	2	Ontario Standard
Selenium	MDL	10	Ontario Guideline
Silver	0.0009	1	Ontario Standard
Strontium	0.0042	120	Ontario Guideline
Tellurium	MDL	10	Ontario Standard
Tin	0.015	10	Ontario Standard
Titanium	0.027	120	Ontario Standard

TABLE 6E-8
Proposed Ambient Air Quality Baseline Levels – Metals Contained in Particulate Matter
Faro Mine Interim Works

Element	Baseline Concentration 24-hour Average (µg/m^3)	AAQC[a] 24-hour Average (µg/m^3)	Jurisdiction
Vanadium	MDL	2	Ontario Standard
Zinc	0.1	120	Ontario Standard

Sources:

[a] Ontario Summary of Standards and Guidelines to support O. Reg. 419, April 2012

Notes:

µg/m^3 = micrograms per cubic metre

MDL = below Method Detection Limit for >98% of samples.

SECTION 5

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Figures

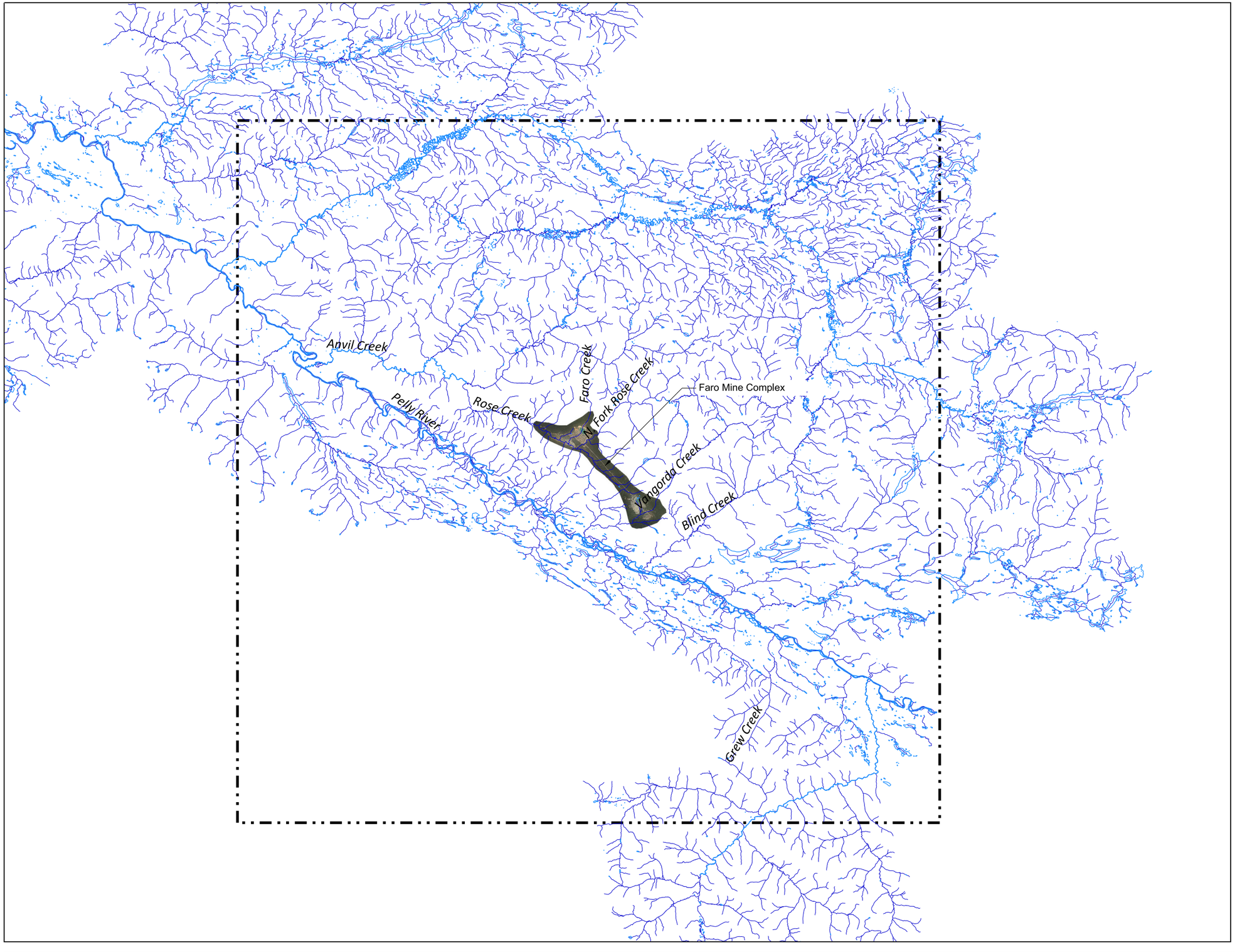


FIGURE 6E-1
Air Quality Study Area
Faro Mine Interim Works



N

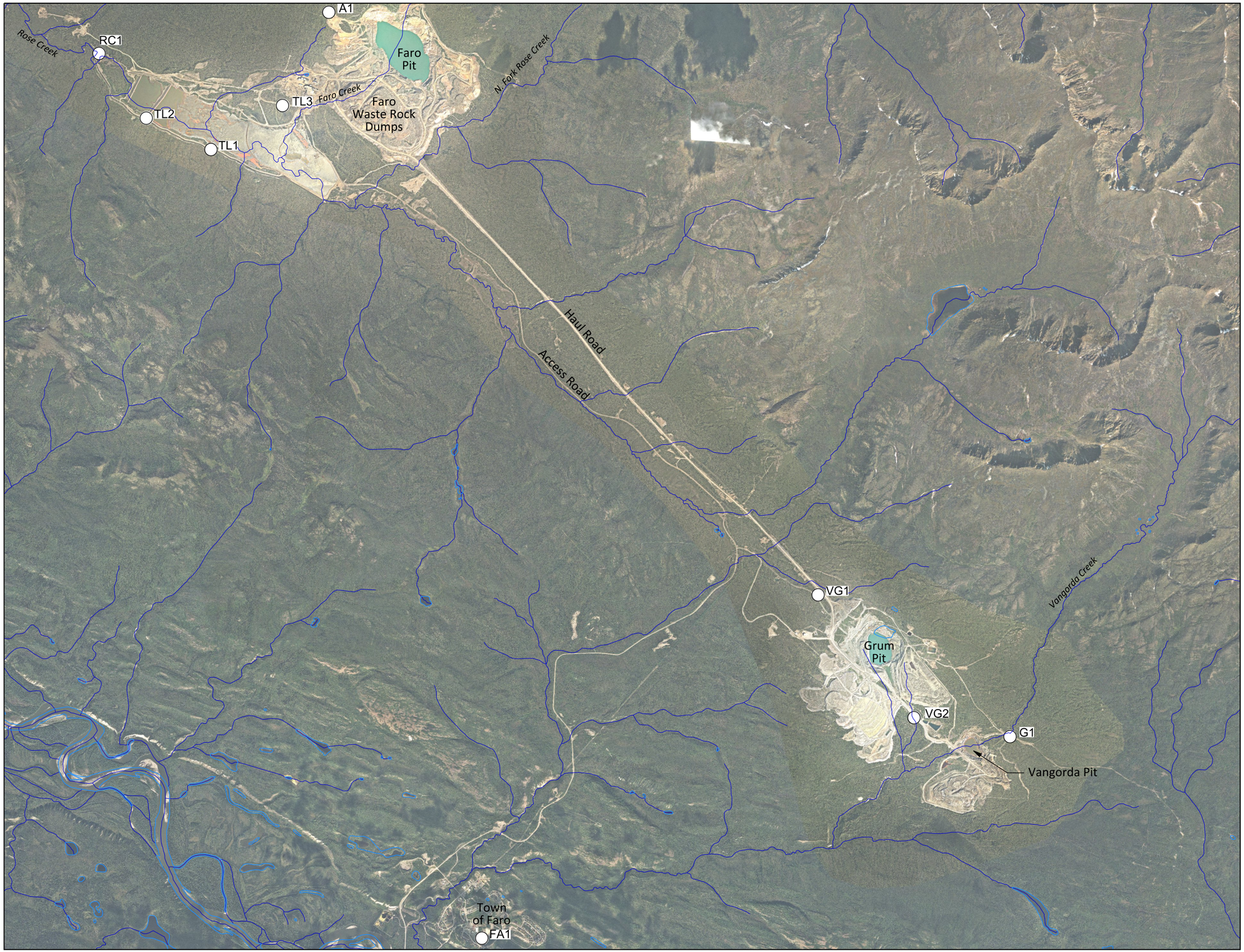
0 100 200

KILOMETRES

NAPs Stations

Faro Mine Complex

FIGURE 6E-2
NAPS Monitoring Stations
used in the Air Quality Baseline Report
Faro Mine Interim Works



N

0 1000 2000

METRES

Air Quality Station

Water Courses

Notes:

1. Air quality monitoring locations from 2008 Baseline Air Quality Monitoring Assessment for Faro Mine Complex, SENES Consultants Limited, January 2009.
2. Aerial photo dated August 2012.

FIGURE 6E-3
Faro Mine Area Air Quality Monitoring Stations
Faro Mine Interim Works

CH2MHILL.

Attachment 6E-1
2008 Baseline Air Quality Monitoring Assessment – SENES Consultants Ltd.

2008 BASELINE AIR QUALITY MONITORING ASSESSMENT

FARO MINE COMPLEX

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24 February 2009

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EXECUTIVE SUMMARY

A baseline air quality monitoring program was conducted at the Faro Mine Complex in the summer of 2008 to establish existing levels of particulate matter and trace heavy metals. A total of nine sampling sites were established in July of 2008 to sample for total suspended particulate (TSP) matter and respirable particulate matter (PM_{10}). Five sites were located in the vicinity of the Faro mine pit and tailings areas, three in the vicinity of the Grum and Vangorda pits, and one site was located in the Town of Faro to provide estimates of background air quality away from the mine site. A dustfall sampling site was also located near the tailings area at the Faro mine site.

TSP and PM_{10} sampling was conducted using battery-operated MiniVol™ samplers during the period July 17th to October 3rd on a 1-in-6 day sampling schedule, for a total of 13 sampling periods (24 hour averages). All TSP and PM_{10} levels were within established ambient air quality objectives defined by Environment Canada or other provincial jurisdictions. The highest and second highest TSP concentrations of 95.5 $\mu g/m^3$ and 70.6 $\mu g/m^3$ were recorded on September 9th near the Grum pit and the Faro mine, respectively. The major elemental constituents of the two TSP samples on that date consisted of aluminium, boron, calcium, chromium, iron, magnesium, phosphorus, potassium and sodium. All other sampling sites had low TSP concentrations (<8 $\mu g/m^3$) on that date. The only other date with TSP concentrations in the range of 35-40 $\mu g/m^3$ occurred on August 4th. One sample was recorded near the Faro mine, while the other two were collected near the Vangorda and Grum pits. The major elemental constituent of one sample was sodium, with smaller concentrations of aluminium, calcium, iron and magnesium in all three samples.

The highest PM_{10} concentration of 24.7 $\mu g/m^3$ was recorded at Rose Creek downwind of the tailings area on July 23rd. All other PM_{10} concentrations were less than 20 $\mu g/m^3$, and there was little difference in PM_{10} concentrations between the mine site and the Town of Faro. The major elemental constituent of the July 23rd sample on Rose Creek was sodium, with smaller quantities of aluminium, calcium, chromium, copper, iron, phosphorus and potassium.

Overall, particulate matter and trace inorganic element concentrations at the Faro Mine Complex were very low, and were often similar to levels recorded in the Town of Faro. Even during the periods with the highest TSP loadings, the composition of the particulate matter was primarily made up of trace elements which either have no ambient air quality criteria or are not of concern for human health exposure. The exception may be chromium which had a relatively high concentration in one sample collected near the Faro pit, but this value is considered anomalous because sample collection did not extend over a full 24-hour period. The 24-hour averaged chromium concentrations in all other samples remained well below any level of concern.

The maximum observed concentrations for inorganic elements with established ambient air quality criteria are listed in Table ES.1 (excluding samples collected near the Faro mine pit which were considered outlier values).

Table ES.1
Comparison of Maximum Observed Elemental Concentrations
And AAQC Values

Element	Maximum Observed Concentration	Sampling Location	PM Size Fraction	Ambient Air Quality Criteria	
	($\mu g/m^3$)			($\mu g/m^3$)	Rationale
Antimony	0.00185	TL1	PM_{10}	25	health
Arsenic	0.00738	TL2	PM_{10}	0.3	health
Barium	0.04565	TL3	TSP	10	health
Beryllium	0.00185	TL1	PM_{10}	0.01	health
Boron	0.09243	TL1	PM_{10}	120	particulate matter
Cadmium	0.00246	RC1	TSP	2	health
Chromium	0.327	TL2	PM_{10}	1.5	health
Cobalt	0.0007	TL3	PM_{10}	0.1	health
Copper	0.477	TL3	TSP	50	health
Iron	1.733	VG2	PM_{10}	4	soiling
Lead	0.0839	TL3	TSP	2	health
Manganese	0.021	TL3	TSP	2.5	health
Molybdenum	0.0011	TL3	TSP	120	particulate matter
Nickel	0.0099	VG1	TSP	2	vegetation
Selenium	0.00185	TL1	PM_{10}	10	health
Silver	0.000896	VG2	TSP	1	health
Strontium	0.00419	TL3	TSP	120	particulate matter
Tellurium	0.00185	TL1	PM_{10}	10	health
Tin	0.0108	VG1	TSP	10	health
Titanium	0.0271	TL3	TSP	120	particulate matter
Vanadium	0.00185	TL1	PM_{10}	2	health
Zinc	0.101	TL3	TSP	120	particulate matter

The total dustfall near the tailings area of the Faro mine was very low, with two of the samples (July and September) having dustfall levels at the method detection limit. The maximum total dustfall deposition rate occurred in August with a rate of 0.12 mg/dm^2.day, although July's rate might have been higher if the sample had been collected over the entire month. This maximum deposition rate is an order of magnitude lower than the dustfall criteria adopted by various provinces in Canada, as well as criteria for new mines in Australia and residential areas of the

United Kingdom and the State of New York. The low dustfall levels are consistent with the generally low particulate matter concentrations observed in the TSP and PM_{10} samples.

With respect to elemental composition, most of the trace inorganic constituents were below the method detection limits for all three dustfall samples. The only contaminants that were observed to be higher than the detection limits included arsenic, barium, cadmium, calcium, copper, iron, lead, manganese, molybdenum, silver, strontium, zinc. With the exception of arsenic and zinc, the remainder of these elements were also noted to have somewhat elevated concentrations relative to the Town of Faro in the TSP and PM_{10} samples. This indicates a reasonable degree of consistency between the TSP/PM_{10} samples and the dustfall samples. The highest concentrations of these 12 constituents in dustfall samples occurred either in July or August. All elemental concentrations in the September dustfall sample were lower than in the previous two sampling periods.

Although there were some difficulties with data recovery in the initial part of the sampling program due to operator error on the part of on-site staff, the overall sampling program was successful in establishing baseline levels of particulate matter and trace inorganic elements. It is recommended that the particulate matter sampling program be continued in 2009 with the following changes:

1. The sampling program should be initiated as soon as possible after the loss of snow cover in late May or early June, depending on site conditions. The continuation of the sampling program to the end of September should be reconsidered, with a termination date in early September at the latest.
2. The same nine sampling sites should be retained for 2009, but the sampling periods should be extended to 48 hours in order to obtain higher particle loadings on the filters.
3. It would be preferable to add at least three additional dustfall sampling sites to the program. These could be established at sites Rose Creek (site RC1), the Faro pit (site A1) and between the Vangorda and Grum pits (site VG2).
4. In order to minimize material loss or damage to the filters during handling, it is recommended that a 'clean' room be identified for this purpose. If this cannot be done at the mine administration building, consideration should be given to finding a location in the Town of Faro for that purpose.

1.0 INTRODUCTION

A baseline air quality monitoring program was conducted at the Faro Mine Complex in the summer of 2008 to establish existing levels of particulate matter and trace heavy metals. The Complex is located near the Town of Faro, Yukon Territory, and is the site of a former lead/zinc mine operated by the Anvil Range Mining Corporation. The mine site is being decommissioned, and the objective of the air quality monitoring program in 2008 was to provide baseline exposure data for worker health and safety prior to the start of remediation activity at the mine.

A total of nine sampling sites were established in July of 2008 to sample for total suspended particulate (TSP) matter and respirable particulate matter (PM_{10}). Five sites were located in the vicinity of the Faro mine pit and tailings areas, three in the vicinity of the Grum and Vangorda pits, and one site was located in the Town of Faro to provide estimates of background air quality away from the mine site.

TSP/PM_{10} sampling was commenced on July 17th and conducted on a 1-in-6 day sampling schedule, consistent with the National Air Pollution Surveillance (NAPS) network sampling schedule operated by Environment Canada, until October 3rd. A total of 13 24-hour averaged TSP/PM_{10} samples were collected during this period. In addition, three dustfall samples were collected at one location near the Faro mine tailings area: a partial sample for the latter half of July and full monthly samples for August and September.

All samples were analysed for total mass, as well as for elemental composition of trace heavy metals and inorganic constituents.

2.0 MONITORING PROGRAM

2.1 SAMPLING LOCATIONS

Figure 2.1 shows the location of the nine TSP/PM_{10} sampling sites at the mine complex. Five sites were established in the Faro Mine area (TL1, TL2, TL3, RC1 and A1). Three sampling sites were located in the vicinity of the Vangorda and Grum mine pits (VG1, VG2 and G1). One site was located in the Town of Faro (FA1) away from the mine complex to provide a measure of background concentrations. The latitude/longitude and UTM coordinates of each site is listed in Table 2.1.

Figure 2.1
TSP/PM_{10} Sampling Locations

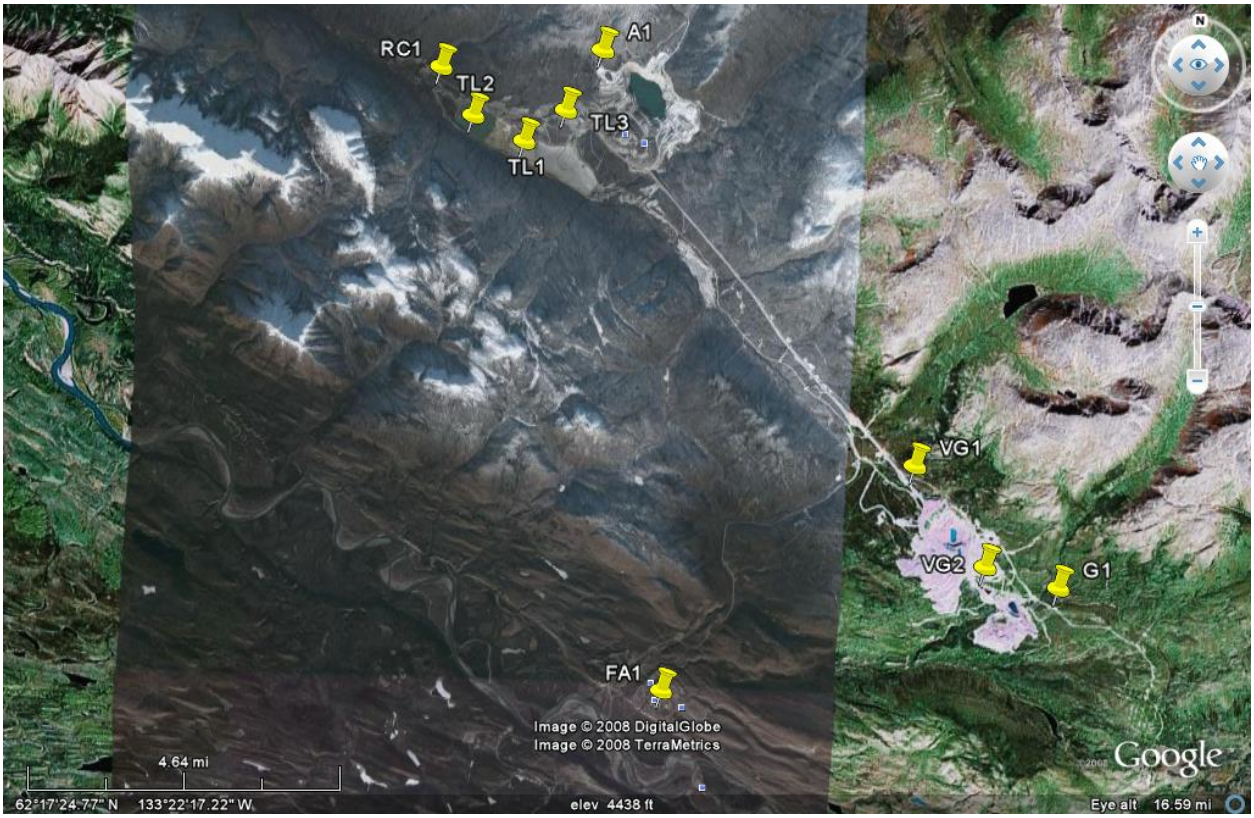


Table 2.1
Sampling Location Coordinates

Site	Latitude N	Longitude W	UTM N (m)	UTM E (m)	Elevation (m)
TL1	62^0 20.566	133^0 25.546	6913359.00	418483.53	1058.6
TL2	62^0 20.866	133^0 26.981	6913886.00	419733.30	1055.5
TL3	62^0 20.973	133^0 24.431	6914124.50	417537.16	1118.9
RC1	62^0 21.474	133^0 27.915	6914980.50	420564.70	1020.2
A1	62^0 21.724	133^0 23.461	6915559.00	415876.30	1293.3
VG1	62^0 16.633	133^0 14.510	6906302.50	408763.66	1282.3
VG2	62^0 15.342	133^0 12.491	6903969.00	406939.25	1178.4
G1	62^0 15.109	133^0 10.478	6903584.00	405196.72	1230.5
FA1	62^0 13.553	133^0 21.185	6900427.50	414383.50	724.8

2.1.1 Faro Mine Site

Figure 2.2 provides an enlarged image of the sampling locations at the Faro mine site. Two sampling sites were located on the southeast side of the tailing area (TL1, TL2) where trace metals concentrations were expected to be elevated. The dustfall sampling site was also located at TL1, along with the meteorological station to record temperature and atmospheric pressure which were used in calculating the TSP/PM_{10} concentrations. Figure 2.3 shows the sampling equipment at TL1, while Figure 2.4 shows the TSP/PM_{10} monitors at TL2. Both Sites are in proximity to the unpaved road running between the tailings areas and Rose Creek.

One sampling site was located at the northwest end of the tailings area beside Rose Creek (RC1) where previous soil sampling had indicate the potential for transport of trace metals along the creek away from the mine complex. The sampling location is shown in Figure 2.5. Although a dirt road runs beside the sampling area, it is seldom used.

One sampling site (TL3) was located below the main mine office complex, between the waste rock dump site to the east and the tailings area. The site is located on the slope beside the main road to the mine administration buildings, and would thus be subject to a fair amount of road dust. The equipment setup at TL3 is depicted in Figure 2.6.

Site A1 is located on the northwest side of the mine pit. The site is beside a road that is no longer in use, in the creek hollow beside an area of exposed soil, and would thus be subject to some potential fugitive dust from the west and southwest. Figure 2.7 shows the equipment set up at the site. The mine pit is located to the left of the samplers in Figure 2.7.

Figure 2.2: Location of Sampling Sites at the Faro Mine Site

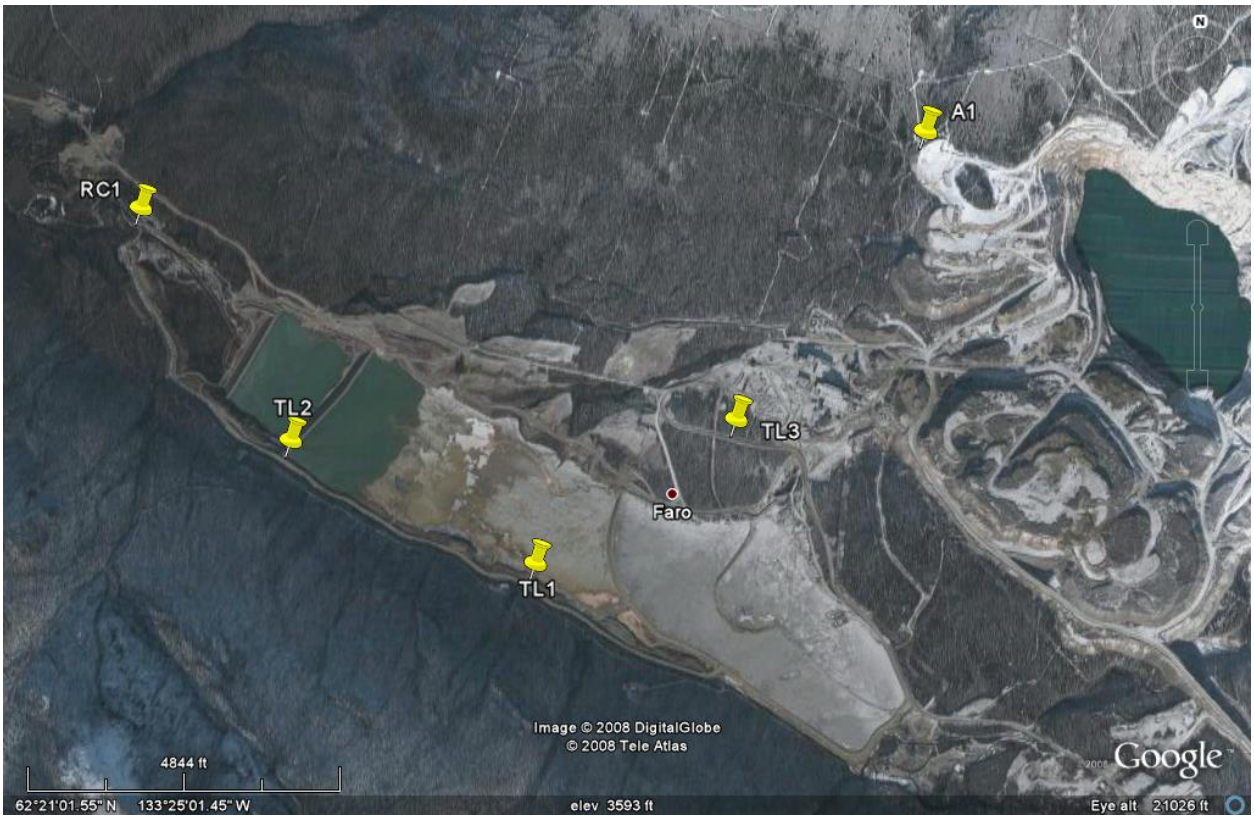


Figure 2.3: TL1 Sampling Site



Figure 2.4: TL2 Sampling Site



Figure 2.5: RC1 Sampling Site



Figure 2.6: TL3 Sampling Site

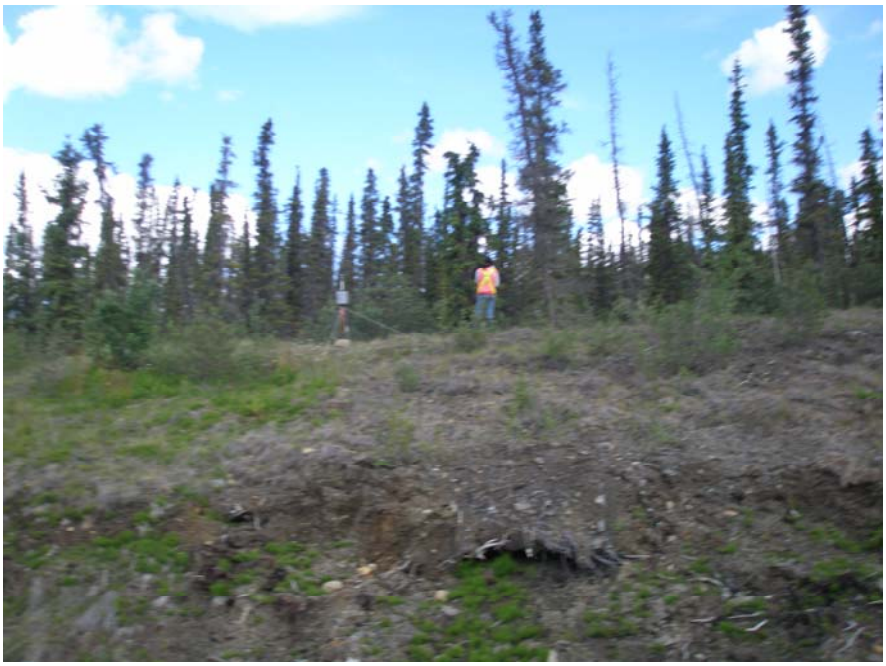


Figure 2.7: A1 Sampling Site



2.1.2 Vangorda and Grum Sites

The three sampling sites near the Vangorda and Grum mine pits were located on the northwest side of the Grum pit (VG1) beside the ore transfer pad, on the breach dam beside the effluent discharge pond between the Vangorda and Grum pits (VG2), and above and to the east of the Vangorda pit (G1) along a road reported to be used by one family in Faro for traditional purposes. All three sites are exposed to fugitive dust from unpaved roads, although VG1 and VG2 would have the greatest potential for exposure to fugitive road dust.

The equipment set up at these three sites is depicted in Figures 2.8, 2.9 and 2.10.

Figure 2.8: VG1 Sampling Site



Figure 2.9: VG2 Sampling Site



Figure 2.10: G1 Sampling Site



2.1.3 Faro Town Site

The background sampling site in the Town of Faro was located on the lawn in front of the medical clinic. The location is depicted in Figure 2.11, while the equipment setup is shown in Figure 2.12. The main source of fugitive dust at this location would be from the unpaved road beside the clinic.

Figure 2.11: Town of Faro Sampling Site

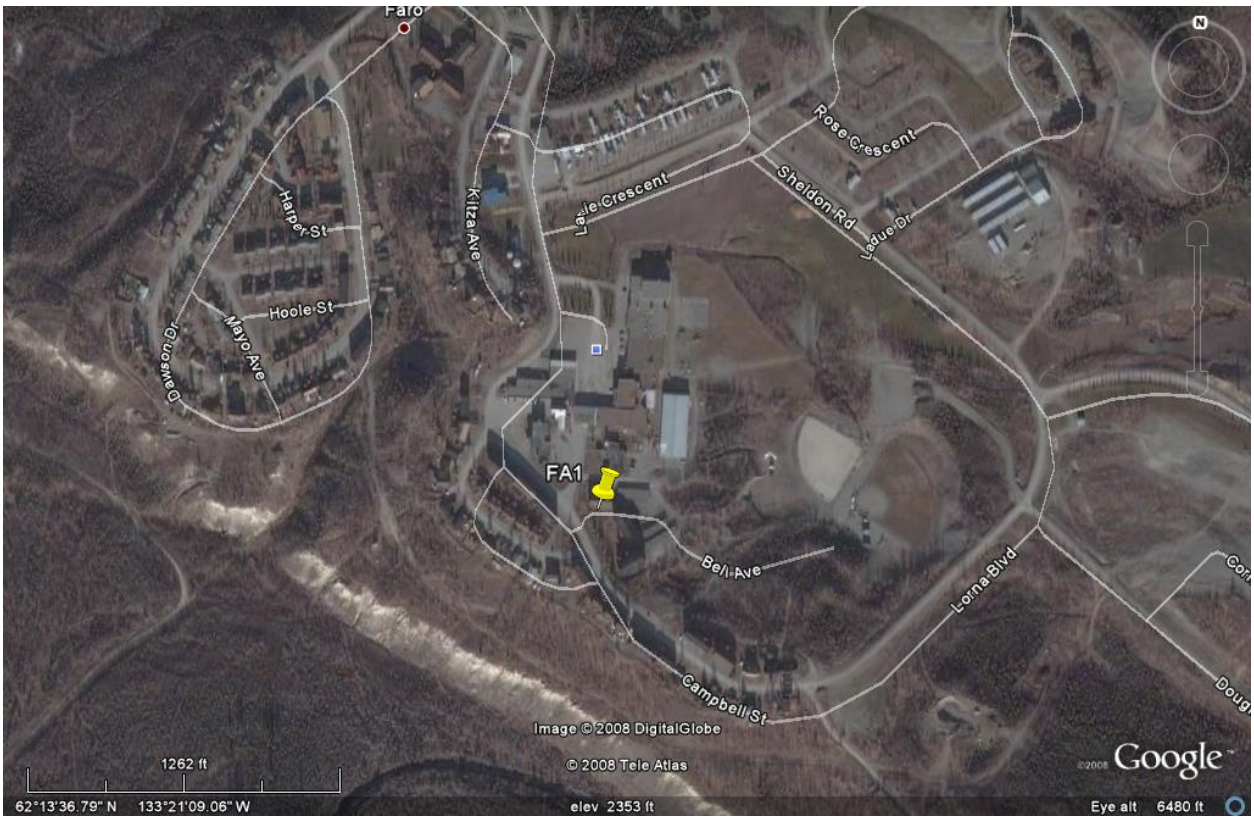


Figure 2.12: FA1 Sampling Site



2.2 SAMPLING METHODOLOGY

2.2.1 TSP/PM_{10} Sampling

The TSP and PM_{10} samples were collected using battery-operated, portable MiniVol™ Tactical Air Samplers (TAS) manufactured by Airmetrics of Eugene, Oregon[1]. The MiniVol™ samplers are designed to operate at a flow rate of 5 litres per minute, and as such provide low volume samples of ambient particulate matter concentrations. While MiniVol™ samplers are not considered a reference sampling method, the mass concentrations derived from MiniVol™ samplers give results that closely agree with reference method concentrations.

Samples were collected on a 1-in-6 day sampling schedule consistent with the National Air Pollution Surveillance (NAPS) particulate matter sampling schedule used by Environment Canada for stations across the country. Appendix A provides details for each set of samples collected during each sampling period.

Samples were collected on 47 mm Teflon filters. Total TSP or PM_{10} concentration was calculated using corrected flow rate (Qact) and the particulate loadings (in mg) on the filters. The following equation to estimate actual flow rate through the filters:

$$Q_{act} = (m_{vol} Q_{ind} + b_{vol}) \times \sqrt{(P_{std}/P_{act}) \times (T_{act}/T_{std})}$$

where

- Q_{act} is the actual flow rate (litres/min)
- Q_{ind} is the rotameter indicated flow rate (litres/min)
- m_{vol} is the slope of the least squares line from the individual sampler calibration report
- b_{vol} is the intercept of the least squares regression line from the individual sampler calibration report
- P_{std} is the standard atmospheric pressure (1013.25 millibars)
- P_{act} is the actual ambient pressure (mbar)
- T_{std} is the standard atmospheric temperature (298^0K)
- T_{act} is the actual ambient temperature (^{0}K)

Total mass of particulate matter on the filters was determined by gravimetric analysis by CANTEST Limited. Elemental composition of the samples was determined by CANTEST using

[1] http://www.airmetrics.com

inductively coupled plasma mass spectrometry (ICP/MS) methods. The method detection limits for the elemental analysis of the filter samples are listed in Table 2.2.

Table 2.2
Method Detection Limits for Trace Inorganic Elemental Analysis in TSP/PM_{10} Samples

Element	Method Detection Limit (MDL) (µg)
Aluminum (Al)-Total	0.025
Antimony (Sb)-Total	0.005
Arsenic (As)-Total	0.005
Barium (Ba)-Total	0.005
Beryllium (Be)-Total	0.005
Boron (B)-Total	0.25
Cadmium (Cd)-Total	0.001
Calcium (Ca)-Total	0.25
Chromium (Cr)-Total	0.005
Cobalt (Co)-Total	0.005
Copper (Cu)-Total	0.005
Iron (Fe)-Total	0.25
Lead (Pb)-Total	0.005
Magnesium (Mg)-Total	0.25
Manganese (Mn)-Total	0.005
Molybdenum (Mo)-Total	0.0025
Nickel (Ni)-Total	0.005
Phosphorus (P)-Total	0.75
Potassium (K)-Total	0.5
Silver (Ag)-Total	0.00125
Sodium (Na)-Total	0.25
Strontium (Sr)-Total	0.005
Tellurium (Te) - Total	0.005
Thallium (Tl)-Total	0.0005
Tin (Sn)-Total	0.005
Titanium (Ti)-Total	0.005
Vanadium (V) - Total	0.005
Zinc (Zn)-Total	0.025
Zirconium (Zr) - Total	0.05

2.2.2 Dustfall Sampling

Two dustfall canisters were established at site TL1 to measure dustfall and the trace inorganic elemental composition of dustfall. Due to concerns about the amount of dustfall that would be present, one canister was used exclusively to analyse for total mass, while the second canister was used to determine chemical composition. Since the sampling program began on July 17th, only a partial month of data was collected for the period July 17th to 31st. Complete monthly samples were collected for both August and September.

The analysis of the dustfall samples was completed by the ASL Laboratory Group using inductively coupled plasma mass spectrometry (ICP/MS) methods as defined by the B.C. Ministry of Environment.

The method detection limits for the analyses are listed in Table 2.3.

Table 2.3
Method Detection Limits for Trace Inorganic Elemental Analysis in Dustfall Samples

Element	Method Detection Limit (MDL) ($mg/dm^2.day$)
Aluminum (Al)-Total	0.001
Antimony (Sb)-Total	0.0001
Arsenic (As)-Total	0.0001
Barium (Ba)-Total	0.00005
Beryllium (Be)-Total	0.0005
Bismuth (Bi)-Total	0.0005
Boron (B)-Total	0.01
Cadmium (Cd)-Total	0.00005
Calcium (Ca)-Total	0.05
Chromium (Cr)-Total	0.0005
Cobalt (Co)-Total	0.0001
Copper (Cu)-Total	0.0001
Iron (Fe)-Total	0.03
Lead (Pb)-Total	0.00005
Lithium (Li)-Total	0.005
Magnesium (Mg)-Total	0.1
Manganese (Mn)-Total	0.00005
Mercury (Hg)-Total	0.00005
Molybdenum (Mo)-Total	0.00005
Nickel (Ni)-Total	0.0005
Phosphorus (P)-Total	0.3
Potassium (K)-Total	2

Element	Method Detection Limit (MDL) ($mg/dm^2.day$)
Selenium (Se)-Total	0.001
Silicon (Si)-Total	0.05
Silver (Ag)-Total	0.00001
Sodium (Na)-Total	2
Strontium (Sr)-Total	0.0001
Thallium (Tl)-Total	0.0001
Tin (Sn)-Total	0.0001
Titanium (Ti)-Total	0.01
Uranium (U)-Total	0.00001
Vanadium (V)-Total	0.001
Zinc (Zn)-Total	0.001

2.2.3 Meteorological Sampling

Ambient temperature and barometric pressure were recorded at 5-minute intervals for the duration of the sampling program using a HOBO Micro Station sampler system located at site TL1. The ambient temperature varied from a high of 21.6^0C to a low of -8.6^0C. Barometric pressure varied from a high of 913.4 mbar to low of 864.9 mbar. The data were used in the calculation of daily TSP and PM_{10} concentrations as discussed in Section 2.2.1, above.

3.0 DISCUSSION OF SAMPLING RESULTS

3.1 TSP/PM_{10} SAMPLES

3.1.1 Data Recovery

Table 3.1 provides a summary of the mass concentrations for TSP and PM_{10} at the nine sampling locations. No sampling data (ND) were recovered for 10.8% of the TSP samples and 8.5% of the PM_{10} samples. This was largely due to some early confusion about instrument operation by field staff at the beginning of the sampling program. The lowest data recovery was for TSP at site A1 where the first five sampling periods were missed for TSP. The second lowest data recovery was for TSP at site FA1 in the Town of Faro where three of the 13 sampling periods did not have recoverable data.

Of the recoverable sampling data, 29.5% of the TSP samples and 43% of the PM_{10} samples had low concentrations that were at the method detection limit (MDL - indicated in italics on Table 3.1) of <5 $\mu g/m^3$. The majority of these samples were collected after August 28th. For TSP, six of the 13 samples collected at site TL2 were at the MDL, while five of 13 samples were at the MDL for sites RC1 and A1. In fact, when coupled with the ND samples, only three of 13 samples at site A1 had measurable TSP levels. For PM_{10}, site VG2 had seven of 13 samples at the MDL, with five of the seven occurring after September 3rd. Sites TL1, TL2 and VG1 all had six of 13 samples at the MDL, while sites TL3, RC1 and A1 had five samples at the MDL.

Therefore, the relative fraction of samples recovered in which there were measurable concentrations of TSP or PM_{10} was low for many of the sampling sites. As indicated in Figure 3.1, less than 50% of the PM_{10} samples collected at sites TL1, TL2, TL3, VG1 and VG2 had measurable concentrations. All of the sampling sites except A1 had more than 50% of the samples with measurable TSP concentrations, and the low data recovery at A1 was due to the previously mentioned operator error in running the samplers early on in the program. Therefore, TSP sampling was relatively more successful than the PM_{10} sampling, and this should be borne in mind in the interpretation of the sampling results.

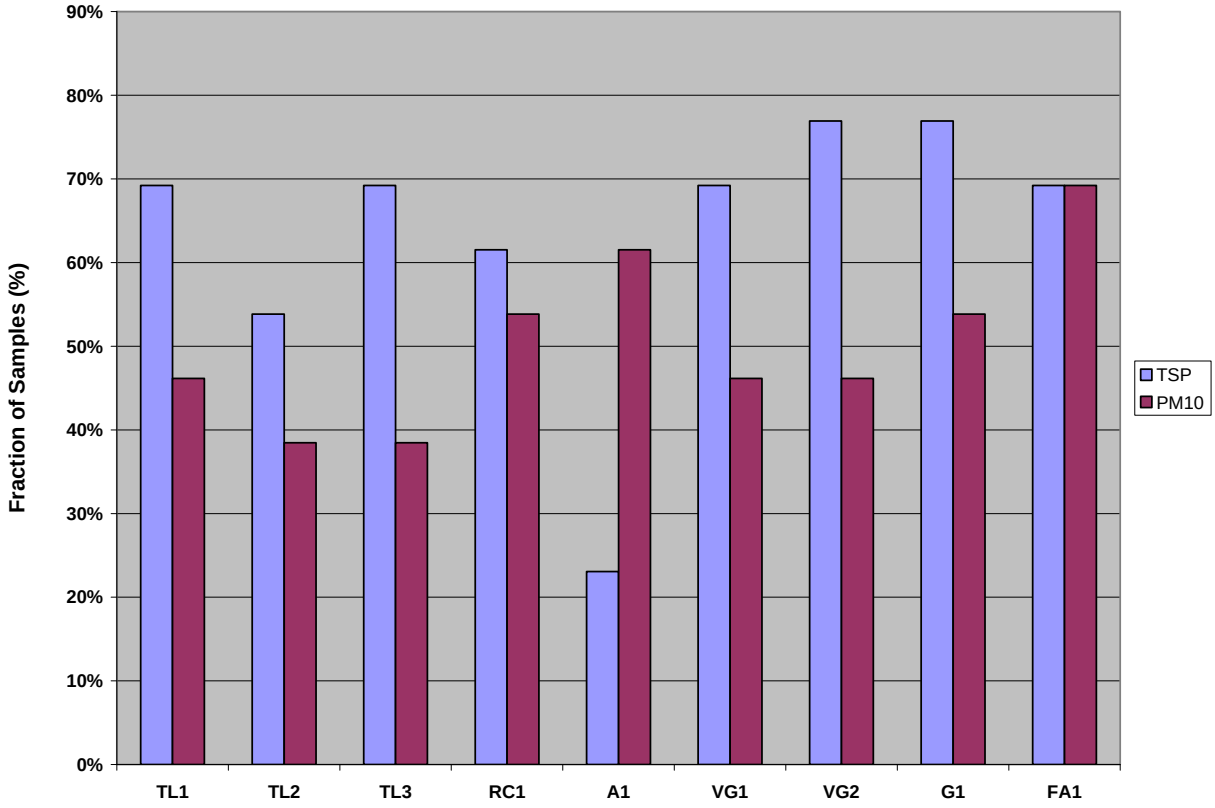
Table 3.1
Summary of TSP and PM_{10} Mass Concentrations

Sampling Date	Total Sampling Time (hours)	Total Suspended Particles (TSP) (µg/m3)									Inhalable Particles (PM10) (µg/m3)								
		TL1	TL2	TL3	RC1	A1	VG1	VG2	G1	FA1	TL1	TL2	TL3	RC1	A1	VG1	VG2	G1	FA1
17-Jul-08	24	10.97	7.80	28.35	18.74	ND	19.87	23.67	18.04	17.19	8.70	16.17	ND	11.01	11.80	19.33	7.72	6.45	11.16
23-Jul-08	24	7.42	7.63	10.53	7.57	ND	10.04	*5.31*	6.17	11.17	6.41	6.28	*5.09*	24.72	12.33	*4.99*	*4.93*	ND	11.27
29-Jul-08	24	ND	11.71	33.31	17.51	ND	ND	11.20	9.23	ND	ND	ND	17.27	9.80	13.38	ND	9.97	11.62	ND
4-Aug-08	24	12.43	8.89	38.24	7.76	ND	40.08	35.95	11.37	ND	5.30	ND	12.48	ND	*4.90*	12.53	5.02	7.80	12.05
10-Aug-08	24	6.75	5.71	ND	*4.93*	ND	15.01	5.12	8.29	ND	9.25	11.27	ND	8.38	6.24	7.09	7.49	10.30	ND
22-Aug-08	24	*4.89*	*4.94*	ND	7.52	*4.88*	8.10	40.67	11.03	10.72	*4.99*	13.47	ND	8.22	7.10	8.54	4.91	5.66	*4.97*
28-Aug-08	24	8.89	*4.97*	*4.99*	6.30	6.86	*5.03*	6.40	*4.93*	6.86	*5.01*	*5.02*	*4.97*	7.16	7.85	22.32	*4.92*	*4.93*	7.85
3-Sep-08	24	4.95	8.76	13.77	*5.08*	11.85	10.22	13.51	9.05	9.73	9.59	5.56	6.26	4.97	*4.94*	9.23	7.80	5.09	10.57
9-Sep-08	24	70.60	*4.98*	6.97	*5.05*	*4.93*	7.53	95.50	6.29	7.48	*5.02*	*5.03*	10.09	*4.94*	*4.91*	*8.60*	*4.93*	*4.94*	6.64
15-Sep-08	24	6.17	11.18	11.23	10.12	*4.92*	8.80	7.55	6.18	6.22	*5.05*	8.81	7.48	*4.97*	4.92	*5.00*	*4.94*	9.89	10.04
21-Sep-08	24	*4.97*	*6.21*	7.53	*5.11*	*4.95*	*5.06*	*5.06*	4.97	10.00	*5.06*	*5.06*	*5.02*	*4.98*	*4.97*	*5.03*	*4.97*	*4.97*	5.05
27-Sep-08	24	*4.96*	*5.01*	*5.01*	*5.08*	*4.94*	*5.05*	5.08	*4.98*	*8.74*	*5.05*	*5.08*	*5.03*	*4.97*	7.41	*5.02*	*4.96*	*4.97*	*4.68*
3-Oct-08	24	13.40	*4.92*	9.85	4.99	7.28	6.20	7.45	*4.88*	8.59	4.96	*4.97*	*4.92*	*4.89*	*4.86*	*4.93*	*4.89*	ND	13.62
Arithmetic Mean		13.0	7.1	15.4	8.1	6.3	11.7	20.2	8.1	9.7	6.2	7.9	7.9	8.3	7.4	9.4	6.0	7.0	8.9
Geometric Mean		8.8	6.8	12.0	7.2	6.0	9.5	12.2	7.5	9.3	6.0	7.1	7.1	7.2	6.8	8.1	5.8	6.6	8.3
50th Percentile		39.1	11.4	35.8	18.0	10.2	29.0	62.6	14.0	14.5	9.4	14.8	15.1	17.2	12.8	20.7	8.7	11.0	12.8
90th Percentile		58.0	11.6	37.3	18.4	11.2	35.6	82.3	16.4	16.1	9.5	15.6	16.4	21.7	13.1	21.7	9.5	11.4	13.3
Minimum		4.9	4.9	5.0	4.9	4.9	5.0	5.1	4.9	6.2	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.7
Maximum		70.6	11.7	38.2	18.7	11.8	40.1	95.5	18.0	17.2	9.6	16.2	17.3	24.7	13.4	22.3	10.0	11.6	13.6

Note:
ND = No Data
Concentrations in italics were calculated at the method detection limit

As indicated in Table 3.1, there were 21 samples in which measured PM_{10} levels were higher than TSP concentrations. However, only six of the 21 samples had PM_{10} levels greater than 5 $\mu g/m^3$, which is considered to be the 'noise' level for the MiniVol™ samplers. At very low concentrations, a difference of 5 $\mu g/m^3$ is not considered to be significant. For the remaining six samples, one sample at site FA1 was barely over the 5 $\mu g/m^3$ level, three samples at site TL2 were had PM_{10} concentrations that were from 5.6 to 8.5 $\mu g/m^3$ higher than TSP, and sites RC1 and VG1 each recorded one PM_{10} level that were 17 $\mu g/m^3$ higher than TSP. These differences may be due to operator error in mislabelling samples in the field or to mishandling of the sample filters prior to or after exposure.

Figure 3.1
Fraction of Samples with Measurable TSP and PM_{10} Concentrations



3.1.2 TSP and PM_{10} Mass Concentrations

Figure 3.2 shows the maximum concentrations of TSP and PM_{10} at each of the sampling sites. All TSP samples were below the National Ambient Air Quality Objective (NAAQO) level of 120 µg/m^3. The highest TSP concentration was measured at site VG2 with 95.5 µg/m^3 on September 9th. The second highest concentration was measured at site TL1 with 70.6 µg/m^3 also on September 9th. All other sampling sites had low concentrations (<8 µg/m^3) on that date. The maximum recorded TSP levels at the other sites were at or below 40 µg/m^3. In fact, TSP levels at sites TL2, RC1, A1 and G1 were similar to, or lower than, the levels measured at site FA1 in the Town of Faro.

The highest PM_{10} concentration of 24.7 µg/m^3 recorded at site RC1 was half the objective level of 50 µg/m^3 that has been adopted by many provinces in Canada and recommended as a guideline value by the World Health Organization (WHO). Maximum PM_{10} concentrations at all other sampling sites were less than 20 µg/m^3, indicating that overall PM_{10} levels at the mine complex and in Faro are fairly low.

Figure 3.2
Maximum TSP and PM_{10} Concentrations in 2008

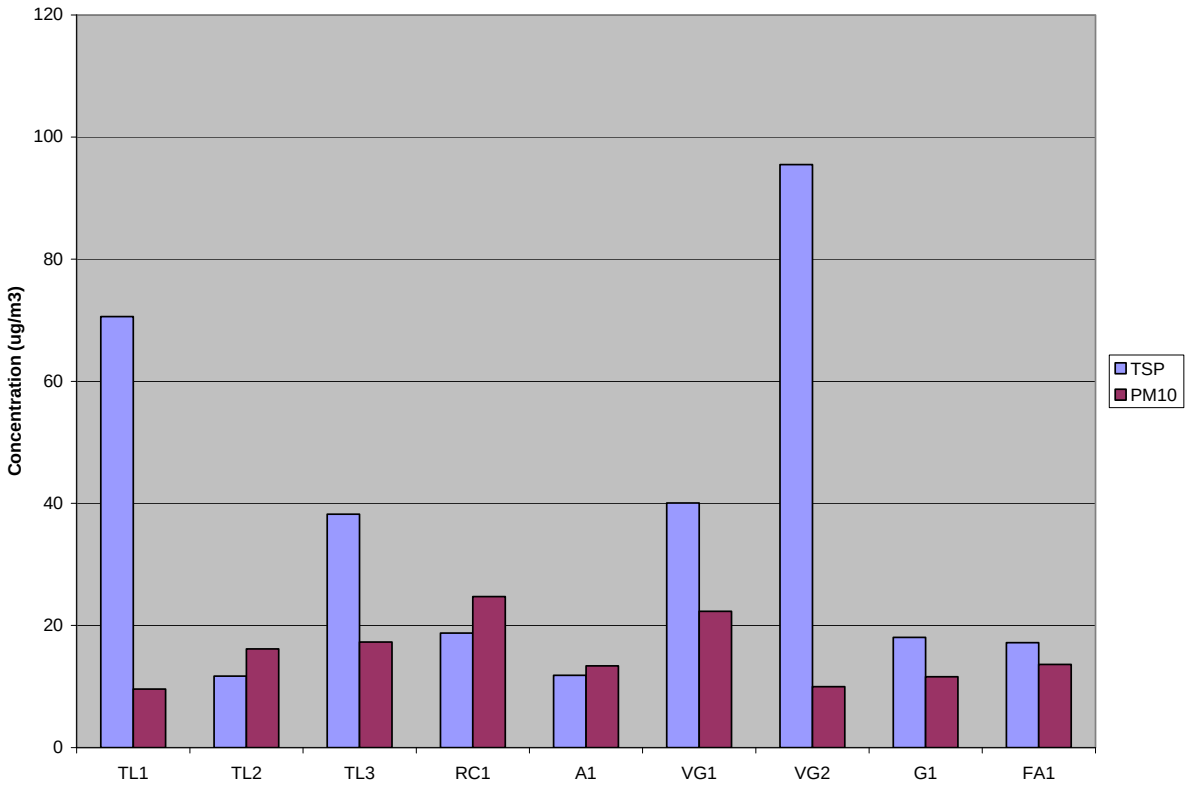
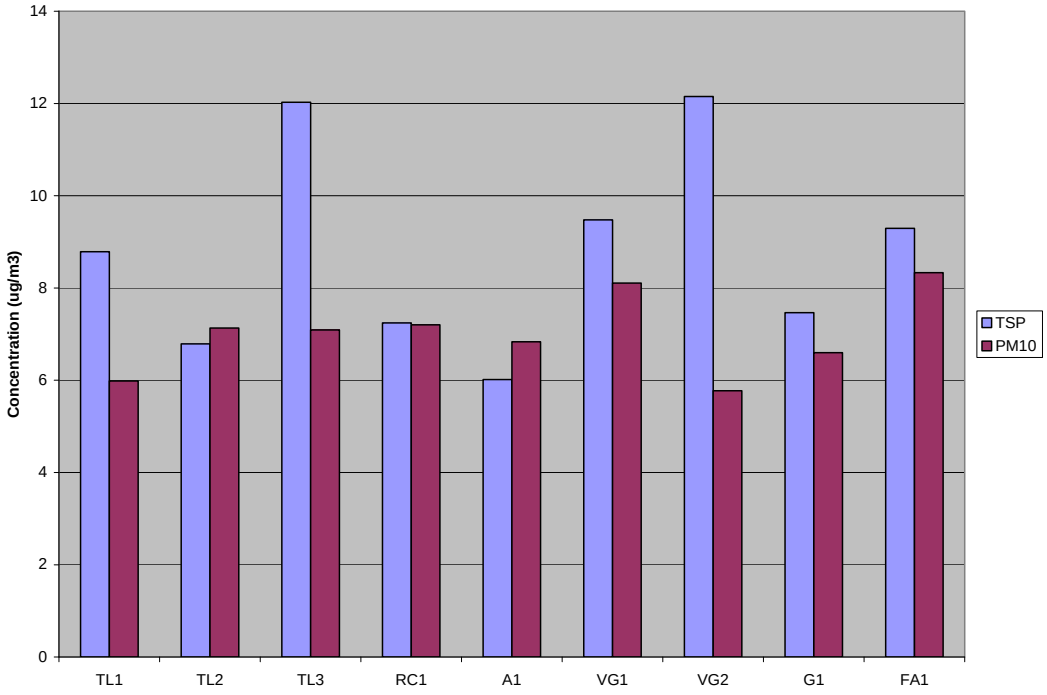


Figure 3.3 shows the geometric mean TSP and PM_{10} concentrations at the sampling sites. The geometric mean is the most appropriate measure of mean concentrations for log-normally

distributed data. Overall, the data show that mean TSP concentrations were very low at 12 μg/m^3 at sites TL3 and VG2, perhaps due to road dust emissions at these two sites. Mean PM_{10} levels were approximately 8 μg/m^3 or lower. In fact, given a MDL of <5 μg/m^3, the mean concentrations at several of the sites were <3 μg/m^3 above the MDL. Therefore, average TSP and PM_{10} concentrations at all sites were very low.

Figure 3.3
Geometric Mean TSP and PM_{10} Concentrations in 2008



3.1.3 Inorganic Trace Element Concentrations

Tables 3.2a, 3.2b and 3.2c summarize the maximum, minimum and geometric mean concentrations of trace inorganic species from the TSP and PM_{10} samples. The highest maximum and geometric mean values are indicated for each element. It should be noted that the highest concentrations are often indicated for site A1, and that these values are not truly representative of 24-hour average concentrations. The high values relate to one TSP sample collected at site A1 on August 4th for a sampling period lasting only 114 minutes (see Appendix A). Therefore, the highest values at site A1 should be regarded as outliers.

Table 3.2a
Summary of Trace Inorganic Element Concentrations

Element	Statistical Parameter	Concentration (µg/m3)																	
		TL1 - TSP	TL1 - PM10	TL2 - TSP	TL2 - PM10	TL3 - TSP	TL3 - PM10	RC1 - TSP	RC1 - PM10	A1 - TSP	A1 - PM10	VG1 - TSP	VG1 - PM10	VG2 - TSP	VG2 - PM10	G1 - TSP	G1 - PM10	FA1 - TSP	FA1 - PM10
Aluminum Al	Maximum	1.40E-01	2.00E-01	7.74E-02	9.14E-02	6.59E-01	1.19E-01	7.76E-02	9.02E-02	1.01E+00	5.64E-02	5.61E-01	1.45E-01	3.73E-01	3.04E-01	9.03E-02	9.36E-02	1.45E-01	8.43E-02
	Minimum	1.49E-02	1.26E-02	2.24E-02	1.27E-02	2.13E-02	1.76E-02	1.40E-02	9.96E-03	1.61E-02	1.85E-02	1.77E-02	1.26E-02	1.65E-02	1.24E-02	1.97E-02	1.24E-02	3.59E-02	2.57E-02
	Geomertic Mean	3.88E-02	3.93E-02	4.10E-02	3.80E-02	9.23E-02	4.32E-02	3.46E-02	3.17E-02	8.62E-02	3.22E-02	6.84E-02	3.58E-02	4.80E-02	3.72E-02	4.06E-02	3.09E-02	7.27E-02	4.00E-02
Antimony Sb	Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	1.12E-03	1.25E-03	6.47E-04	1.22E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
	Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04
	Geomertic Mean	6.66E-04	6.86E-04	6.23E-04	6.84E-04	6.79E-04	7.00E-04	6.30E-04	6.83E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Arsenic As	Maximum	5.12E-03	7.03E-03	3.61E-03	7.38E-03	3.08E-03	3.94E-03	4.92E-03	5.78E-03	4.16E-02	3.06E-03	5.53E-03	3.76E-03	3.39E-03	3.27E-03	2.77E-03	2.47E-03	5.11E-03	3.13E-03
	Minimum	6.12E-04	6.31E-04	5.36E-04	6.24E-04	6.16E-04	6.24E-04	6.16E-04	6.11E-04	6.15E-04	6.07E-04	6.28E-04	6.19E-04	6.24E-04	6.11E-04	6.13E-04	6.52E-04	6.22E-04	6.22E-04
	Geomertic Mean	1.44E-03	1.50E-03	1.46E-03	1.46E-03	1.55E-03	1.61E-03	1.48E-03	1.68E-03	3.91E-03	1.22E-03	1.62E-03	1.52E-03	1.38E-03	1.37E-03	1.36E-03	1.35E-03	1.87E-03	1.56E-03
Barium Ba	Maximum	7.90E-03	2.11E-02	6.77E-03	6.68E-03	4.56E-02	2.74E-02	8.13E-03	4.04E-03	3.49E-02	7.78E-03	2.76E-02	5.71E-03	1.60E-02	1.06E-02	5.15E-03	7.93E-03	1.75E-02	6.03E-03
	Minimum	6.21E-04	6.31E-04	4.46E-04	6.27E-04	6.26E-04	6.29E-04	6.16E-04	6.16E-04	8.50E-04	6.07E-04	6.31E-04	6.16E-04	6.33E-04	6.11E-04	6.16E-04	6.16E-04	1.60E-03	5.85E-04
	Geomertic Mean	3.04E-03	2.02E-03	1.34E-03	1.38E-03	7.75E-03	2.84E-03	1.65E-03	1.22E-03	3.62E-03	1.57E-03	3.06E-03	1.39E-03	2.09E-03	2.01E-03	1.39E-03	1.09E-03	4.11E-03	1.92E-03
Beryllium Be	Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
	Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04
	Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.47E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Boron B	Maximum	6.73E-02	9.24E-02	3.88E-02	8.79E-02	4.61E-02	6.23E-02	3.23E-02	5.78E-02	4.59E-01	3.28E-02	7.28E-02	5.88E-02	3.33E-02	3.22E-02	3.30E-02	3.26E-02	3.13E-02	3.15E-02
	Minimum	3.05E-02	2.65E-02	2.26E-02	3.11E-02	3.08E-02	3.08E-02	3.08E-02	3.05E-02	3.03E-02	3.03E-02	3.10E-02	3.08E-02	3.11E-02	3.06E-02	3.05E-02	3.08E-02	3.07E-02	2.92E-02
	Geomertic Mean	3.33E-02	3.39E-02	3.12E-02	3.42E-02	3.23E-02	3.50E-02	3.15E-02	3.24E-02	7.99E-02	3.09E-02	3.34E-02	3.36E-02	3.18E-02	3.10E-02	3.12E-02	3.15E-02	3.10E-02	3.11E-02
Cadmium Cd	Maximum	1.08E-03	3.85E-04	6.21E-04	1.05E-03	1.71E-03	6.37E-04	2.46E-03	9.25E-04	3.67E-03	1.36E-03	6.26E-04	4.71E-04	4.97E-04	1.73E-03	3.87E-04	2.61E-04	3.68E-04	4.96E-04
	Minimum	1.22E-04	1.06E-04	1.23E-04	1.24E-04	1.23E-04	3.11E-05	1.23E-04	1.22E-04	1.21E-04	1.21E-04	1.23E-04	1.23E-04	1.23E-04	1.22E-04	1.22E-04	1.23E-04	1.23E-04	1.17E-04
	Geomertic Mean	2.08E-04	1.73E-04	1.94E-04	2.18E-04	1.86E-04	1.81E-04	2.22E-04	2.04E-04	3.96E-04	1.84E-04	1.73E-04	1.81E-04	2.03E-04	1.90E-04	1.68E-04	1.43E-04	1.51E-04	1.77E-04
Calcium Ca	Maximum	5.38E-01	3.33E-01	2.34E-01	2.81E-01	9.75E-01	2.96E-01	1.90E-01	2.23E-01	1.46E+00	1.23E-01	6.51E-01	1.95E-01	3.55E-01	2.12E-01	1.62E-01	1.85E-01	2.25E-01	2.15E-01
	Minimum	7.65E-03	1.42E-02	1.09E-02	9.51E-03	1.25E-02	7.78E-03	1.12E-02	1.07E-02	1.21E-02	7.57E-03	9.52E-03	6.27E-03	9.51E-03	7.62E-03	7.64E-03	9.18E-03	1.24E-02	6.30E-03
	Geomertic Mean	8.79E-02	9.65E-02	1.12E-01	9.20E-02	1.57E-01	1.01E-01	9.12E-02	9.01E-02	2.16E-01	7.80E-02	1.23E-01	8.71E-02	1.03E-01	8.61E-02	8.64E-02	8.33E-02	1.24E-01	8.71E-02
Chromium Cr	Maximum	2.61E-01	2.51E-01	9.92E-02	3.27E-01	1.40E-01	1.60E-01	1.13E-01	1.30E-01	1.16E+00	1.25E-01	1.46E-01	1.15E-01	8.28E-02	2.61E-01	1.04E-01	1.02E-01	7.74E-02	8.55E-02
	Minimum	5.40E-02	5.47E-02	5.36E-02	5.71E-02	5.21E-02	5.10E-02	5.42E-02	5.17E-02	4.85E-02	5.19E-02	5.00E-02	5.12E-02	4.99E-02	5.01E-02	4.88E-02	3.72E-02	5.17E-02	4.41E-02
	Geomertic Mean	7.36E-02	7.55E-02	6.85E-02	7.91E-02	7.08E-02	7.80E-02	7.42E-02	7.50E-02	1.70E-01	7.12E-02	7.33E-02	6.59E-02	6.44E-02	7.06E-02	6.56E-02	6.85E-02	6.29E-02	6.61E-02
Cobalt Co	Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.59E-04	6.52E-04	6.25E-04	1.12E-03	1.05E-01
	Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04	6.18E-04
	Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.57E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.24E-04	6.29E-04	6.20E-04	6.56E-04	2.94E-03

denotes highest concentration level for maximum and geometric means for each element

Table 3.2b
Summary of Trace Inorganic Element Concentrations

Element	Statistical Parameter	Concentration (µg/m3)																	
		TL1 - TSP	TL1 - PM10	TL2 - TSP	TL2 - PM10	TL3 - TSP	TL3 - PM10	RC1 - TSP	RC1 - PM10	A1 - TSP	A1 - PM10	VG1 - TSP	VG1 - PM10	VG2 - TSP	VG2 - PM10	G1 - TSP	G1 - PM10	FA1 - TSP	FA1 - PM10
Copper Cu	Maximum	1.05E-01	2.48E-02	1.55E-02	1.55E-01	4.77E-01	1.36E-01	6.12E-02	3.23E-01	2.43E-01	3.23E-02	9.65E-03	1.67E-02	9.97E-03	6.04E-02	7.47E-03	1.21E-02	8.72E-03	1.51E-02
	Minimum	6.18E-04	7.53E-04	7.46E-04	6.27E-04	1.11E-03	7.55E-04	6.34E-04	6.18E-04	7.35E-04	6.13E-04	7.48E-04	6.20E-04	6.28E-04	6.15E-04	7.44E-04	6.20E-04	1.24E-03	6.25E-04
	Geomertic Mean	2.94E-03	2.58E-03	3.14E-03	1.99E-03	4.45E-03	2.73E-03	2.65E-03	2.45E-03	3.97E-03	2.34E-03	2.63E-03	2.18E-03	2.04E-03	2.26E-03	2.78E-03	1.77E-03	2.37E-03	1.81E-03
Iron Fe	Maximum	3.70E-01	4.07E-01	1.65E-01	3.87E-01	1.39E+00	2.47E-01	7.36E-01	2.08E-01	1.47E+00	6.88E-01	1.18E+00	3.06E-01	6.92E-01	1.73E+00	1.93E-01	1.69E-01	3.49E-01	2.89E-01
	Minimum	3.72E-02	3.78E-02	4.97E-02	3.79E-02	5.01E-02	3.76E-02	3.81E-02	3.74E-02	3.68E-02	3.69E-02	6.27E-02	3.10E-02	3.78E-02	3.72E-02	3.08E-02	3.10E-02	6.19E-02	3.75E-02
	Geomertic Mean	1.16E-01	8.50E-02	9.31E-02	6.89E-02	1.91E-01	9.79E-02	9.93E-02	7.34E-02	1.43E-01	8.81E-02	1.43E-01	8.41E-02	1.12E-01	1.04E-01	7.96E-02	6.48E-02	1.50E-01	9.90E-02
Lead Pb	Maximum	5.26E-03	1.81E-02	2.79E-03	3.87E-03	8.39E-02	2.13E-02	1.63E-02	9.67E-03	6.24E-02	6.74E-03	2.38E-02	1.07E-02	1.23E-02	7.85E-03	5.08E-03	2.60E-03	3.96E-03	5.40E-03
	Minimum	1.36E-04	6.20E-04	1.49E-04	1.09E-04	1.00E-03	5.02E-04	3.47E-04	2.12E-04	6.15E-04	4.04E-04	5.77E-04	3.44E-04	6.21E-04	3.81E-04	5.56E-04	6.15E-04	7.77E-05	5.28E-04
	Geomertic Mean	1.46E-03	1.65E-03	8.85E-04	7.77E-04	9.84E-03	2.85E-03	1.25E-03	1.09E-03	3.56E-03	1.56E-03	1.99E-03	1.11E-03	1.63E-03	1.30E-03	1.27E-03	1.05E-03	8.89E-04	1.16E-03
Magnesium Mg	Maximum	8.08E-02	9.24E-02	5.08E-02	8.79E-02	4.93E-01	8.74E-02	3.88E-02	5.78E-02	4.59E-01	3.93E-02	6.26E-01	1.25E-01	3.46E-01	4.86E-01	3.87E-02	3.26E-02	1.37E-01	4.96E-02
	Minimum	3.06E-02	3.10E-02	6.21E-04	3.12E-02	3.08E-02	3.08E-02	3.08E-02	3.05E-02	3.03E-02	3.03E-02	3.10E-02	3.08E-02	3.11E-02	3.06E-02	3.05E-02	3.08E-02	3.10E-02	2.92E-02
	Geomertic Mean	3.74E-02	3.43E-02	2.42E-02	3.58E-02	7.35E-02	4.39E-02	3.24E-02	3.28E-02	8.11E-02	3.17E-02	6.18E-02	3.84E-02	5.21E-02	4.38E-02	3.21E-02	3.15E-02	5.24E-02	3.35E-02
Manganese Mn	Maximum	4.19E-03	4.81E-03	1.37E-02	3.51E-03	2.10E-02	3.99E-03	3.17E-03	2.54E-03	1.62E-02	2.36E-03	1.63E-02	4.59E-03	1.17E-02	7.11E-03	2.83E-03	3.71E-03	7.98E-03	5.02E-03
	Minimum	6.18E-04	1.72E-04	1.84E-04	1.10E-04	1.57E-04	3.10E-04	2.84E-04	1.36E-04	9.13E-05	9.17E-05	1.88E-04	6.20E-04	2.03E-04	1.51E-04	6.16E-04	6.16E-04	1.98E-04	1.42E-04
	Geomertic Mean	1.30E-03	1.16E-03	1.37E-03	9.20E-04	2.08E-03	1.24E-03	1.26E-03	9.53E-04	1.73E-03	7.37E-04	2.07E-03	1.17E-03	1.62E-03	1.18E-03	1.16E-03	1.02E-03	1.91E-03	1.16E-03
Molybdenum Mo	Maximum	6.73E-04	9.24E-04	3.88E-04	8.79E-04	1.11E-03	6.23E-04	5.01E-04	5.78E-04	4.59E-03	3.93E-04	7.53E-04	5.88E-04	5.26E-04	3.74E-04	5.15E-04	3.26E-04	3.13E-04	3.77E-04
	Minimum	3.05E-04	3.10E-04	2.23E-04	3.11E-04	3.08E-04	3.08E-04	3.08E-04	3.05E-04	3.03E-04	3.03E-04	3.10E-04	3.08E-04	3.11E-04	3.06E-04	3.05E-04	3.08E-04	3.07E-04	2.92E-04
	Geomertic Mean	3.33E-04	3.43E-04	3.11E-04	3.42E-04	3.65E-04	3.50E-04	3.36E-04	3.36E-04	7.99E-04	3.17E-04	3.63E-04	3.36E-04	3.30E-04	3.14E-04	3.28E-04	3.15E-04	3.10E-04	3.16E-04
Nickel Ni	Maximum	5.85E-03	8.50E-03	4.55E-03	7.38E-03	8.51E-03	4.19E-03	7.77E-03	4.04E-03	3.08E-02	4.20E-03	9.90E-03	4.18E-03	4.87E-03	5.24E-03	3.96E-03	2.84E-03	3.44E-03	4.79E-03
	Minimum	6.17E-04	6.20E-04	6.21E-04	6.21E-04	6.16E-04	6.15E-04	6.24E-04	6.11E-04	6.07E-04	6.07E-04	6.23E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.17E-04	6.24E-04	6.19E-04
	Geomertic Mean	1.44E-03	1.47E-03	1.46E-03	1.31E-03	1.49E-03	1.24E-03	1.43E-03	1.19E-03	2.70E-03	1.42E-03	1.45E-03	1.13E-03	1.37E-03	1.21E-03	1.27E-03	1.04E-03	1.12E-03	1.26E-03
Phosphorus P	Maximum	2.69E-01	3.33E-01	1.52E-01	3.16E-01	1.48E-01	1.97E-01	1.55E-01	2.31E-01	1.65E+00	1.47E-01	2.91E-01	2.35E-01	1.46E-01	1.37E-01	1.58E-01	1.56E-01	1.37E-01	1.50E-01
	Minimum	9.18E-02	9.31E-02	6.70E-02	9.36E-02	9.23E-02	9.32E-02	9.24E-02	9.20E-02	9.14E-02	9.18E-02	9.34E-02	9.29E-02	9.44E-02	9.17E-02	9.19E-02	9.23E-02	9.32E-02	9.33E-02
	Geomertic Mean	1.20E-01	1.11E-01	1.08E-01	1.15E-01	1.12E-01	1.18E-01	1.08E-01	1.17E-01	2.60E-01	1.03E-01	1.16E-01	1.12E-01	1.14E-01	1.04E-01	1.09E-01	1.08E-01	1.12E-01	1.03E-01
Potassium K	Maximum	4.39E-01	1.85E-01	1.38E-01	1.76E-01	1.73E-01	1.99E-01	2.01E-01	1.47E-01	9.18E-01	9.87E-02	1.75E-01	1.73E-01	1.50E-01	1.11E-01	1.23E-01	1.23E-01	1.49E-01	1.49E-01
	Minimum	5.30E-02	6.15E-02	6.21E-02	6.16E-02	6.15E-02	6.24E-02	6.11E-02	6.07E-02	6.07E-02	6.20E-02	6.16E-02	6.21E-02	6.11E-02	6.10E-02	6.17E-02	6.13E-02	5.85E-02	6.09E-04
	Geomertic Mean	9.41E-02	7.53E-02	7.82E-02	7.98E-02	9.03E-02	8.16E-02	7.87E-02	7.75E-02	1.78E-01	6.74E-02	8.65E-02	7.75E-02	7.62E-02	7.08E-02	6.95E-02	7.43E-02	7.74E-02	7.33E-02
Selenium Se	Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
	Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04
	Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.47E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04

denotes highest concentration level for maximum and geometric means for each element

Table 3.2c
Summary of Trace Inorganic Element Concentrations

Element	Statistical Parameter	Concentration (µg/m3)																	
		TL1 - TSP	TL1 - PM10	TL2 - TSP	TL2 - PM10	TL3 - TSP	TL3 - PM10	RC1 - TSP	RC1 - PM10	A1 - TSP	A1 - PM10	VG1 - TSP	VG1 - PM10	VG2 - TSP	VG2 - PM10	G1 - TSP	G1 - PM10	FA1 - TSP	FA1 - PM10
Silver Ag	Maximum	3.37E-04	4.62E-04	1.94E-04	4.39E-04	2.30E-04	3.12E-04	2.52E-04	4.63E-04	2.30E-03	3.68E-04	5.82E-04	2.94E-04	8.96E-04	5.02E-04	6.32E-04	2.58E-04	3.68E-04	8.68E-04
	Minimum	1.52E-04	1.32E-04	1.12E-04	1.55E-04	1.54E-04	1.54E-04	1.54E-04	1.53E-04	1.52E-04	1.52E-04	1.55E-04	1.54E-04	1.55E-04	1.53E-04	1.52E-04	1.54E-04	1.53E-04	1.46E-04
	Geomertic Mean	1.66E-04	1.69E-04	1.56E-04	1.78E-04	1.62E-04	1.75E-04	1.63E-04	1.74E-04	4.14E-04	1.65E-04	1.92E-04	1.87E-04	2.17E-04	1.88E-04	1.97E-04	1.64E-04	1.69E-04	1.82E-04
Sodium Na	Maximum	1.50E+01	2.03E+01	8.70E+00	1.89E+01	6.69E+00	1.21E+01	8.58E+00	1.08E+01	8.40E+01	8.64E+00	1.30E+01	1.10E+01	8.85E+00	8.78E+00	8.63E+00	8.38E+00	7.06E+00	7.67E+00
	Minimum	1.37E-02	1.58E-02	1.25E-02	1.43E-02	1.25E-02	1.40E-02	1.28E-02	1.54E-02	1.37E-02	1.21E-02	1.58E-02	1.26E-02	1.43E-02	1.07E-02	1.53E-02	7.66E-03	1.40E-02	9.46E-03
	Geomertic Mean	5.29E-01	4.76E-01	4.96E-01	4.24E-01	3.40E-01	3.64E-01	4.46E-01	5.32E-01	1.02E+00	4.49E-01	4.70E-01	4.47E-01	4.77E-01	4.02E-01	4.42E-01	3.42E-01	1.91E-01	2.43E-01
Strontium Sr	Maximum	1.35E-03	1.85E-03	1.48E-03	1.76E-03	4.19E-03	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	3.26E-03	1.18E-03	1.33E-03	1.12E-03	6.59E-04	6.52E-04	1.37E-03	6.31E-04
	Minimum	6.09E-04	5.30E-04	4.46E-04	6.22E-04	6.16E-04	6.15E-04	6.16E-04	6.12E-04	6.07E-04	6.07E-04	4.07E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04
	Geomertic Mean	6.66E-04	6.86E-04	6.66E-04	7.25E-04	1.03E-03	7.00E-04	6.30E-04	6.57E-04	1.60E-03	6.17E-04	7.72E-04	6.81E-04	7.06E-04	6.48E-04	6.24E-04	6.29E-04	6.96E-04	6.22E-04
Tellurium Te	Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
	Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04
	Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.47E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Thallium Tl	Maximum	3.45E-04	3.98E-04	1.69E-04	1.99E-04	1.47E-04	1.75E-04	1.63E-04	2.08E-04	9.18E-04	8.58E-05	9.21E-04	1.98E-04	1.37E-04	1.35E-04	1.35E-04	1.48E-04	1.11E-04	1.24E-04
	Minimum	6.09E-05	5.30E-05	4.46E-05	6.21E-05	6.16E-05	6.15E-05	6.24E-05	6.11E-05	6.07E-05	6.07E-05	6.20E-05	6.16E-05	6.21E-05	6.11E-05	6.10E-05	6.16E-05	6.13E-05	5.85E-05
	Geomertic Mean	9.38E-05	8.76E-05	7.32E-05	7.99E-05	7.10E-05	7.96E-05	7.96E-05	7.63E-05	1.66E-04	6.51E-05	9.02E-05	8.09E-05	6.76E-05	6.59E-05	6.63E-05	6.81E-05	6.58E-05	6.91E-05
Tin Sn	Maximum	9.50E-03	3.98E-03	2.41E-03	4.92E-03	3.58E-03	3.99E-03	3.53E-03	3.24E-03	8.63E-02	1.48E-02	1.08E-02	6.82E-03	2.82E-03	5.58E-03	2.14E-03	1.55E-03	1.08E-02	3.84E-03
	Minimum	1.84E-04	6.31E-04	7.38E-04	7.97E-05	7.83E-05	1.88E-04	2.42E-04	6.23E-04	7.61E-05	6.07E-04	7.95E-05	6.25E-04	6.33E-04	7.66E-05	6.22E-04	1.08E-04	7.77E-05	1.27E-04
	Geomertic Mean	1.44E-03	1.29E-03	1.22E-03	1.11E-03	9.00E-04	1.19E-03	1.28E-03	1.23E-03	3.20E-03	1.48E-03	1.27E-03	1.50E-03	1.33E-03	1.24E-03	1.25E-03	8.42E-04	9.89E-04	1.06E-03
Titanium Ti	Maximum	8.88E-03	1.44E-02	7.45E-03	1.30E-02	2.71E-02	8.73E-03	6.37E-03	7.17E-03	5.69E-02	5.64E-03	2.00E-02	7.10E-03	8.26E-03	1.99E-02	5.93E-03	6.31E-03	9.73E-03	5.85E-03
	Minimum	3.32E-03	3.41E-03	1.87E-03	3.63E-03	4.21E-03	4.10E-03	1.60E-03	2.09E-03	3.78E-03	2.69E-03	4.02E-03	2.50E-03	2.94E-03	2.46E-03	3.08E-03	2.36E-03	3.72E-03	3.26E-03
	Geomertic Mean	5.11E-03	4.81E-03	4.85E-03	4.88E-03	8.05E-03	5.71E-03	4.46E-03	4.55E-03	1.11E-02	4.30E-03	6.64E-03	4.92E-03	5.12E-03	5.03E-03	4.48E-03	4.24E-03	6.31E-03	5.03E-03
Vanadium V	Maximum	1.35E-03	1.85E-03	7.80E-04	1.76E-03	1.48E-03	1.25E-03	6.47E-04	1.16E-03	9.23E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
	Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04
	Geomertic Mean	6.66E-04	6.77E-04	6.32E-04	6.84E-04	7.07E-04	7.00E-04	6.30E-04	6.48E-04	1.62E-03	6.17E-04	6.86E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Zinc Zn	Maximum	7.54E-02	6.66E-02	3.77E-02	9.84E-02	1.01E-01	6.66E-02	4.00E-02	7.15E-02	6.80E-01	2.43E-02	8.02E-02	2.59E-02	4.08E-02	3.22E-02	2.53E-02	3.13E-02	1.84E-02	3.39E-02
	Minimum	3.77E-04	2.55E-03	3.08E-03	1.72E-03	3.08E-03	3.08E-03	1.42E-03	2.12E-03	3.03E-03	1.78E-03	3.10E-03	1.03E-03	3.11E-03	3.06E-03	6.08E-04	3.10E-03	2.29E-03	1.71E-03
	Geomertic Mean	5.89E-03	6.95E-03	6.88E-03	6.59E-03	1.57E-02	8.35E-03	6.52E-03	8.18E-03	1.68E-02	6.08E-03	1.07E-02	5.87E-03	8.07E-03	7.56E-03	5.82E-03	6.18E-03	6.13E-03	5.61E-03
Zirconium Zr	Maximum	1.35E-02	1.85E-02	7.76E-03	1.76E-02	9.22E-03	1.25E-02	6.47E-03	1.16E-02	9.18E-02	6.55E-03	1.46E-02	1.18E-02	6.66E-03	6.44E-03	6.59E-03	6.52E-03	6.25E-03	6.31E-03
	Minimum	6.09E-03	5.30E-03	4.46E-03	6.21E-03	6.16E-03	6.15E-03	6.16E-03	6.11E-03	6.07E-03	6.07E-03	6.20E-03	6.16E-03	6.21E-03	6.11E-03	6.10E-03	6.15E-03	6.13E-03	5.85E-03
	Geomertic Mean	6.66E-03	6.77E-03	6.23E-03	7.11E-03	6.47E-03	7.00E-03	6.30E-03	6.48E-03	1.60E-02	6.17E-03	6.69E-03	6.71E-03	6.37E-03	6.20E-03	6.24E-03	6.29E-03	6.20E-03	6.22E-03

denotes highest concentration level for maximum and geometric means for each element

All of the values in Tables 3.2 a, 3.2b and 3.2c fall below the ambient air quality criteria listed in Table 3.3 that have been established for trace element concentrations in the Province of Ontario (N.B. Manitoba has adopted 24-hour average criteria for arsenic, cadmium, copper, lead nickel and zinc that are identical to those in Ontario, while the objective in British Columbia for lead is less stringent than the ones adopted by Ontario and Manitoba). All of the elemental concentrations listed in Tables 3.2a to 3.2c were below the AAQC levels in Table 3.3.

Table 3.3
Ambient Air Quality Criteria (AAQC) for Trace Inorganic Elements

Element	AAQC 24-h average ($\mu g/m^3$)	Rationale
Aluminium	n/a	
Antimony	25	health
Arsenic	0.3	health
Barium	10	health
Beryllium	0.01	health
Boron	120	particulate matter
Cadmium	2	health
Calcium	n/a	
Chromium	1.5	health
Cobalt	0.1	health
Copper	50	health
Iron	4	soiling
Lead	2	health
Magnesium	n/a	
Manganese	2.5	health
Molybdenum	120	particulate matter
Nickel	2	vegetation
Phosphorus	n/a	
Potassium	n/a	
Selenium	10	health
Silver	1	health
Sodium	n/a	
Strontium	120	particulate matter
Tellurium	10	health
Thallium	n/a	
Tin	10	health
Titanium	120	particulate matter
Vanadium	2	health
Zinc	120	particulate matter
Zirconium	n/a	

n/a – not applicable

Table 3.4 lists the highest concentration level measured for each element (excluding values for site A1), the sampling location and particulate matter fraction in which it was measured. Also listed are the AAQC for each element for comparison.

Table 3.4
Comparison of Maximum Observed Elemental Concentrations
And AAQC Values

Element	Maximum Observed Concentration ($\mu g/m^3$)	Sampling Location	PM Size Fraction	Ambient Air Quality Criteria	
				($\mu g/m^3$)	Rationale
Antimony	0.00185	TL1	PM_{10}	25	health
Arsenic	0.00738	TL2	PM_{10}	0.3	health
Barium	0.04565	TL3	TSP	10	health
Beryllium	0.00185	TL1	PM_{10}	0.01	health
Boron	0.09243	TL1	PM_{10}	120	particulate matter
Cadmium	0.00246	RC1	TSP	2	health
Chromium	0.327	TL2	PM_{10}	1.5	health
Cobalt	0.0007	TL3	PM_{10}	0.1	health
Copper	0.477	TL3	TSP	50	health
Iron	1.733	VG2	PM_{10}	4	soiling
Lead	0.0839	TL3	TSP	2	health
Manganese	0.021	TL3	TSP	2.5	health
Molybdenum	0.0011	TL3	TSP	120	particulate matter
Nickel	0.0099	VG1	TSP	2	vegetation
Selenium	0.00185	TL1	PM_{10}	10	health
Silver	0.000896	VG2	TSP	1	health
Strontium	0.00419	TL3	TSP	120	particulate matter
Tellurium	0.00185	TL1	PM_{10}	10	health
Tin	0.0108	VG1	TSP	10	health
Titanium	0.0271	TL3	TSP	120	particulate matter
Vanadium	0.00185	TL1	PM_{10}	2	health
Zinc	0.101	TL3	TSP	120	particulate matter

Table 3.4 shows that the highest concentrations of antimony, arsenic beryllium, boron, chromium, selenium tellurium and vanadium were recorded in the PM_{10} size fraction near the tailing areas at sites TL1 and TL2. The highest concentrations of barium, copper, lead, manganese, molybdenum, strontium, titanium and zinc were recorded in the TSP size fraction at site TL3. Only the highest concentration of cobalt was recorded at site TL3 in a PM_{10} sample. Site VG1 had the highest levels of nickel and tin in the TSP size fraction, while site VG2 had the highest iron concentration in the PM_{10} size fraction. The highest cadmium concentration was recorded in TSP at site RC1.

The concentrations of the following elements showed little variation between sites, and, excluding the anomalously high value at site A1, some were either frequently or almost always below the method detection limit:

- Antimony (Sb)
- Arsenic (As)
- Beryllium (Be)
- Boron (B)
- Cobalt (Co)
- Selenium (Se)
- Tellurium (Te)
- Tin (Sn)
- Vanadium (V)
- Zinc (Zn)
- Zirconium (Zr)

The trace elements that showed the largest degree of variation between sites were:

- Aluminium (Al)
- Barium (Ba)
- Cadmium (Cd)
- Calcium (Ca)
- Copper (Cu)
- Iron (Fe)
- Lead (Pb)
- Magnesium (Mg)
- Manganese (Mn)
- Sodium (Na)
- Thallium (Th)

The group of elements consisting of Al, Ca, Fe and Mg would all be consistent with surface soil-derived fugitive dust emissions, and are not necessarily associated with the Faro Mine Complex *per se*. There was some evidence of slightly elevated concentrations of the following elements in the vicinity of the mine complex compared with the Town of Faro:

- Chromium (Cr)
- Molybdenum (Mo)
- Nickel (Ni)
- Phosphorus (P)
- Potassium (K)
- Strontium (Sr)
- Titanium (Ti)
- Vanadium (V)

Figures 3.4 to 3.33 show the range of concentrations recorded at each of the sites using the values in Tables 3.2a to 3.2c. (Note that the anomalously high values at site A1 are included in Figures 3.4 to 3.33).

Figure 3.4: Aluminium in TSP and PM_{10}

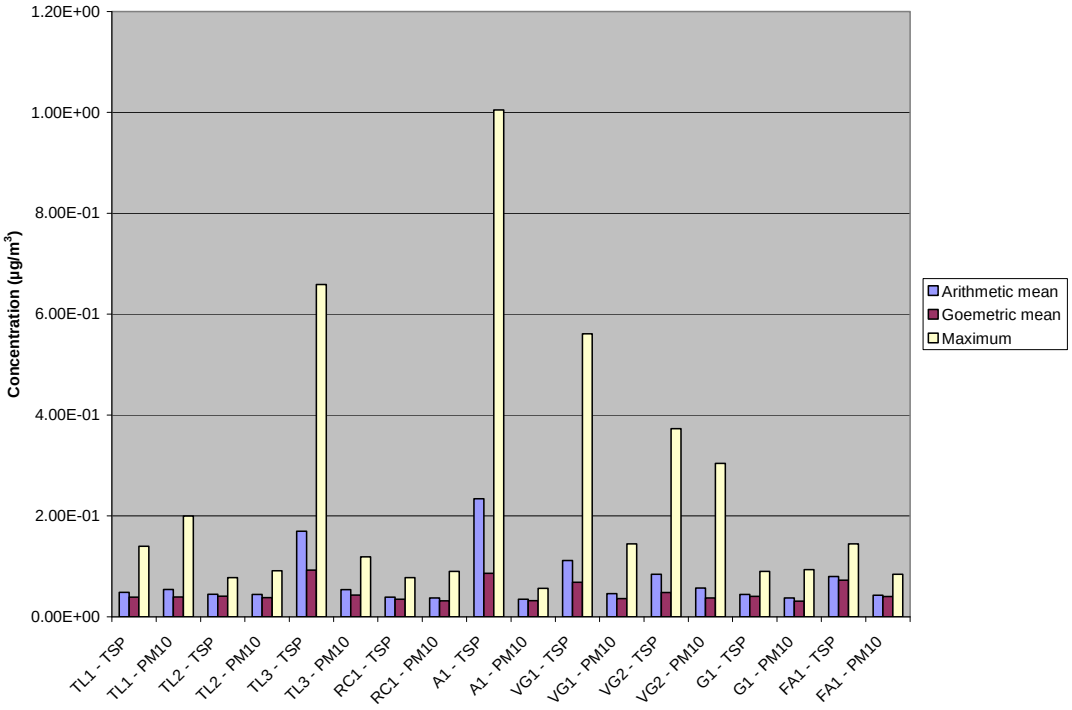


Figure 3.5: Antimony in TSP and PM_{10}

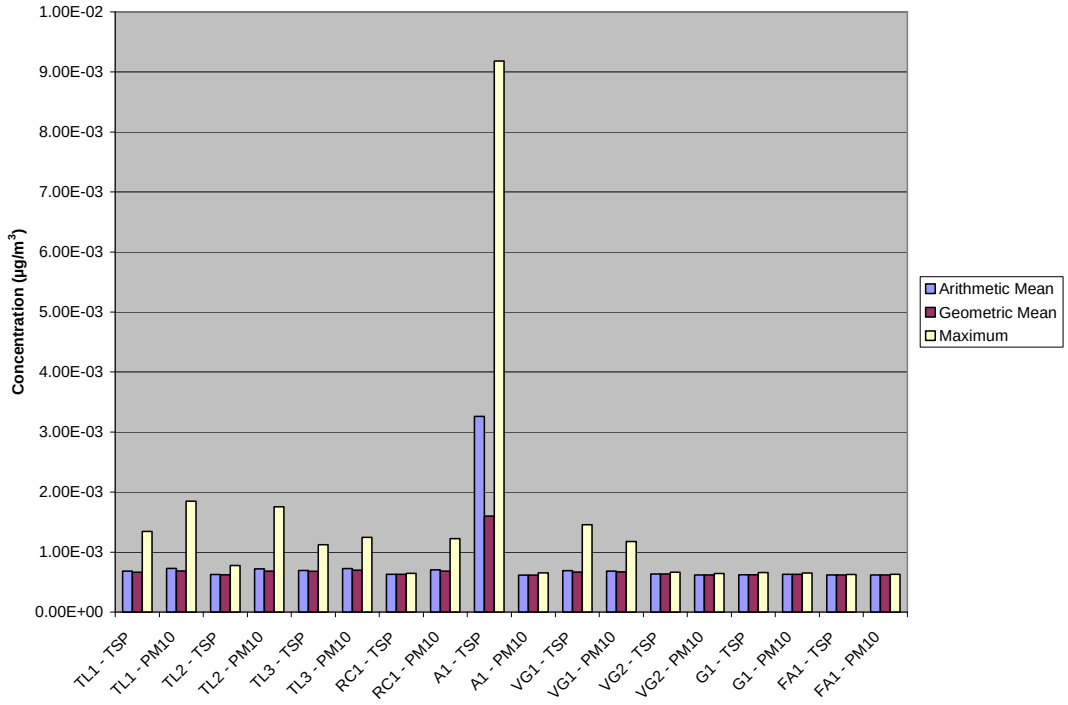


Figure 3.6: Arsenic in TSP and PM_{10}

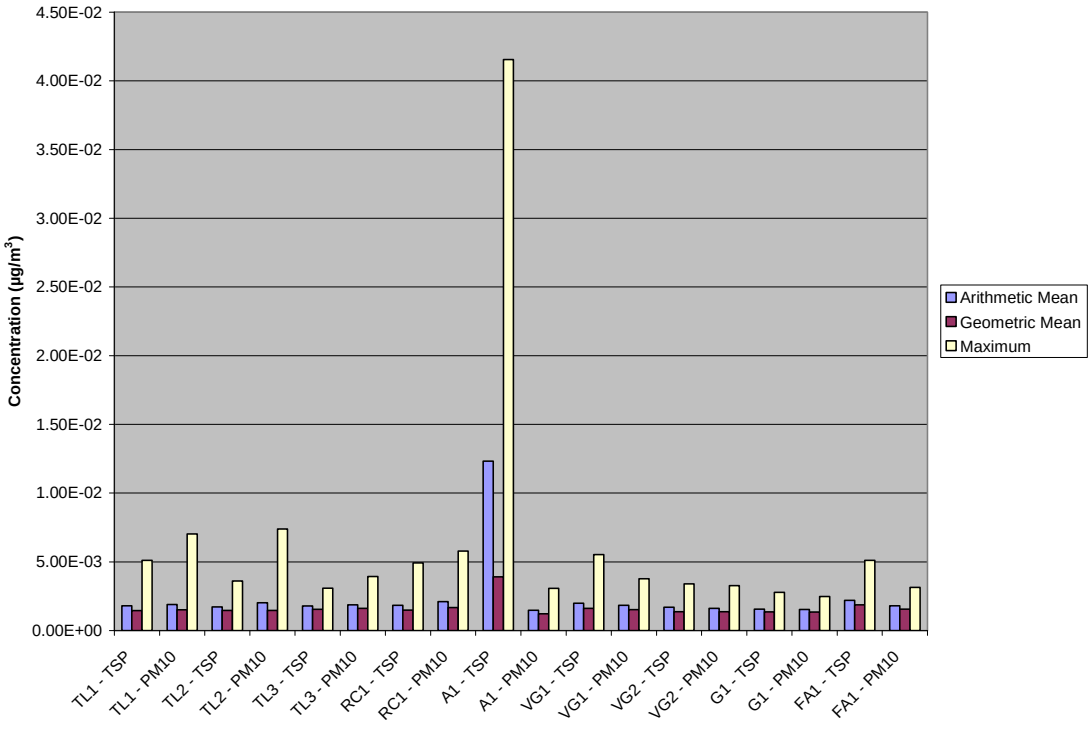


Figure 3.7: Barium in TSP and PM_{10}

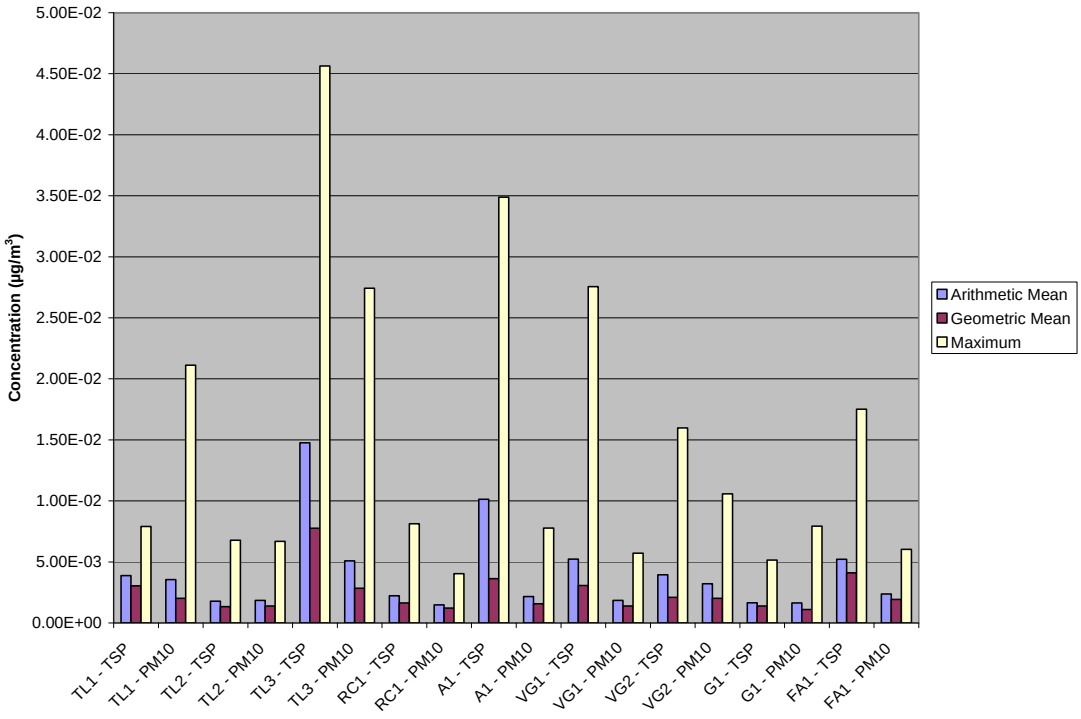


Figure 3.8: Beryllium in TSP and PM_{10}

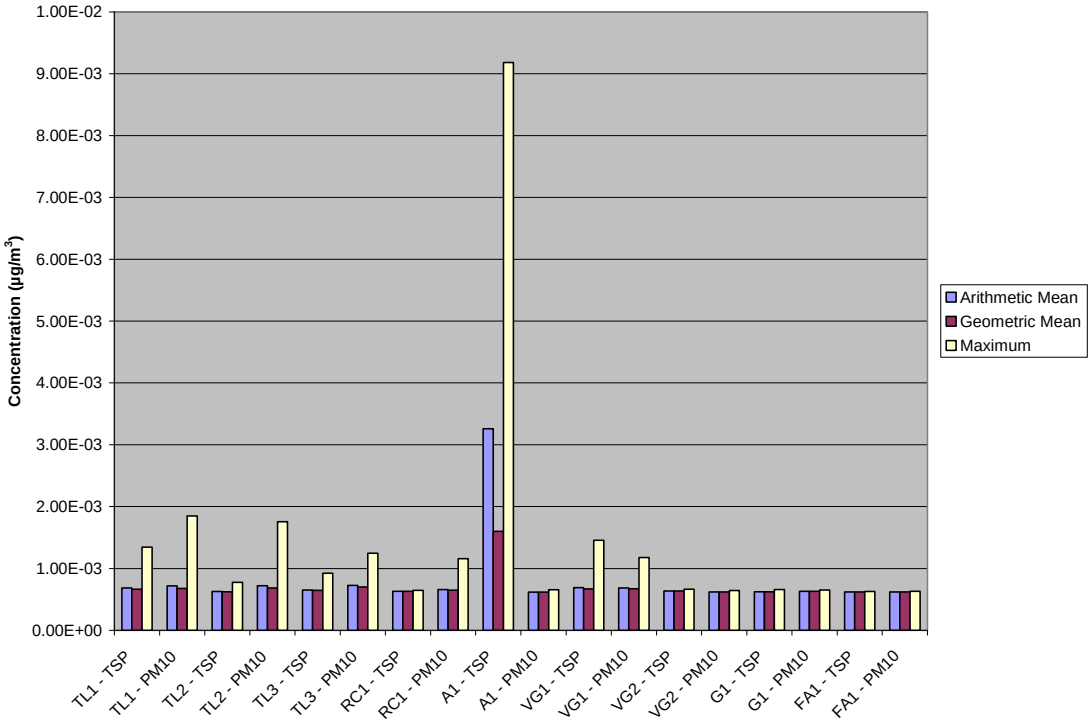


Figure 3.9: Boron in TSP and PM_{10}

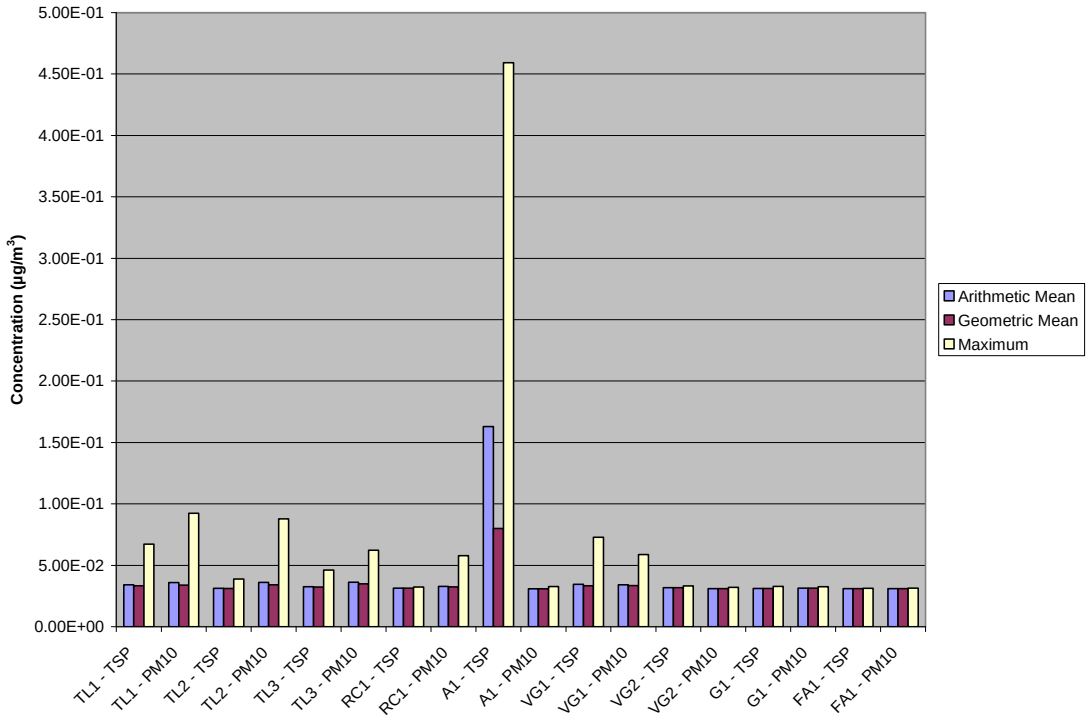


Figure 3.10: Cadmium in TSP and PM_{10}

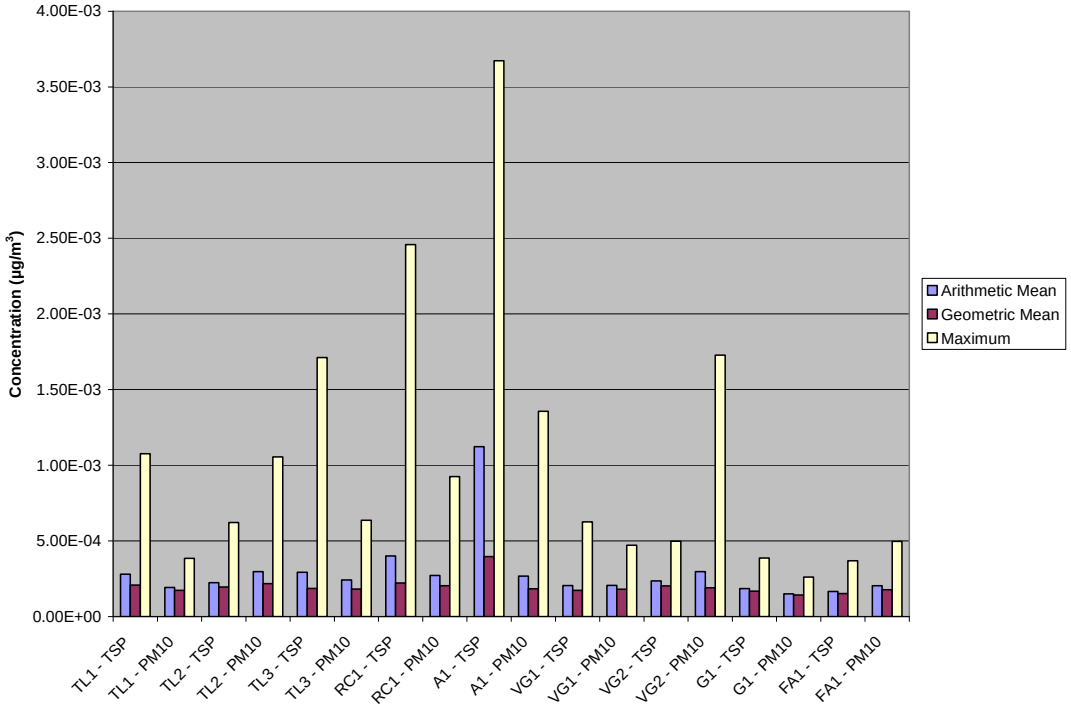


Figure 3.11: Calcium in TSP and PM_{10}

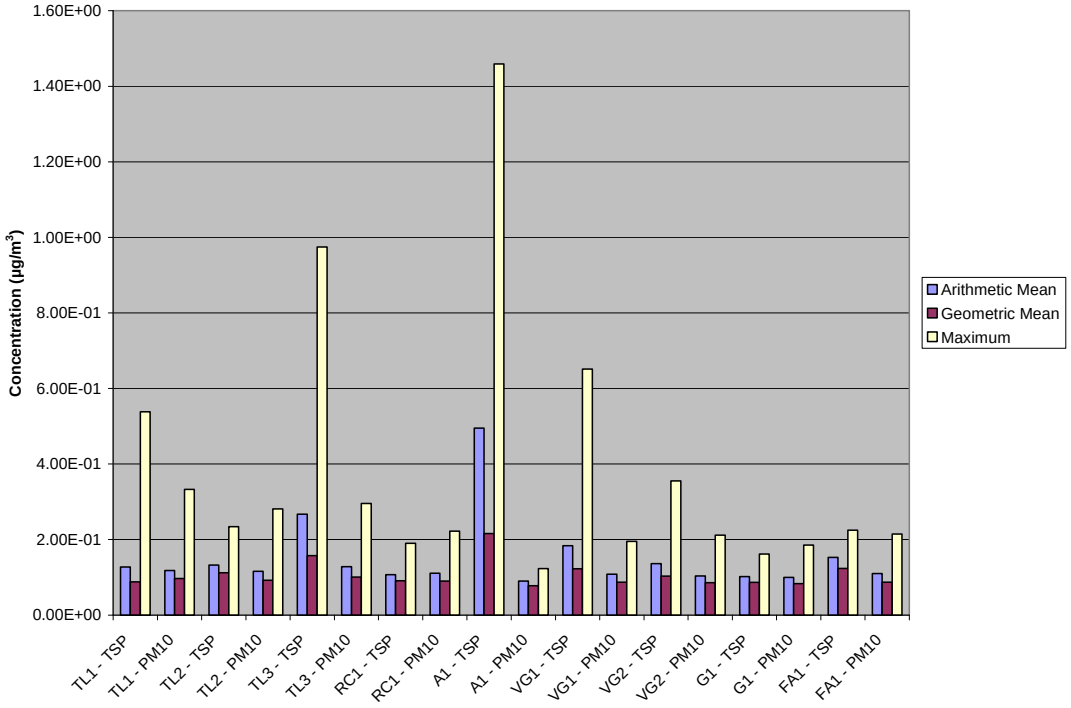


Figure 3.12: Chromium in TSP and PM_{10}

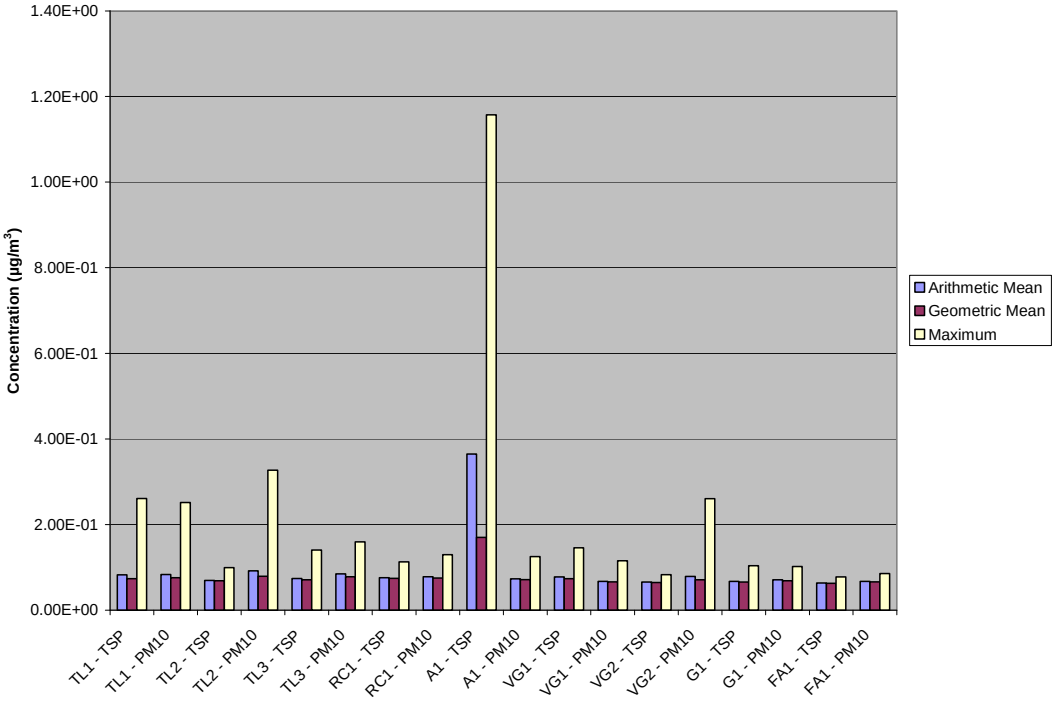


Figure 3.13: Cobalt in TSP and PM_{10}

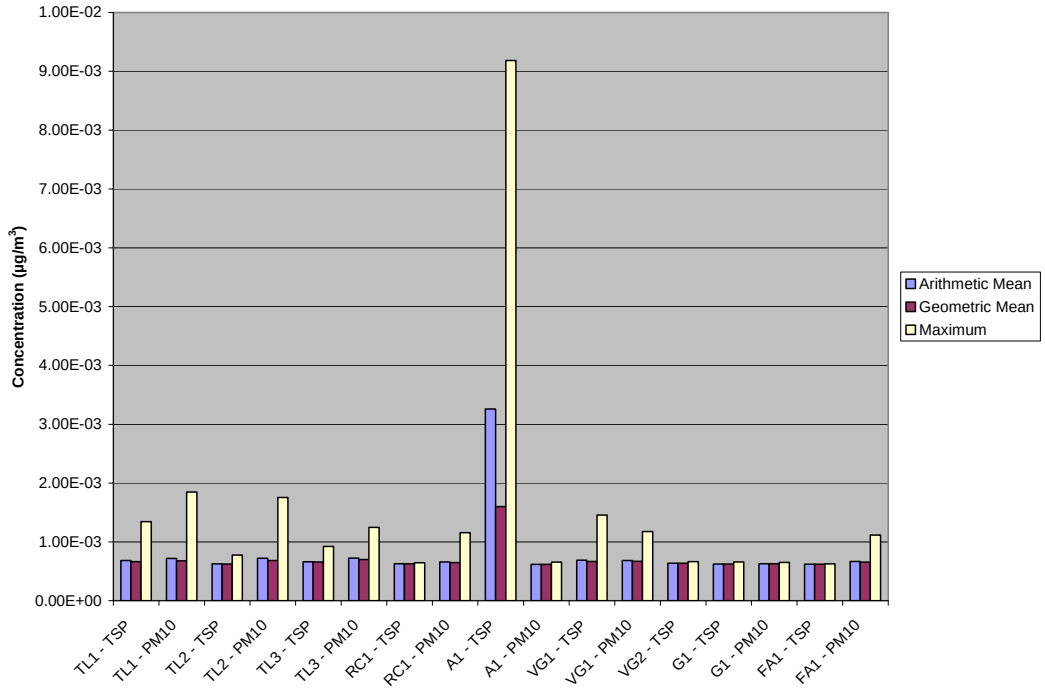


Figure 3.14: Copper in TSP and PM_{10}

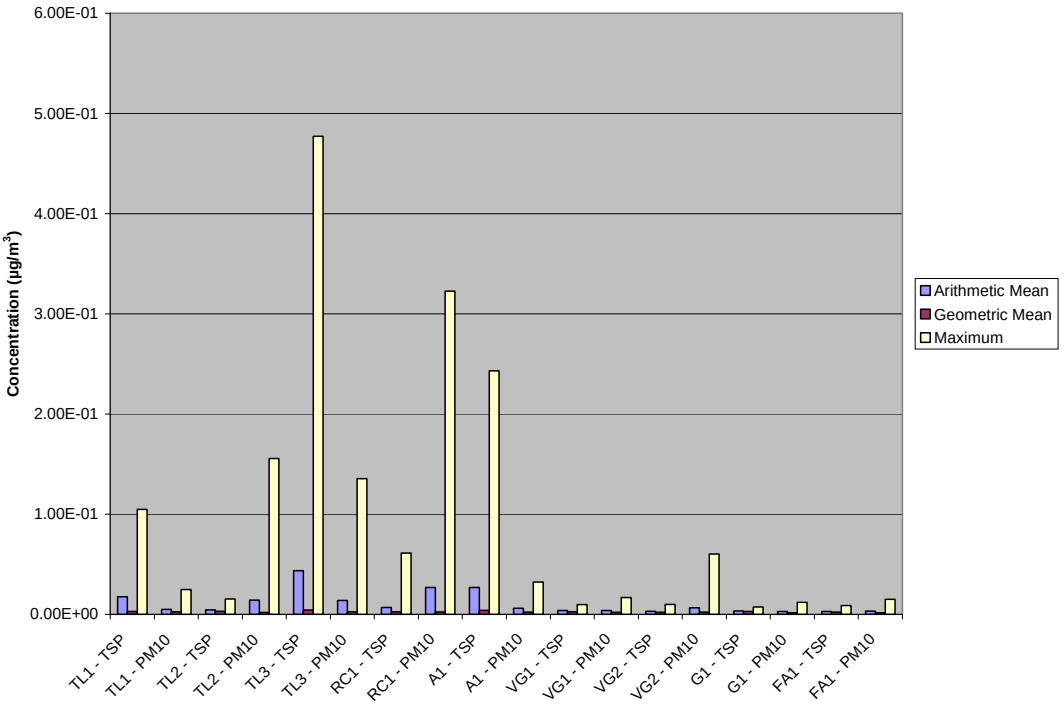


Figure 3.15: Iron in TSP and PM_{10}

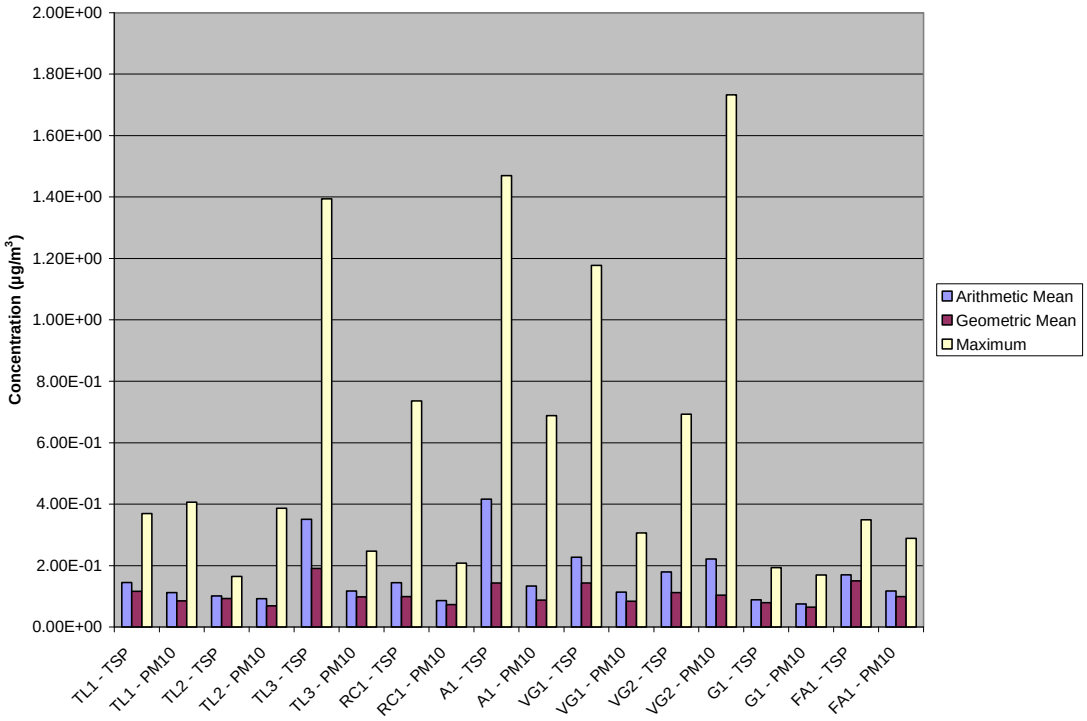


Figure 3.16: Lead in TSP and PM_{10}

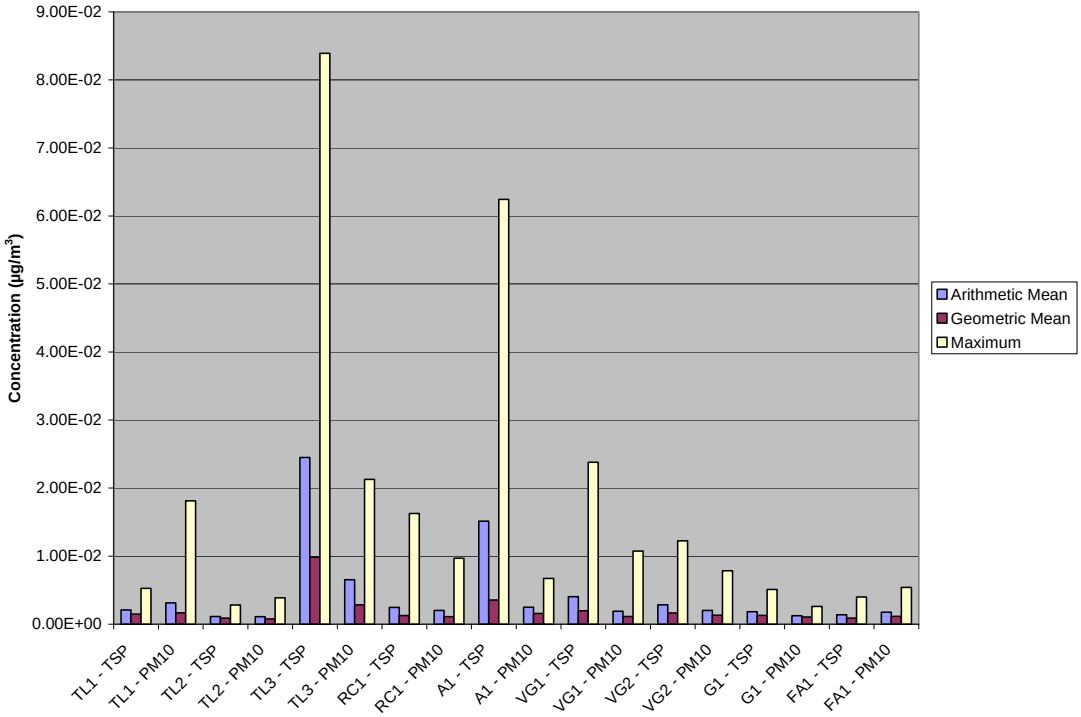


Figure 3.17: Magnesium in TSP and PM_{10}

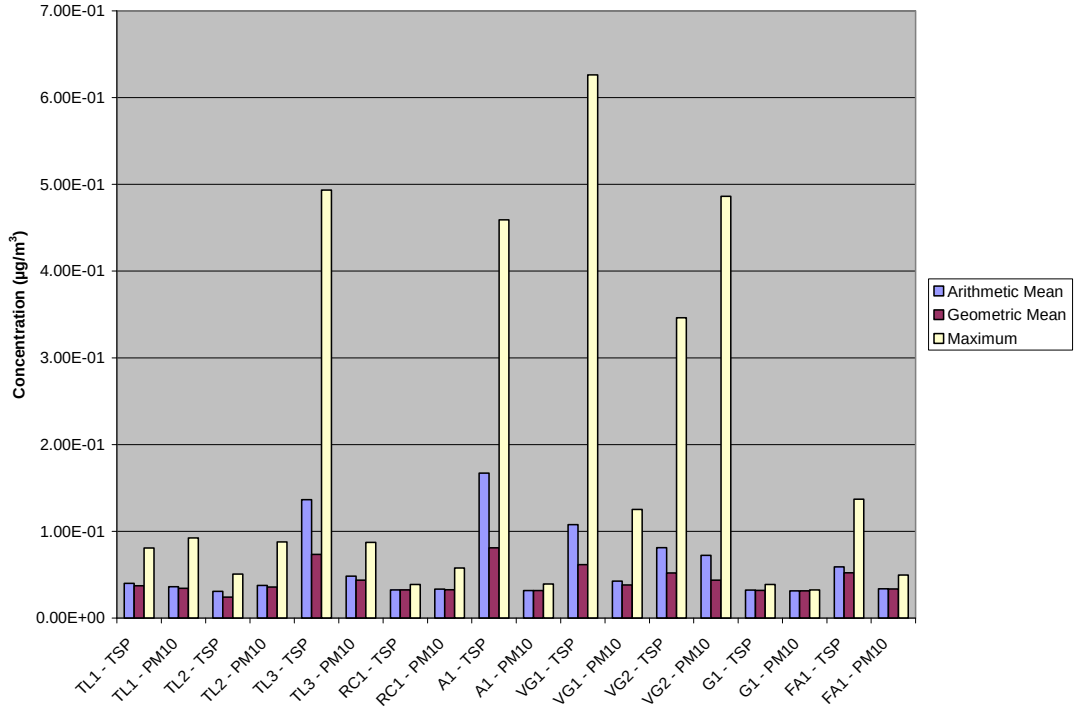


Figure 3.18: Manganese in TSP and PM_{10}

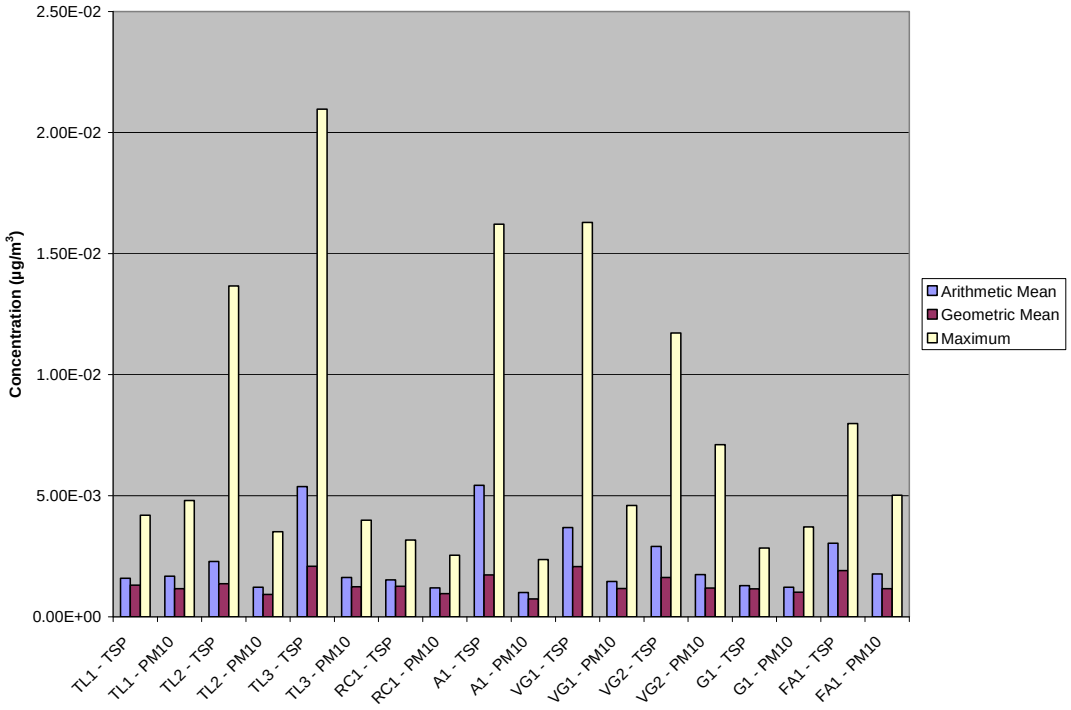


Figure 3.19: Molybdenum in TSP and PM_{10}

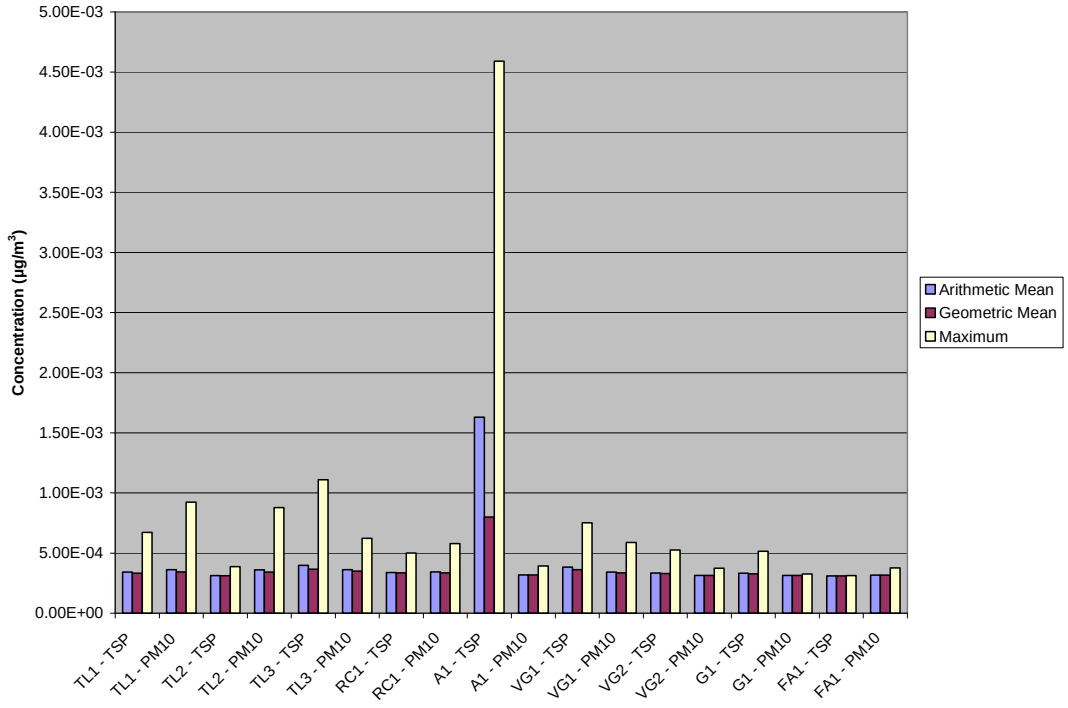


Figure 3.20: Nickel in TSP and PM_{10}

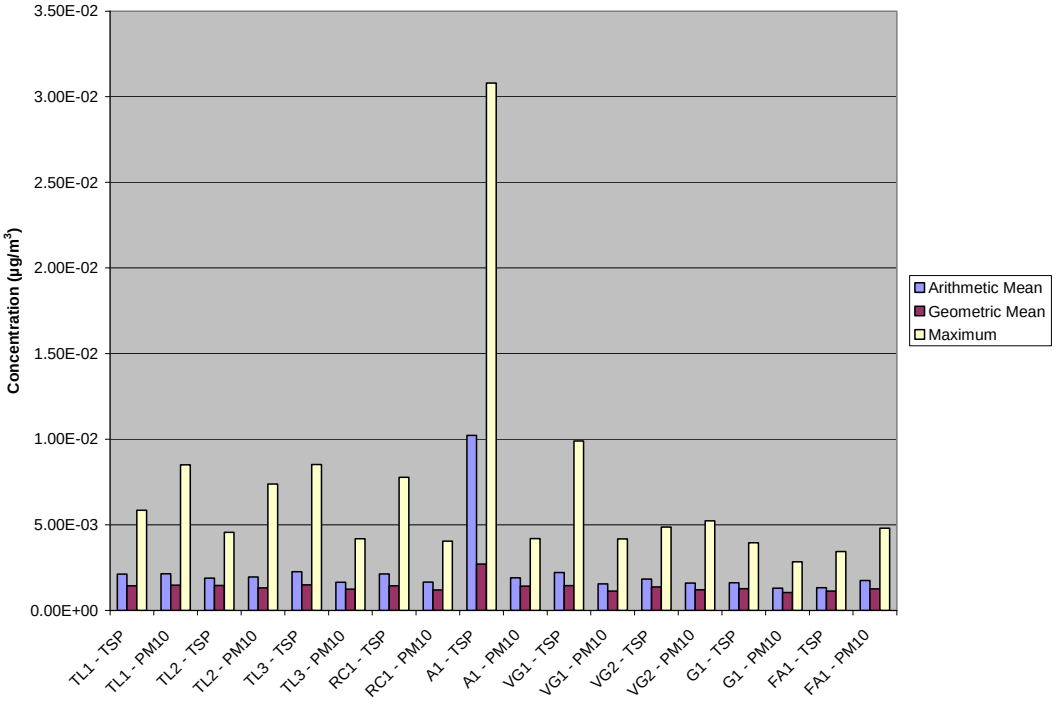


Figure 3.21: Phosphorus in TSP and PM_{10}

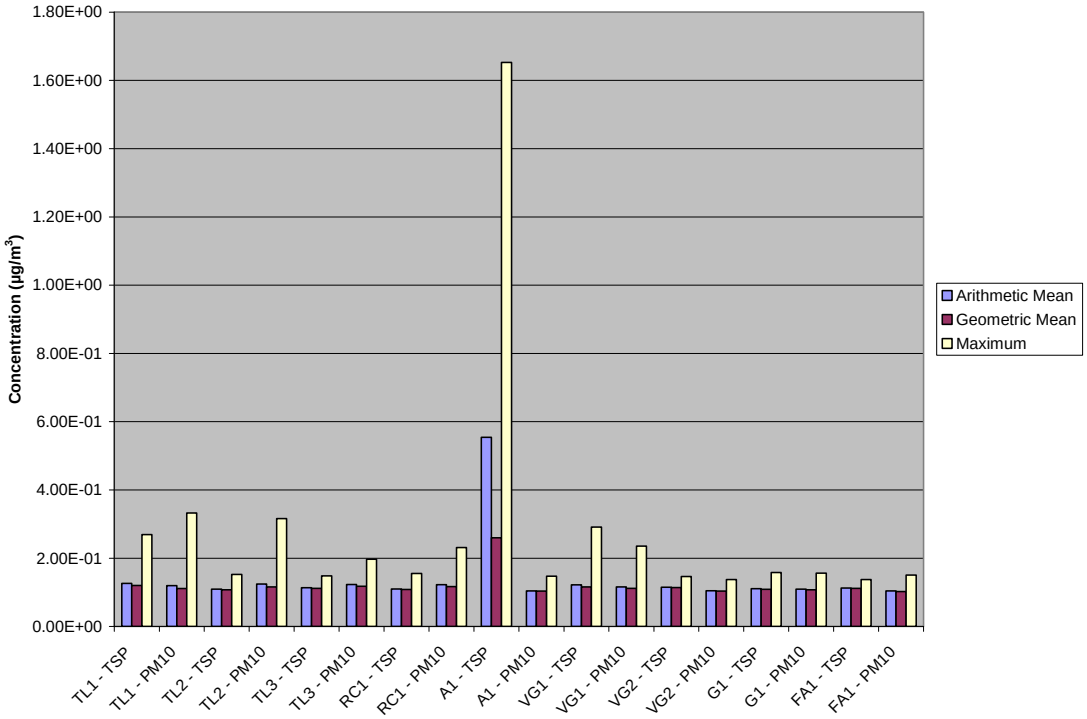


Figure 3.22: Potassium in TSP and PM_{10}

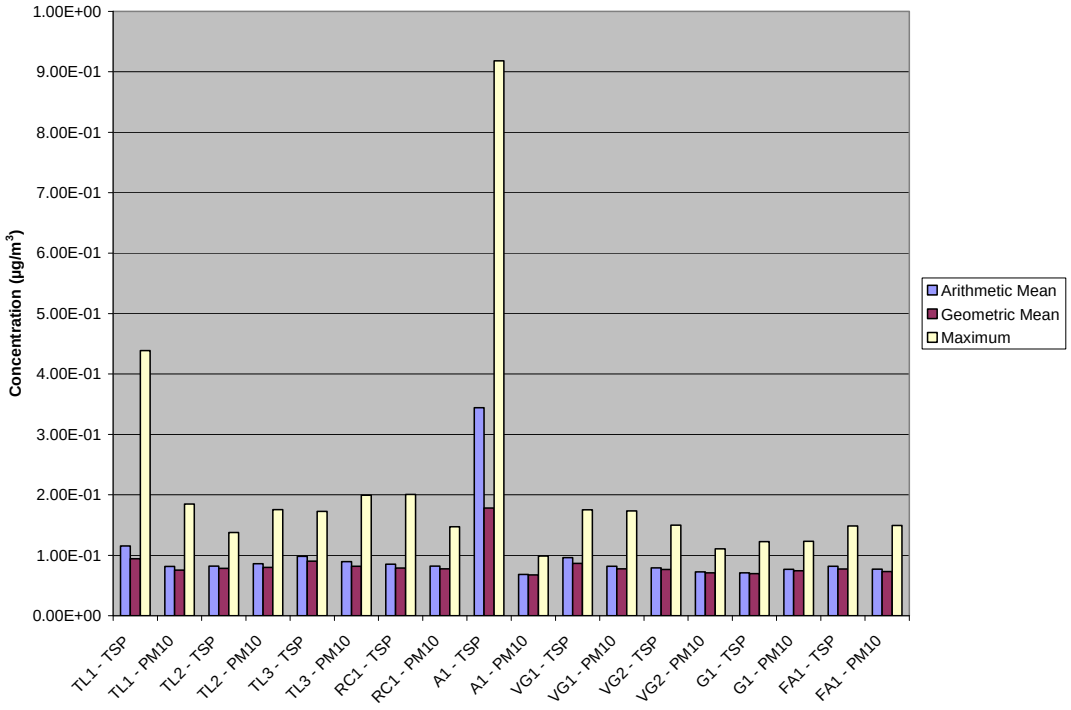


Figure 3.23: Selenium in TSP and PM_{10}

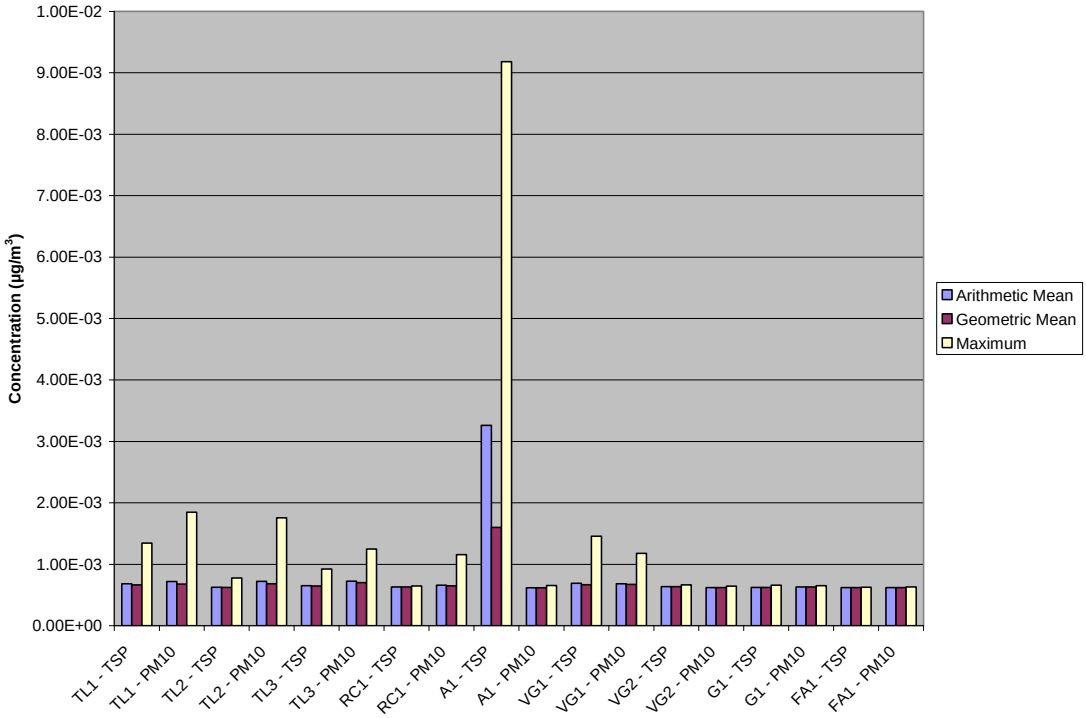


Figure 3.24: Silver in TSP and PM_{10}

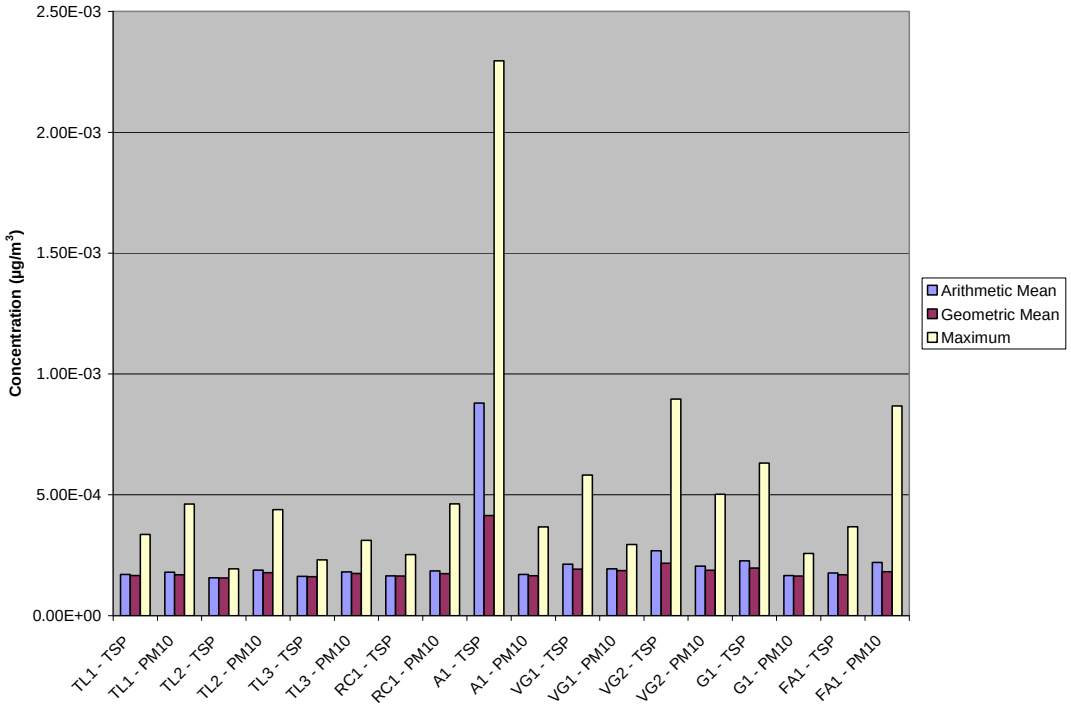


Figure 3.25: Sodium in TSP and PM_{10}

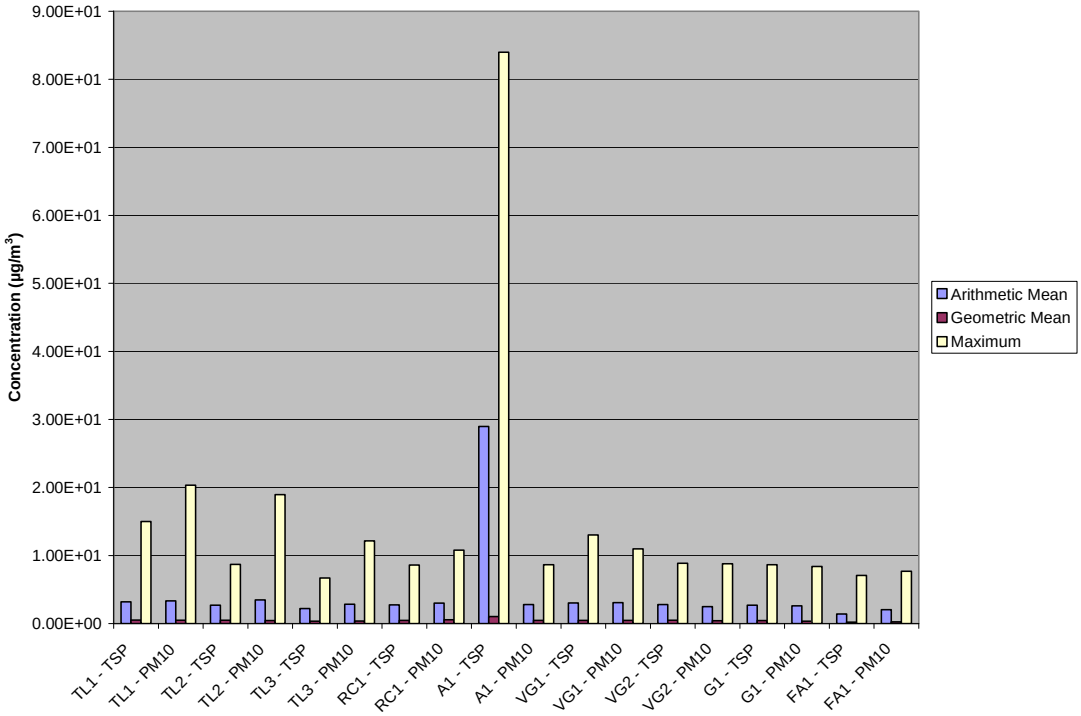


Figure 3.26: Strontium in TSP and PM_{10}

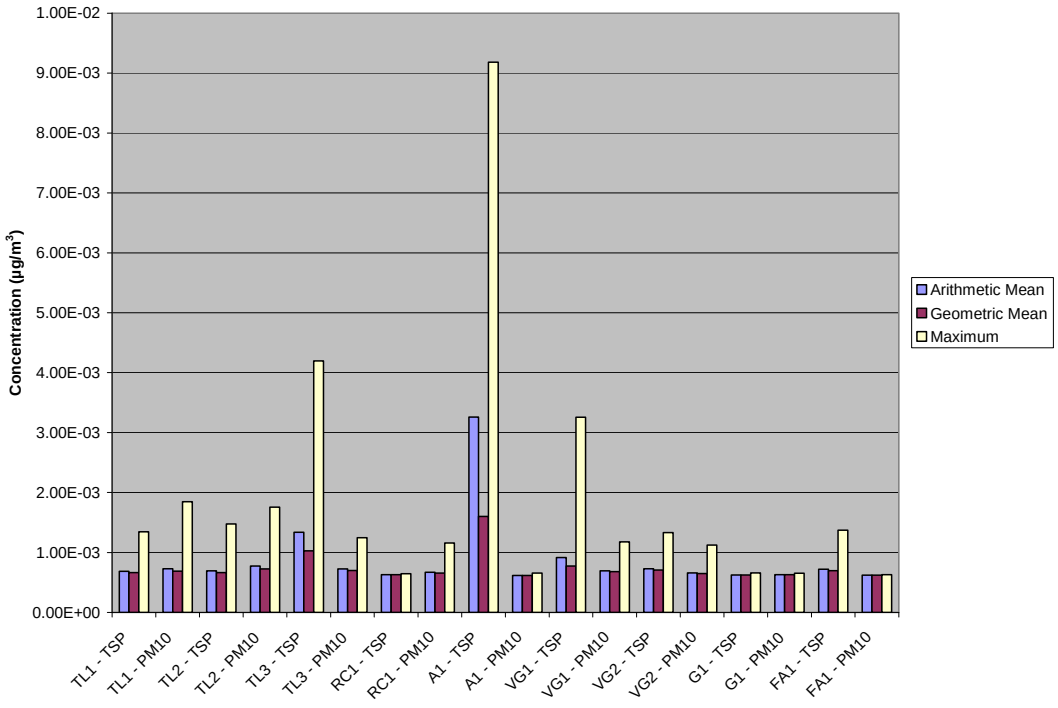


Figure 3.27: Tellurium in TSP and PM_{10}

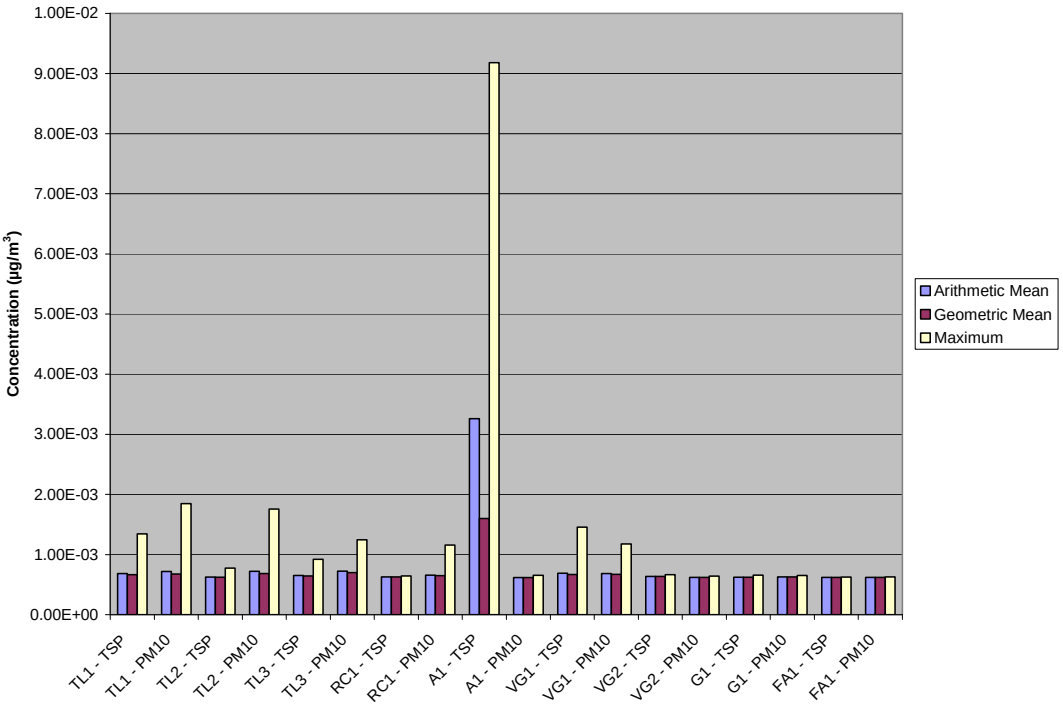


Figure 3.28: Thallium in TSP and PM_{10}

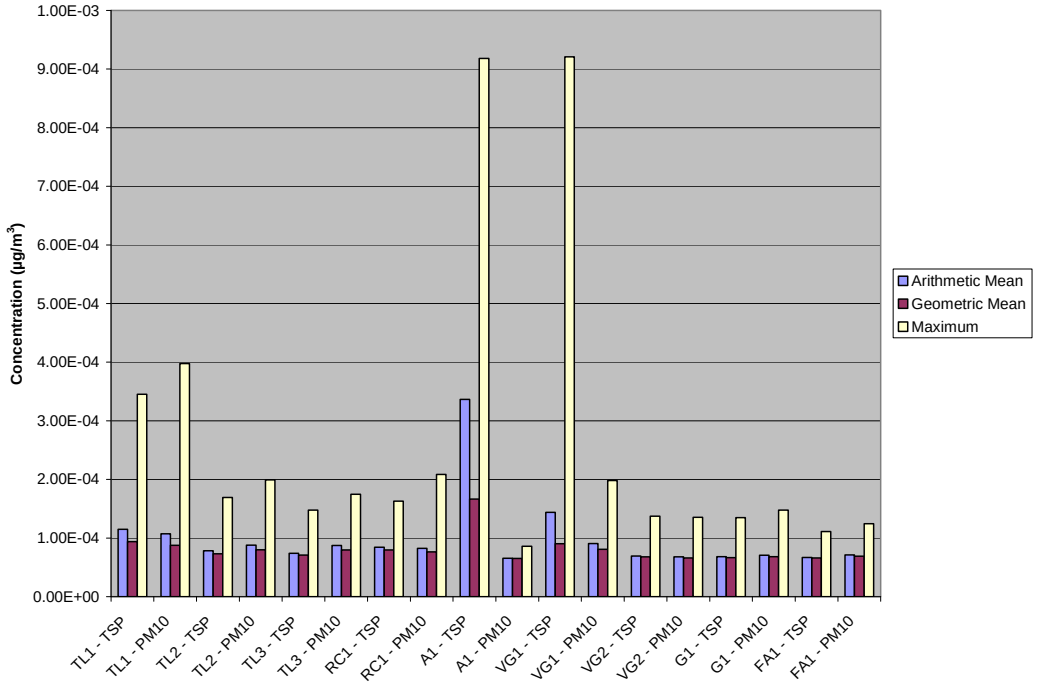


Figure 3.29: Tin in TSP and PM_{10}

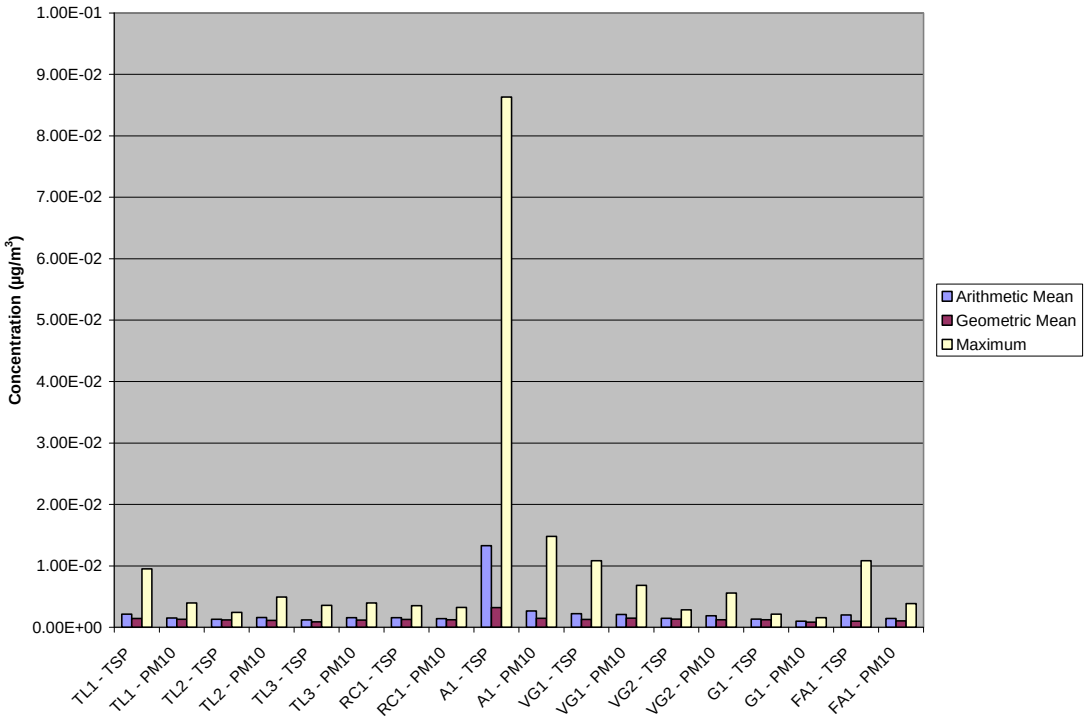


Figure 3.30: Titanium in TSP and PM_{10}

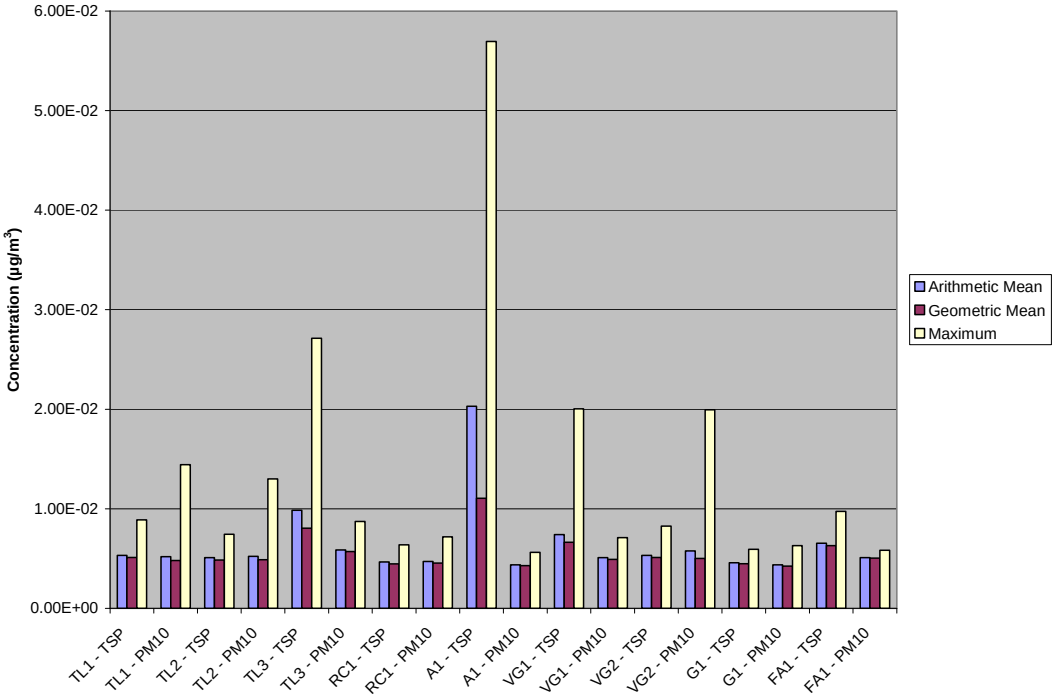


Figure 3.31: Vanadium in TSP and PM_{10}

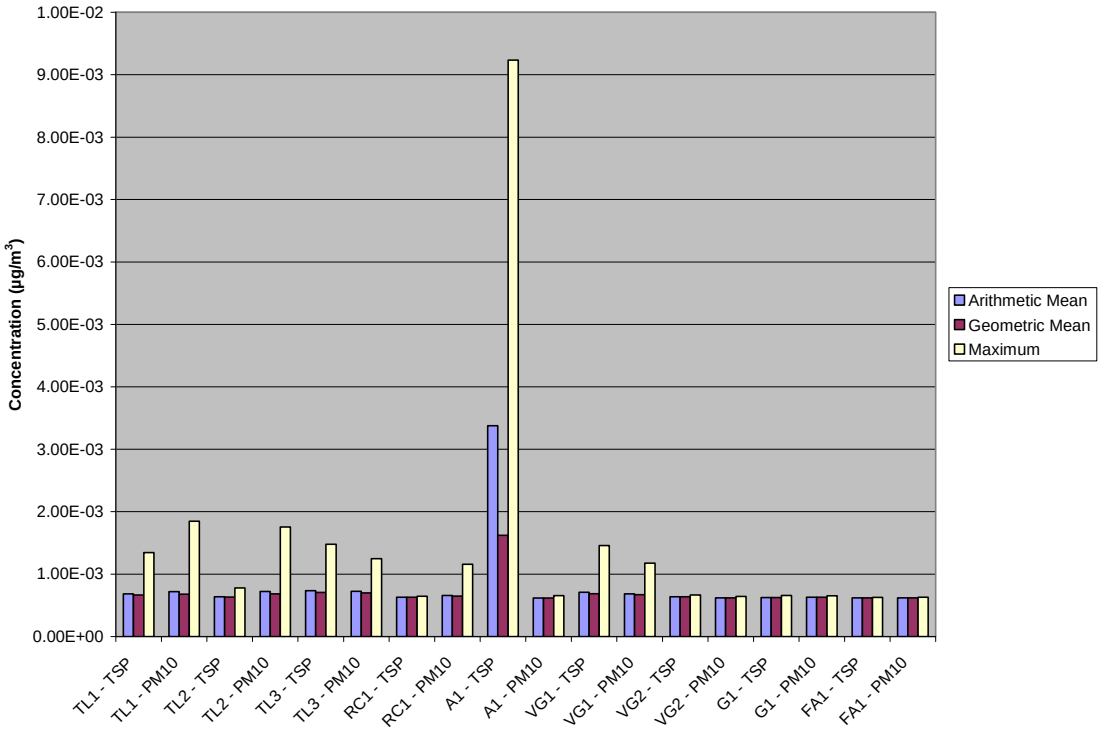


Figure 3.32: Zinc in TSP and PM_{10}

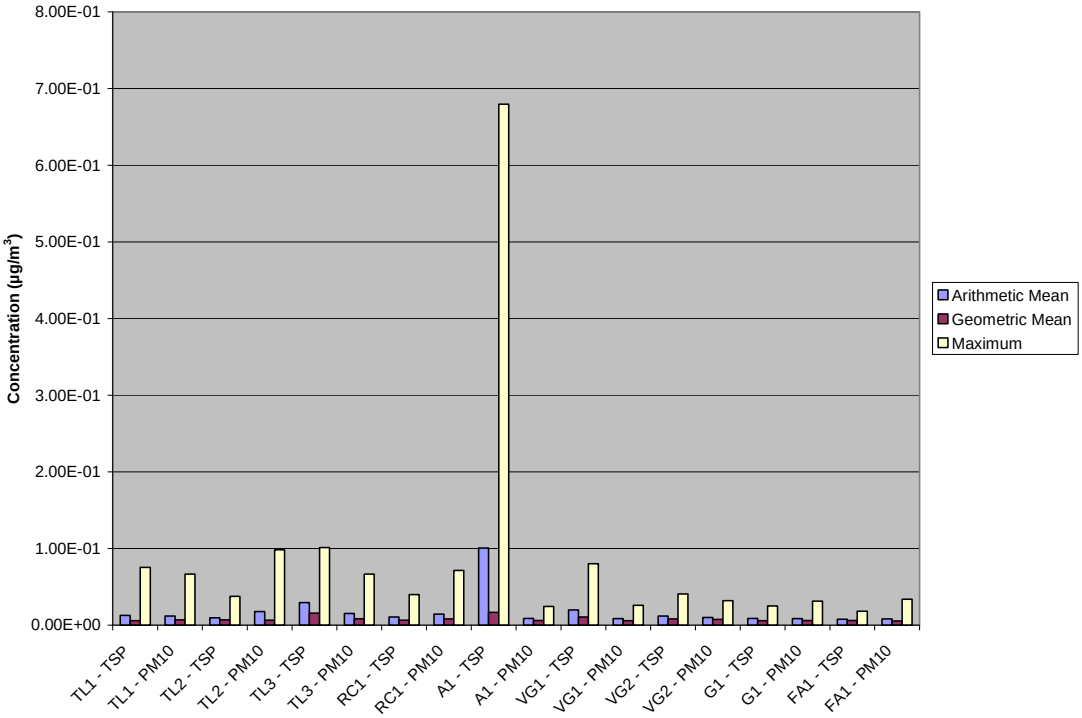
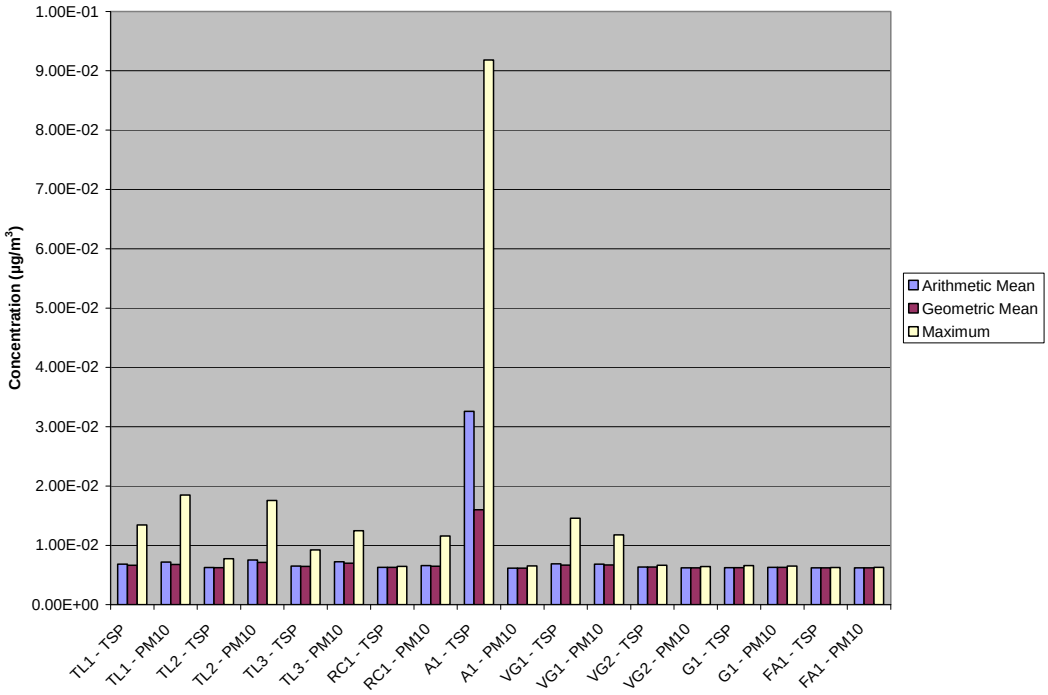


Figure 3.33: Zirconium in TSP and PM_{10}



3.1.4 Samples with Elevated Particulate Matter Concentrations

As noted in Section 3.1.2, the highest TSP concentrations were recorded on September 9th with concentrations of 95.5 μg/m^3 at site VG2 and 70.6 5 μg/m^3 at site TL1. The second highest sampling period for TSP concentrations occurred on August 4th with concentrations of 38.2 μg/m^3 at site TL3, 40.1 μg/m^3 at site VG1, and 36 μg/m^3 at site VG2. Figures 3.34 and 3.35 show that the levels of TSP at the other sampling sites were much lower on both days, as were the PM_{10} levels at all 9 sites. Therefore, the higher levels of TSP on August 4th and September 9th were limited to the TL1, TL3, VG1 and VG2 sites.

Figure 3.36 shows the elemental composition of the TSP samples at sites VG2 and TL1 on September 9th. They indicate that the major trace elemental constituents of the TSP consisted of aluminium, boron, calcium, chromium, iron, magnesium, phosphorus, potassium and sodium. Similarly, Figure 3.37 indicates that the elevated TSP samples on August 4th contained large amount of sodium, with smaller concentrations of aluminium, calcium, iron and magnesium.

There are no ambient air quality criteria for aluminium, calcium, magnesium, phosphorus, potassium or sodium as these are not of concern to human health (see Table 3.3, Section 3.1.3). Boron is only of concern with respect to exposure as particulate matter, while the AAQC for iron is based on soiling effects, not health concerns. Therefore, of the major constituents present on the TSP samples on August 4th and September 9th, only chromium is of concern to human health, and the maximum chromium concentration of 0.0752 μg/m^3 on September 9th was only 1/20th of the AAQC of 1.5 μg/m^3.

This level of chromium was comparable to the highest concentrations measured at any of the sites during the sampling program (see Figure 3.12), with the exception of the anomalous value recorded at site A1 on August 4th during an abbreviated sampling period lasting less than 2 hours. During that brief sampling period, the TSP level was 110.2 μg/m^3 (see Table A.1, Appendix A), with a chromium concentration of 1.16 μg/m^3. This suggests that both the TSP and chromium levels at A1 could have approached their criteria levels of 120 μg/m^3 and 1.5 μg/m^3, respectively, if the sampling period had been completed over the entire 24-hour period. Therefore, while the sampling program at site A1 was largely unsuccessful, with only 3 complete samples of the 13 sampling periods in 2008, the values on August 4th suggest that elevated concentrations at that location may be present and that sampling should be continued at this site in the future.

Figure 3.36: Elemental Composition of TSP Samples at Sites TL1 and VG2
September 9, 2008

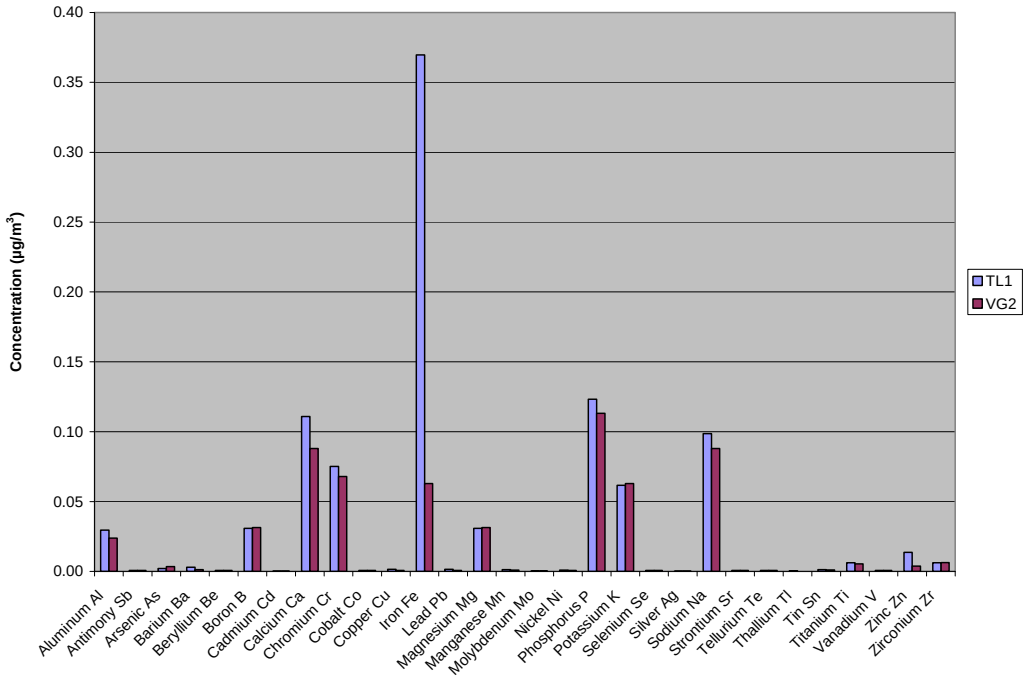
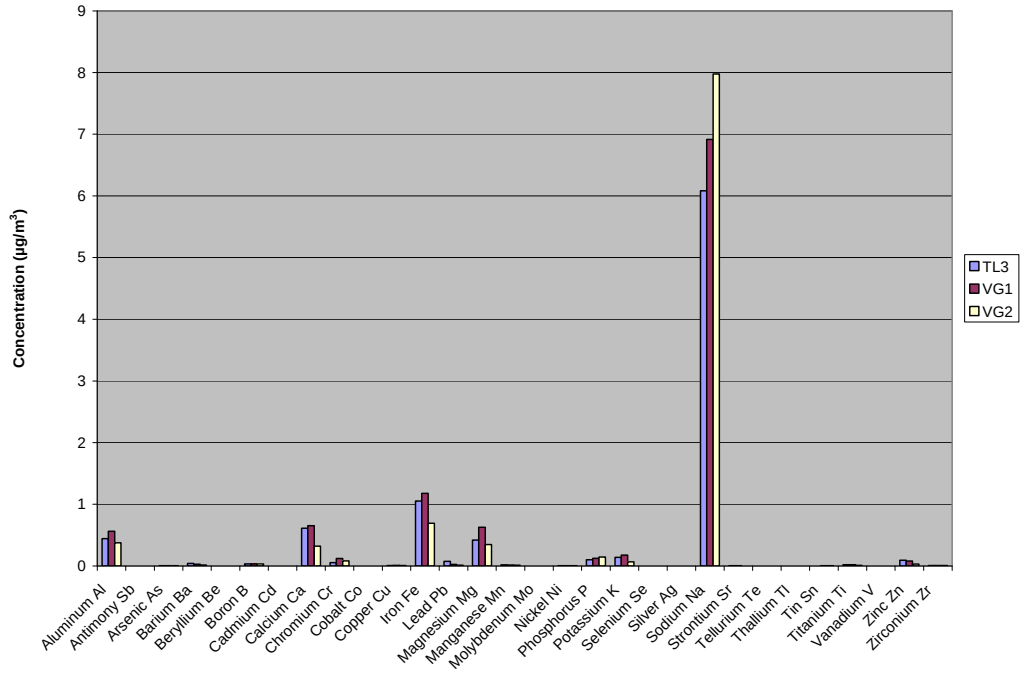
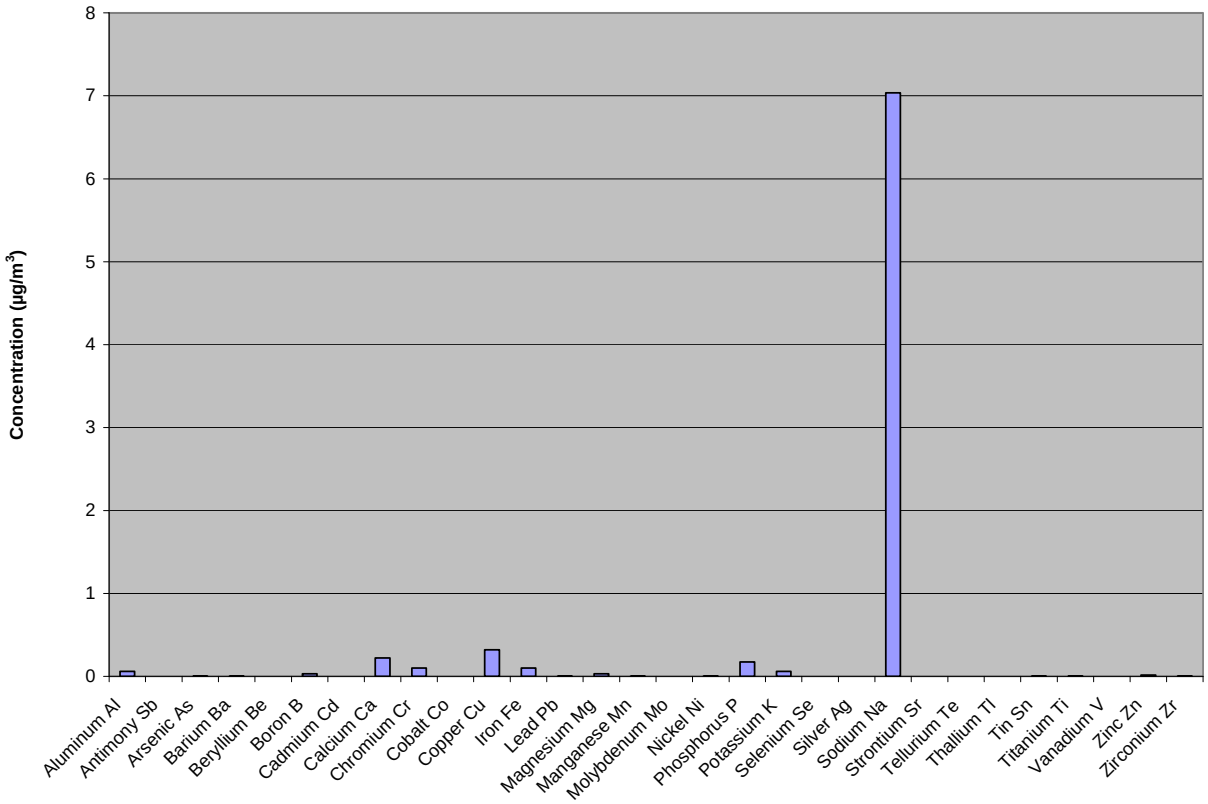


Figure 3.37: Elemental Composition of TSP Samples at Sites TL3, VG1 and VG2
August 4, 2008



The highest PM_{10} concentration during the sampling program was 24.7 µg/m^3 and was recorded at site RC1 on July 23rd. All other PM_{10} samples on that date were much lower at ≤12 µg/m^3. Figure 3.38 indicates that sodium was the major elemental constituent of the sample at RC1 on that date. Smaller quantities of aluminium, calcium, chromium, copper, iron, phosphorus and potassium were also present.

Figure 3.38
Elemental Composition of PM_{10} Sample at Site RC1
July 23, 2008



3.2 DUSTFALL SAMPLES

Table 3.5 lists the concentrations of total particulate matter and trace inorganic elements derived from the three sets of dustfall samples collected at site TL1 in 2008. The total dustfall was very low, with two of the samples (July and September) having dustfall levels at the method detection limit. The low value in July was not surprising because the sample represented only about half the month's potential dustfall deposition (i.e., from July 17th to 31st).

The maximum total dustfall deposition rate occurred in August with a rate of 0.12 mg/dm^2.day, although July's rate might have been higher if the sample had been collected over the entire month. This maximum deposition rate is an order of magnitude lower than the established dustfall criteria in British Columbia, Alberta and Ontario, as well as for new mines in Australia (see Table 3.6). It is also well below the most stringent dustfall depositions rates considered acceptable in residential areas of the United Kingdom and New York State.

The low dustfall levels are consistent with the generally low particulate matter concentrations observed in the TSP and PM_{10} samples.

With respect to elemental composition, most of the trace inorganic constituents were below the method detection limits for all three samples. The only contaminants that were observed to be higher than the detection limits included:

Arsenic (As)	Lead (Pb)
Barium (Ba)	Manganese (Mn)
Cadmium (Cd)	Molybdenum (Mo)
Calcium (Ca)	Silver (Ag)
Copper (Cu)	Strontium (Sr)
Iron (Fe)	Zinc (Zn)

With the exception of As and Zn, the remainder of the above elements were also noted to have somewhat elevated concentrations relative to the Town of Faro in the TSP and PM_{10} samples. This indicates a reasonable degree of consistency between the TSP/PM_{10} samples and the dustfall samples.

The highest concentrations of these 12 constituents in dustfall samples occurred either in July or August. All concentrations in the September sample were lower than in the previous two sampling periods.

Table 3.5
Summary of Dustfall Sampling Results

Contaminant	Date Sampled			Maximum	MDL
	17-31 Jul 08	1-31 Aug 08	1-30 Sep 08		
Particulate Matter					
Total Dustfall	<0.18	0.12	<0.10	0.12	
Total Insoluble Dustfall	<0.18	<0.10	<0.10	<0.18	
Total Soluble Dustfall	<0.18	<0.10	<0.10	<0.18	
Trace Inorganic Elements					
Aluminum (Al)-Total	0.000578	0.000700	0.000338	0.000700	0.00002
Antimony (Sb)-Total	<0.0000020	<0.0000020	<0.0000020	<0.0000020	0.000002
Arsenic (As)-Total	0.0000027	0.0000040	<0.0000020	0.0000040	0.000002
Barium (Ba)-Total	0.000157	0.000245	0.000153	0.000245	0.000001
Beryllium (Be)-Total	<0.000010	<0.000010	<0.000010	<0.000010	0.00001
Bismuth (Bi)-Total	<0.000010	<0.000010	<0.000010	<0.000010	0.00001
Boron (B)-Total	<0.00020	<0.00020	<0.00020	<0.00020	0.0002
Cadmium (Cd)-Total	0.0000014	<0.0000010	<0.0000010	0.0000014	0.000001
Calcium (Ca)-Total	0.0051	0.0015	0.0028	0.0051	0.001
Chromium (Cr)-Total	<0.000010	<0.000010	<0.000010	<0.000010	0.00001
Cobalt (Co)-Total	<0.0000020	<0.0000020	<0.0000020	<0.0000020	0.000002
Copper (Cu)-Total	0.00664	0.00316	0.00302	0.00664	0.000002
Iron (Fe)-Total	<0.00070	0.00075	<0.00070	0.00075	0.0007
Lead (Pb)-Total	0.0000675	0.0000553	0.0000238	0.0000675	0.000001
Lithium (Li)-Total	<0.00010	<0.00010	<0.00010	<0.00010	0.0001
Magnesium (Mg)-Total	<0.0020	<0.0020	<0.0020	<0.0020	0.002
Manganese (Mn)-Total	0.0000590	0.0000360	0.0000286	0.0000590	0.000001
Mercury (Hg)-Total	<0.0000010	<0.0000010	<0.0000020	<0.0000020	0.000001
Molybdenum (Mo)-Total	0.0000022	0.0000041	<0.0000010	0.0000041	0.000001
Nickel (Ni)-Total	<0.000010	<0.000010	<0.000010	<0.000010	0.00001
Phosphorus (P)-Total	<0.0070	<0.0070	<0.0070	<0.0070	0.007
Potassium (K)-Total	<0.050	<0.050	<0.050	<0.050	0.05
Selenium (Se)-Total	<0.000020	<0.000020	<0.000020	<0.000020	0.00002
Silicon (Si)-Total	<0.0010	<0.0010	<0.0010	<0.0010	0.001
Silver (Ag)-Total	0.00000037	0.00000041	<0.00000020	0.00000041	0.0000002
Sodium (Na)-Total	<0.050	<0.050	<0.050	<0.050	0.05
Strontium (Sr)-Total	0.0000174	0.0000077	0.0000066	0.0000174	0.000002
Thallium (Tl)-Total	<0.0000020	<0.0000020	<0.0000020	<0.0000020	0.000002
Tin (Sn)-Total	<0.0000020	<0.0000020	<0.0000020	<0.0000020	0.000002
Titanium (Ti)-Total	<0.00020	<0.00020	<0.00020	<0.00020	0.0002
Uranium (U)-Total	<0.00000020	<0.00000020	<0.00000020	<0.00000020	0.0000002
Vanadium (V)-Total	<0.000020	<0.000020	<0.000020	<0.000020	0.00002
Zinc (Zn)-Total	0.000267	0.000068	0.000071	0.000267	0.00002

Elements in **bold** indicate those which had concentrations above the MDL

Table 3.6
Dustfall Criteria from Various Jurisdictions

Jurisdiction	Application	Dustfall Criteria ($mg/dm^2.day$)	Comments
British Columbia	desirable	1.75	
Alberta	residential & recreational areas	1.75	averaged over 30 days
	commercial & recreational areas	5.3	averaged over 30 days
Ontario		2.3	averaged over 30 days
Australia	new mines	1.3	pro-rata compensation if level exceeded
		3.3	total compensation if level exceeded
United Kingdom	open country	1	95th percentile - complaints likely if exceeded
	residential areas	1.5	95th percentile - complaints likely if exceeded
	commercial areas	1.9	95th percentile - complaints likely if exceeded
New York	Level I	1	
	Level II	1	
	Level III	1.3	
	Level IV	2	

The amount of dustfall in a month strongly depends on precipitation rates during that time. Since summer 2008 was noted to be a relatively wet summer, the dustfall amounts recorded and presented in this report may be lower than would be found in other years.

4.0 SUMMARY AND RECOMMENDATIONS

The TSP and PM_{10} sampling program was successfully completed at nine locations over the period July 17th to October 3rd, 2008. In addition, dustfall sampling was conducted at one of the TSP/PM_{10} sampling sites.

Data recovery of the TSP samples ranged between 54% and 77% for eight of the sampling sites, but only 24% at the key A1 site near the Faro mine pit. Data recovery was lower for PM_{10} samples than for TSP samples, ranging from 39% to 69%. Part of the reason for the low data recovery at some sites was due to operator error in the early part of the program due to unfamiliarity of the operator with the equipment. This was corrected after the initial period with help from an individual at the mine site who had previously operated similar samplers. It is hoped that the data recovery will be improved in 2009 if the same operator can be retained in order to minimize operational errors.

Many of the samples collected in 2008 had very low particulate matter loadings on the filters. This was also true of the dustfall samples collected at site TL1. Especially during sampling periods in September, many TSP/ PM_{10} samples were close to the 'noise' level of the MiniVol™ samplers of 5 $\mu g/m^3$, while two of the three dustfall samples were essentially below the method detection limit for dustfall sampling. These low particulate matter concentrations affected the degree to which trace elemental analysis could be used to determine concentrations of heavy metals in the samples. Although the standard TSP/PM_{10} sampling period for particulate matter is 24 hours, the program should consider increasing the sampling period to 48 hours in 2009 in order to provide higher filter loadings for laboratory analysis. The battery packs on the MiniVol™ samplers can be run for longer periods of up to 48 hours, so there is no operational limitation for increasing the sampling period.

There were some concerns related to a few samples where the measured PM_{10} concentrations were higher than the TSP levels at a given location. While operator error in mislabelling samples may be one cause for such discrepancies, it is also possible that some filters were damaged during handling. Furthermore, the space at the administration complex at the mine site that was made available for use in loading/unloading filters was not ideal with respect to minimizing dust levels during sample handling. It would benefit the monitoring program if a more suitable location could be identified for the 2009 sampling program.

Based on the results of the 2008 sampling program, all measured TSP, PM_{10} and trace inorganic elements were well within established ambient air quality criteria for all elements. Trace elemental concentrations were generally higher in July and August than in September, indicating that sampling in the early part of the summer season (June, July and early August) may be more important than sampling in late September or October.

The overall conclusion of the 2008 sampling program is that particulate matter and trace inorganic element concentrations at the Faro Mine Complex were very low, and were often similar to levels recorded in the Town of Faro. Even during the periods with the highest TSP loadings, the composition of the particulate matter is primarily made up of trace elements which either have no ambient air quality criteria or are not of concern for human health exposure. The exception may be chromium, although the concentrations of this trace metal remained well below any level of concern.

It is recommended that the particulate matter sampling program be continued in 2009 with the following changes:

1. The sampling program should be initiated as soon as possible after the loss of snow cover in late May or early June, depending on site conditions. The continuation of the sampling program to the end of September should be reconsidered, with a termination date in early September at the latest.
2. The same nine sampling sites should be retained for 2009, but the sampling periods should be extended to 48 hours in order to obtain higher particle loadings on the filters.
3. It would be preferable to add at least three additional dustfall sampling sites to the program. These should be established at sites RC1, A1 and VG2.
4. In order to minimize material loss or damage to the filters during handling, it is recommended that a 'clean' room be identified for this purpose. If this cannot be done at the mine administration building, consideration should be given to finding a location in the Town of Faro for that purpose.

APPENDIX A

MiniVol™ Sampler Data and Mass Concentration Calculation Data

Table A.1: TSP/PM_{10} Sampler Data – July 2008

Start Date	Location	MiniVol Unit #	Filter ID	RotoFlow (start)	RotoFlow (end)	Average	Daily Average Temperature (K)	Daily Average Pressure (mm Hg)	Qact (L/min)	Elasped Time Start	Elasped Time End	Sampling Duration (min)	Volume Sampled (m^3)	TSP Result (mg)	TSP Result (µg)	TSP Concentration (µg/m3)	Comments
17-Jul-08	TL1 - PM10	4854	P8634	5	5	5	286.1	668.6	5.590	0.0	24.0	1,440	8.1	0.07	70	8.7	
	TL1 - TSP	4841	P8633	5	5	5	286.1	668.6	5.695	0.0	24.0	1,440	8.2	0.09	90	11.0	
	TL2 - PM10	4848	P8632	5	5	5	286.1	668.6	5.584	0.0	24.0	1,440	8.0	0.13	130	16.2	
	TL2 - TSP	4858	P8631	5	4.5	4.75	286.1	668.6	5.340	0.0	24.0	1,440	7.7	0.06	60	7.8	
	TL3 - PM10	4849	8682	5	5	5	286.1	668.6	5.636	0.0	12.0	720	4.1	0.08	80	19.7	Elapsed time was lower than the others.
	TL3 - TSP	4844	8696	5	5	5	286.1	668.6	5.634	0.0	24.0	1,440	8.1	0.23	230	28.3	
	RC1 - PM10	4843	8630	5	5	5	286.1	668.6	5.677	0.0	24.0	1,440	8.2	0.09	90	11.0	
	RC1 - TSP	4857	8627	5	5	5	286.1	668.6	5.559	0.0	24.0	1,440	8.0	0.15	150	18.7	
	A1 - PM10	4845	8629	5	4.3	4.65	286.1	668.6	5.297	0.0	24.0	1,440	7.6	0.09	90	11.8	Filter was put in upside down.
	A1 - TSP	4853	8622	5	3	4	286.1	668.6	4.517	0.0	3.3	198	0.9	0.12	120	134.2	Elapsed time and Rotoflow was lower than the others.
	VG1 - PM10	4852	8623	5	4	4.5	286.1	668.6	5.030	0.0	24.0	1,440	7.2	0.14	140	19.3	
	VG1 - TSP	4855	8620	5	5	5	286.1	668.6	5.592	0.0	24.0	1,440	8.1	0.16	160	19.9	
	VG2 - PM10	4856	8624	5	4.5	4.75	286.1	668.6	5.395	0.0	24.0	1,440	7.8	0.06	60	7.7	
	VG2 - TSP	4850	8628	5	4.5	4.75	286.1	668.6	5.281	0.0	24.0	1,440	7.6	0.18	180	23.7	Filter was put in upside down.
	G1 - PM10	4842	8618	5	4.5	4.75	286.1	668.6	5.385	0.0	24.0	1,440	7.8	0.05	50	6.4	
	G1 - TSP	4846	8621	5	4.5	4.75	286.1	668.6	5.389	0.0	24.0	1,440	7.8	0.14	140	18.0	
	FA1 - PM10	4851	8616	5	5	5	286.1	668.6	5.602	0.0	24.0	1,440	8.1	0.09	90	11.2	
	FA1 - TSP	4847	8613	5	5	5	286.1	668.6	5.655	0.0	24.0	1,440	8.1	0.14	140	17.2	
23-Jul-08	TL1 - PM10	4854	P8700	5	4.8	4.9	280.5	669.3	5.414	24.0	48.0	1,440	7.8	0.05	50.00	6.4	
	TL1 - TSP	4841	P8679	5	5	5	280.5	669.3	5.636	24.1	48.0	1,434	8.1	0.06	60.00	7.4	
	TL2 - PM10	4848	P8661	5	5	5	280.5	669.3	5.526	24.0	48.0	1,440	8.0	0.05	50.00	6.3	In field log, the elapsed time is zero but this appears to be a written error.
	TL2 -TSP	4858	P8702	5	4.8	4.9	280.5	669.3	5.460	24.0	48.0	1,440	7.9	0.06	60.00	7.6	
	TL3 - PM10	4849	P8626	5	4.8	4.9	280.5	669.3	5.455	12.0	36.0	1,440	7.9	< 0.04	40.00	*5.1*	
	TL3 - TSP	4844	P8657	5	4.5	4.75	280.5	669.3	5.275	24.0	48.0	1,440	7.6	0.08	80.00	10.5	
	RC1 - PM10	4843	P8701	5	5	5	280.5	669.3	5.618	24.0	48.0	1,440	8.1	0.2	200.00	24.7	
	RC1 - TSP	4857	P8699	5	5	5	280.5	669.3	5.501	24.0	48.0	1,440	7.9	0.06	60.00	7.6	
	A1 - PM10	4845	P8697	5	5	5	280.5	669.3	5.655	24.0	47.9	1,434	8.1	0.1	100.00	12.3	
	A1 - TSP	4853	P8680	5	3	4	280.5	669.3	4.470	3.3	5.6	138	0.6	< 0.04	40.00	*64.8*	
	VG1 - PM10	4852	P8681	5	5	5	280.5	669.3	5.569	24.0	48.0	1,440	8.0	< 0.04	40.00	*5.0*	
	VG1 - TSP	4855	P8656	5	5	5	280.5	669.3	5.534	24.0	48.0	1,440	8.0	0.08	80.00	10.0	
	VG2 - PM10	4856	P8653	5	5	5	280.5	669.3	5.636	24.0	48.0	1,440	8.1	< 0.04	40.00	*4.9*	
	VG2 - TSP	4850	P8660	5	4.5	4.75	280.5	669.3	5.226	24.0	48.0	1,440	7.5	< 0.04	40.00	*5.3*	
	G1 - PM10	4842	P8654	5	4	4.5	280.5	669.3	5.034	24.0	24.0	0	0.0	0.04	40.00	#DIV/0!	
	G1 - TSP	4846	P8655	5	5	5	280.5	669.3	5.628	24.0	48.0	1,440	8.1	0.05	50.00	6.2	
	FA1 - PM10	4851	P8676	5	5	5	280.5	669.3	5.544	24.0	48.0	1,440	8.0	0.09	90.00	11.3	
	FA1 - TSP	4847	P8658	5	5	5	280.5	669.3	5.596	24.0	48.0	1,440	8.1	0.09	90.00	11.2	
29-Jul-08	TL1 - PM10	4854	P8698	5	0	2.5	283.5	663.7	2.591	48.0	65.4	1,044	2.7	0.09	90.00	33.3	No Rotoflow, no noise.
	TL1 - TSP	4841	P8688	5	0	2.5	283.5	663.7	2.764	48.0	70.4	1,344	3.7	< 0.04	40.00	*10.8*	No Rotoflow, no noise.
	TL2 - PM10	4848	P8683	5	5	5	283.5	663.7	5.579	24.0	32.5	510	2.8	0.1	100.00	35.1	Dead battery
	TL2 -TSP	4858	P8695	5	4.5	4.75	283.5	663.7	5.335	48.0	72.0	1,440	7.7	0.09	90.00	11.7	
	TL3 - PM10	4849	P8686	5	5	5	283.5	663.7	5.630	36.0	60.0	1,440	8.1	0.14	140.00	17.3	
	TL3 - TSP	4844	P8693	5	5	5	283.5	663.7	5.629	48.0	72.0	1,440	8.1	0.27	270.00	33.3	
	RC1 - PM10	4843	P8684	5	5	5	283.5	663.7	5.671	48.0	72.0	1,440	8.2	0.08	80.00	9.8	
	RC1 - TSP	4857	P8687	5	5	5	283.5	663.7	5.553	48.0	72.0	1,440	8.0	0.14	140.00	17.5	
	A1 - PM10	4845	P8685	5	5	5	283.5	663.7	5.709	47.9	71.9	1,440	8.2	0.11	110.00	13.4	
	A1 - TSP	4853	P8650	5	3	4	283.5	663.7	4.513	5.6	8.0	144	0.6	< 0.04	40.00	*61.6*	
	VG1 - PM10	4852	P8649	5	5	5	283.5	663.7	5.622	48.0	60.6	756	4.3	0.04	40.00	9.4	Battery was dead when arrived on site.
	VG1 - TSP	4855	P8643	5	0	2.5	283.5	663.7	2.556	48.0	70.4	1,344	3.4	0.06	60.00	17.5	No Rotoflow, no noise.
	VG2 - PM10	4856	P8651	5	4.8	4.9	283.5	663.7	5.570	48.0	72.0	1,440	8.0	0.08	80.00	10.0	
	VG2 - TSP	4850	P8644	5	5	5	283.5	663.7	5.579	48.0	72.0	1,440	8.0	0.09	90.00	11.2	
	G1 - PM10	4842	P8646	5	4.5	4.75	283.5	663.7	5.380	24.0	48.0	1,440	7.7	0.09	90.00	11.6	
	G1 - TSP	4846	P8645	5	4.3	4.65	283.5	663.7	5.265	48.0	72.0	1,440	7.6	0.07	70.00	9.2	
	FA1 - PM10	4851	P8691	5	5	5	283.5	663.7	5.597	48.0	72.0	1,440	8.1		0.00	0.0	
	FA1 - TSP	4847	P8694	5	5	5	283.5	663.7	5.649	48.0	72.0	1,440	8.1		0.00	0.0	

Notes:

Cells highlighted in yellow indicate that MiniVols did not run for a 24 hr sampling period

Cells highlighted in green indicate that samples were not submitted for analysis.

Cells highlighted in blue indicate that hand writing on sampling log was not legible

Concentrations in italics were calculated at the method detection limit

Table A.2: TSP/PM_{10} Sampler Data – August 2008

Start Date	Location	MiniVol Unit #	Filter ID	RotoFlow (start)	RotoFlow (end)	Average	Daily Average Temperature (K)	Daily Average Pressure (mm Hg)	Qact (L/min)	Elasped Time Start	Elasped Time End	Sampling Duration (min)	Volume Sampled (m^3)	TSP Result (mg)	TSP Result (µg)	TSP Concentration (µg/m3)	Comments
4-Aug-08	TL1 - PM10	4854	P8662	5	4.8	4.9	283.6	674.0	4.652	65.4	94.4	1,740	8.1	0.05	50.00	6.2	
	TL1 - TSP	4841	P8664	5	5	5	283.6	674.0	5.066	70.4	89.4	1,140	5.8	0.08	80.00	13.9	
	TL2 - PM10	4848	P8665	5	5	5	283.6	674.0	5.537	32.5	32.5	0	0.0	0.05	50.00	#DIV/0!	
	TL2 - TSP	4858	P8666	5	4.8	4.9	283.6	674.0	5.471	72.0	96.0	1,440	7.9	0.07	70.00	8.9	
	TL3 - PM10	4849	P8670	5	5	5	283.6	674.0	5.588	60.0	83.9	1,434	8.0	0.1	100.00	12.5	
	TL3 - TSP	4844	P8669	5	4.8	4.9	283.6	674.0	5.466	72.0	96.0	1,440	7.9	0.301	301.00	38.2	
	RC1 - PM10	4843	P8668	5	5	5	283.6	674.0	5.629	72.0	84.8	768	4.3	0.07	70.00	16.2	
	RC1 - TSP	4857	P8667	5	4.8	4.9	283.6	674.0	5.392	72.0	95.9	1,434	7.7	0.06	60.00	7.8	
	A1 - PM10	4845	P8642	5	5	5	283.6	674.0	5.666	71.9	95.9	1,440	8.2	< 0.04	40.00	*4.9*	
	A1 - TSP	4853	P8647	5	3.5	4.25	283.6	674.0	4.776	8.0	9.9	114	0.5	0.06	60.00	110.2	
	VG1 - PM10	4852	P8641	5	4	4.5	283.6	674.0	4.988	60.6	84.6	1,440	7.2	0.09	90.00	12.5	
	VG1 - TSP	4855	P8703	5	5	5	283.6	674.0	5.545	70.4	94.4	1,440	8.0	0.32	320.00	40.1	
	VG2 - PM10	4856	P8648	5	4.8	4.9	283.6	674.0	5.528	72.0	96.0	1,440	8.0	0.04	40.00	5.0	Ripped filter.
	VG2 - TSP	4850	P8614	5	4.5	4.75	283.6	674.0	5.237	72.0	95.9	1,434	7.5	0.27	270.00	36.0	
	G1 - PM10	4842	P8690	5	4.5	4.75	283.6	674.0	5.340	48.0	72.0	1,440	7.7	0.06	60.00	7.8	
	G1 - TSP	4846	P8615	5	4.8	4.9	283.6	674.0	5.521	72.0	95.9	1,434	7.9	0.09	90.00	11.4	
	FA1 - PM10	4851	P8692	5	5	5	283.6	674.0	5.555	72.0	95.9	1,434	8.0	0.096	96.00	12.1	
	FA1 - TSP	4847	P8619	5	5	5	283.6	674.0	5.607	72.0	72.0	0	0.0	0.045	45.00	#DIV/0!	
10-Aug-08	TL1 - PM10	4854	P8678	5	4.5	4.75	282.3	669.2	5.253	94.4	118.4	1,440	7.6	0.07	70.00	9.3	
	TL1 - TSP	4841	P8635	5	5	5	282.3	669.2	5.654	89.4	113.4	1,440	8.1	0.055	55.00	6.8	
	TL2 - PM10	4848	P8675	5	5	5	282.3	669.2	5.545	32.5	56.5	1,440	8.0	0.09	90.00	11.3	
	TL2 - TSP	4858	P8677	5	9	7	282.3	669.2	7.944	96.0	119.5	1,410	11.2	0.064	64.00	5.7	
	TL3 - PM10	4849				#DIV/0!	282.3	669.2				0	0.0		0.00	#DIV/0!	No Filter
	TL3 - TSP	4844				#DIV/0!	282.3	669.2				0	0.0		0.00	#DIV/0!	No Filter
	RC1 - PM10	4843	P8672	5	5	5	282.3	669.2	5.636	84.8	108.8	1,440	8.1	0.068	68.00	8.4	
	RC1 - TSP	4857	P8671	5	5	5	282.3	669.2	5.519	95.4	119.9	1,470	8.1	< 0.04	40.00	*4.9*	
	A1 - PM10	4845	P8674	5	5	5	282.3	669.2	5.673	95.9	119.9	1,440	8.2	0.051	51.00	6.2	
	A1 - TSP	4853	P8673	5	3	4	282.3	669.2	4.485	9.9	12.6	162	0.7	< 0.04	40.00	*55.1*	
	VG1 - PM10	4852	P8638	5	4	4.5	282.3	669.2	4.994	84.6	108.6	1,440	7.2	0.051	51.00	7.1	
	VG1 - TSP	4855	P8639	5	5	5	282.3	669.2	5.552	94.4	118.4	1,440	8.0	0.12	120.00	15.0	
	VG2 - PM10	4856	P8652	5	5	5	282.3	669.2	5.655	96.0	120.0	1,440	8.1	0.061	61.00	7.5	
	VG2 - TSP	4850	P8640	5	4.8	4.9	282.3	669.2	5.424	95.9	119.9	1,440	7.8	0.04	40.00	5.1	
	G1 - PM10	4842	P8636	5	4.5	4.75	282.3	669.2	5.347	72.0	95.9	1,434	7.7	0.079	79.00	10.3	
	G1 - TSP	4846	P8637	5	4.8	4.9	282.3	669.2	5.528	95.9	119.9	1,440	8.0	0.066	66.00	8.3	
	FA1 - PM10	4851				#DIV/0!	282.3	669.2				0	0.0		0.00	#DIV/0!	No filter
	FA1 - TSP	4847				#DIV/0!	282.3	669.2				0	0.0		0.00	#DIV/0!	No filter
22-Aug-08	TL1 - PM10	4854	8941	5	5	5	282.3	664.1	5.572	118.4	142.4	1,440	8.0	< 0.04	40.00	*5.0*	
	TL1 - TSP	4841	8949	5	5	5	282.3	664.1	5.676	113.4	137.4	1,440	8.2	< 0.04	40.00	*4.9*	
	TL2 - PM10	4848	8938	5	5	5	282.3	664.1	5.566	56.5	80.5	1,440	8.0	0.108	108.00	13.5	
	TL2 - TSP	4858	8936	5	5	5	282.3	664.1	5.617	119.5	143.5	1,440	8.1	< 0.04	40.00	*4.9*	
	TL3 - PM10	4849	8951	5	5	5	282.3	664.1	5.617	96.0	107.9	714	4.0	0.052	52.00	13.0	
	TL3 - TSP	4844	8950	5	5	5	282.3	664.1	5.616	103.9	120.0	966	5.4	< 0.04	40.00	*7.4*	
	RC1 - PM10	4843	8937	5	5	5	282.3	664.1	5.658	108.8	132.8	1,440	8.1	0.067	67.00	8.2	
	RC1 - TSP	4857	8945	5	5	5	282.3	664.1	5.540	119.9	143.9	1,440	8.0	0.06	60.00	7.5	
	A1 - PM10	4845	8944	5	5	5	282.3	664.1	5.695	119.9	143.8	1,434	8.2	0.058	58.00	7.1	
	A1 - TSP	4853	8940	5	5	5	282.3	664.1	5.697	12.6	36.6	1,440	8.2	< 0.04	40.00	*4.9*	
	VG1 - PM10	4852	8946	5	5	5	282.3	664.1	5.609	108.6	132.6	1,440	8.1	0.069	69.00	8.5	
	VG1 - TSP	4855	8942	5	5	5	282.3	664.1	5.574	118.4	142.4	1,440	8.0	0.065	65.00	8.1	
	VG2 - PM10	4856	8935	5	5	5	282.3	664.1	5.677	120.0	143.9	1,434	8.1	0.04	40.00	4.9	
	VG2 - TSP	4850	8947	5	5	5	282.3	664.1	5.566	119.9	143.9	1,440	8.0	0.326	326.00	40.7	
	G1 - PM10	4842	8939	5	5	5	282.3	664.1	5.666	96.0	119.9	1,434	8.1	0.046	46.00	5.7	
	G1 - TSP	4846	8948	5	5	5	282.3	664.1	5.668	119.9	143.9	1,440	8.2	0.09	90.00	11.0	
	FA1 - PM10	4851	8953	5	5	5	282.3	664.1	5.584	95.9	119.9	1,440	8.0	< 0.04	40.00	*5.0*	
	FA1 - TSP	4847	8952	5	5	5	282.3	664.1	5.636	72.0	96.0	1,440	8.1	0.087	87.00	10.7	

Notes:

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Cells highlighted in blue indicate that hand writing on sampling log was not legible

Concentrations in italics were calculated at the method detection limit

Table A.2: TSP/PM_{10} Sampler Data – August 2008 (continued)

Start Date	Location	MiniVol Unit #	Filter ID	RotoFlow (start)	RotoFlow (end)	Average	Daily Average Temperature (K)	Daily Average Pressure (mm Hg)	Qact (L/min)	Elasped Time Start	Elasped Time End	Sampling Duration (min)	Volume Sampled (m^3)	TSP Result (mg)	TSP Result (µg)	TSP Concentration (µg/m3)	Comments
28-Aug-08	TL1 - PM10	4854	P8999	5	5	5	278.6	662.7	5.541	142.4	166.4	1,440	8.0	< 0.04	40.00	*5.0*	
	TL1 - TSP	4841	P8998	5	5	5	278.6	662.7	5.645	137.4	161.3	1,434	8.1	0.072	72.00	8.9	
	TL2 - PM10	4848	P8992	5	5	5	278.6	662.7	5.535	80.5	104.5	1,440	8.0	< 0.04	40.00	*5.0*	
	TL2 - TSP	4858	P8991	5	5	5	278.6	662.7	5.586	143.5	167.5	1,440	8.0	< 0.04	40.00	*5.0*	
	TL3 - PM10	4849	P8988	5	5	5	278.6	662.7	5.586	107.9	131.9	1,440	8.0	< 0.04	40.00	*5.0*	
	TL3 - TSP	4844	P8989	5	5	5	278.6	662.7	5.585	120.0	143.9	1,434	8.0	< 0.04	40.00	*5.0*	
	RC1 - PM10	4843	P8995	5	5	5	278.6	662.7	5.627	132.8	156.8	1,440	8.1	0.058	58.00	7.2	
	RC1 - TSP	4857	P8997	5	5	5	278.6	662.7	5.510	143.9	167.9	1,440	7.9	0.05	50.00	6.3	
	A1 - PM10	4845	P8984	5	5	5	278.6	662.7	5.664	143.8	167.8	1,440	8.2	0.064	64.00	7.8	
	A1 - TSP	4853	P8985	5	5	5	278.6	662.7	5.666	36.6	60.6	1,440	8.2	0.056	56.00	6.9	
	VG1 - PM10	4852	P8983	5	5	5	278.6	662.7	5.578	132.6	156.7	1,446	8.1	0.18	180.00	22.3	
	VG1 - TSP	4855	P8982	5	5	5	278.6	662.7	5.543	142.4	166.3	1,434	7.9	< 0.04	40.00	*5.0*	
	VG2 - PM10	4856	P8990	5	5	5	278.6	662.7	5.646	143.9	167.9	1,440	8.1	< 0.04	40.00	*4.9*	
	VG2 - TSP	4850	P8943	5	5	5	278.6	662.7	5.535	143.9	167.9	1,440	8.0	0.051	51.00	6.4	
	G1 - PM10	4842	P8994	5	5	5	278.6	662.7	5.634	119.9	143.9	1,440	8.1	< 0.04	40.00	*4.9*	
	G1 - TSP	4846	P8993	5	5	5	278.6	662.7	5.637	143.9	167.9	1,440	8.1	< 0.04	40.00	*4.9*	
	FA1 - PM10	4851	P8987	5	5	5	278.6	662.7	5.553	119.9	143.9	1,440	8.0	0.054	54.00	6.8	
	FA1 - TSP	4847	P8986	5	5	5	278.6	662.7	5.605	96.0	120.0	1,440	8.1	0.467	467.00	57.9	

Notes:

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Concentrations in italics were calculated at the method detection limit

Table A.3: TSP/PM_{10} Sampler Data – September 2008

				(start)	(end)		Temperature (K)	Pressure (mm Hg)	(L/min)	Time Start	Time End	Duration (min)	Sampled (m^3)	(mg)	(µg)	Concentration (µg/m3)	
3-Sep-08	TL1 - PM10	4854	P8959	5	5	5	278.9	672.3	5.505	166.4	190.4	1,440	7.9	0.076	76.00	9.6	
	TL1 - TSP	4841	P8981	5	5	5	#REF!	#REF!	5.636	161.3	185.3	1,440	8.1	0.04	40.00	4.9	
	TL2 - PM10	4848	P8958	5	5	5	278.9	672.3	5.499	104.5	128.5	1,440	7.9	0.044	44.00	5.6	
	TL2 - TSP	4858	P8957	5	5	5	278.9	672.3	5.549	167.5	191.5	1,440	8.0	0.07	70.00	8.8	
	TL3 - PM10	4849	P8979	5	5	5	278.9	672.3	5.549	131.9	155.9	1,440	8.0	0.05	50.00	6.3	
	TL3 - TSP	4844	P8980	5	5	5	278.9	672.3	5.548	143.9	167.9	1,440	8.0	0.11	110.00	13.8	
	RC1 - PM10	4843	P8956	5	5	5	278.9	672.3	5.590	156.8	180.8	1,440	8.0	0.04	40.00	5.0	
	RC1 - TSP	4857	P8955	5	5	5	278.9	672.3	5.473	167.9	191.9	1,440	7.9	< 0.04	40.00	*5.1*	
	A1 - PM10	4845	P8954	5	5	5	278.9	672.3	5.626	167.8	191.8	1,440	8.1	< 0.04	40.00	*4.9*	
	A1 - TSP	4853	P8963	5	5	5	278.9	672.3	5.628	60.6	84.6	1,440	8.1	0.096	96.00	11.8	
	VG1 - PM10	4852	P8964	5	5	5	278.9	672.3	5.541	156.7	180.5	1,428	7.9	0.073	73.00	9.2	
	VG1 - TSP	4855	P8965	5	5	5	278.9	672.3	5.506	166.3	190.3	1,440	7.9	0.081	81.00	10.2	
	VG2 - PM10	4856	P8966	5	5	5	278.9	672.3	5.608	167.9	191.9	1,440	8.1	0.063	63.00	7.8	
	VG2 - TSP	4850	P8961	5	5	5	278.9	672.3	5.499	167.9	191.9	1,440	7.9	0.107	107.00	13.5	
	G1 - PM10	4842	P8962	5	5	5	278.9	672.3	5.597	143.9	167.9	1,440	8.1	0.041	41.00	5.1	
	G1 - TSP	4846	P8960	5	5	5	278.9	672.3	5.600	167.9	191.9	1,440	8.1	0.073	73.00	9.1	
	FA1 - PM10	4851	P8978	5	5	5	278.9	672.3	5.516	143.9	167.9	1,440	7.9	0.084	84.00	10.6	
	FA1 - TSP	4847	P8977	5	5	5	278.9	672.3	5.568	120.0	144.0	1,440	8.0	0.078	78.00	9.7	
9-Sep-08	TL1 - PM10	4854	P8973	5	5	5	279.8	667.7	5.533	190.4	214.4	1,440	8.0	< 0.04	40.00	*5.0*	
	TL1 - TSP	4841	P8974	5	5	5	279.8	667.7	5.636	185.3	209.3	1,440	8.1	0.573	573.00	70.6	
	TL2 - PM10	4848	P8975	5	5	5	279.8	667.7	5.527	128.5	152.5	1,440	8.0	< 0.04	40.00	*5.0*	
	TL2 - TSP	4858	P8976	5	5	5	279.8	667.7	5.578	191.5	215.5	1,440	8.0	< 0.04	40.00	*5.0*	
	TL3 - PM10	4849	P8903	5	5	5	279.8	667.7	5.577	155.9	179.9	1,440	8.0	0.081	81.00	10.1	
	TL3 - TSP	4844	P8901	5	5	5	279.8	667.7	5.576	167.9	191.9	1,440	8.0	0.056	56.00	7.0	
	RC1 - PM10	4843	P8972	5	5	5	279.8	667.7	5.618	180.8	204.8	1,440	8.1	< 0.04	40.00	*4.9*	
	RC1 - TSP	4857	P8971	5	5	5	279.8	667.7	5.501	191.9	215.9	1,440	7.9	< 0.04	40.00	*5.0*	
	A1 - PM10	4845	P8933	5	5	5	279.8	667.7	5.655	191.8	215.8	1,440	8.1	< 0.04	40.00	*4.9*	
	A1 - TSP	4853	P8931	5	5	5	279.8	667.7	5.657	84.6	108.5	1,434	8.1	< 0.04	40.00	*4.9*	
	VG1 - PM10	4852	P8967	5	5	5	279.8	667.7	5.569	180.5	204.5	1,440	8.0	0.069	69.00	8.6	
	VG1 - TSP	4855	P8968	5	5	5	279.8	667.7	5.534	190.3	214.3	1,440	8.0	0.06	60.00	7.5	
	VG2 - PM10	4856	P8970	5	5	5	279.8	667.7	5.637	191.9	215.9	1,440	8.1	< 0.04	40.00	*4.9*	
	VG2 - TSP	4850	P8969	5	5	5	279.8	667.7	5.527	191.9	215.9	1,440	8.0	0.76	760.00	95.5	
	G1 - PM10	4842	P8934	5	5	5	279.8	667.7	5.625	167.9	191.9	1,440	8.1	< 0.04	40.00	*4.9*	
	G1 - TSP	4846	P8932	5	5	5	279.8	667.7	5.628	191.9	215.9	1,440	8.1	0.051	51.00	6.3	
	FA1 - PM10	4851	P8902	5	5	5	279.8	667.7	5.544	167.9	191.9	1,440	8.0	0.053	53.00	6.6	
	FA1 - TSP	4847	P8900	5	5	5	279.8	667.7	5.596	144.0	167.9	1,434	8.0	0.06	60.00	7.5	
15-Sep-08	TL1 - PM10	4854	P8915	5	5	5	279.9	670.0	5.523	214.4	238.3	1,434	7.9	< 0.04	40.00	*5.1*	
	TL1 - TSP	4841	P8914	5	5	5	279.9	670.0	5.627	209.3	233.3	1,440	8.1	0.05	50.00	6.2	
	TL2 - PM10	4848	P8913	5	5	5	279.9	670.0	5.517	152.5	176.5	1,440	7.9	0.07	70.00	8.8	
	TL2 - TSP	4858	P8911	5	5	5	279.9	670.0	5.568	215.3	239.4	1,446	8.1	0.09	90.00	11.2	
	TL3 - PM10	4849	P8920	5	5	5	279.9	670.0	5.568	179.9	203.9	1,440	8.0	0.06	60.00	7.5	
	TL3 - TSP	4844	P8916	5	5	5	279.9	670.0	5.567	191.9	215.9	1,440	8.0	0.09	90.00	11.2	
	RC1 - PM10	4843	P8912	5	5	5	279.9	670.0	5.609	204.8	228.7	1,434	8.0	< 0.04	40.00	*5.0*	
	RC1 - TSP	4857	P8908	5	5	5	279.9	670.0	5.492	215.9	239.9	1,440	7.9	0.08	80.00	10.1	
	A1 - PM10	4845	P8917	5	5	5	279.9	670.0	5.645	215.8	239.8	1,440	8.1	0.04	40.00	4.9	
	A1 - TSP	4853	P8918	5	5	5	279.9	670.0	5.647	108.5	132.5	1,440	8.1	< 0.04	40.00	*4.9*	
	VG1 - PM10	4852	P8910	5	5	5	279.9	670.0	5.560	204.5	228.5	1,440	8.0	< 0.04	40.00	*5.0*	
	VG1 - TSP	4855	P8907	5	5	5	279.9	670.0	5.525	214.3	238.3	1,440	8.0	0.07	70.00	8.8	
	VG2 - PM10	4856	P8906	5	5	5	279.9	670.0	5.627	215.9	239.9	1,440	8.1	< 0.04	40.00	*4.9*	
	VG2 - TSP	4850	P8909	5	5	5	279.9	670.0	5.517	215.9	239.9	1,440	7.9	0.06	60.00	7.6	
	G1 - PM10	4842	P8905	5	5	5	279.9	670.0	5.616	191.9	215.9	1,440	8.1	0.08	80.00	9.9	
	G1 - TSP	4846	P8904	5	5	5	279.9	670.0	5.619	215.9	239.9	1,440	8.1	0.05	50.00	6.2	
	FA1 - PM10	4851	P8919	5	5	5	279.9	670.0	5.535	191.9	215.9	1,440	8.0	0.08	80.00	10.0	
	FA1 - TSP	4847	P8923	5	5	5	279.9	670.0	5.587	167.9	191.9	1,440	8.0	0.05	50.00	6.2	

Notes:

Cells highlighted in yellow indicate that MiniVols did not run for a 24 hr sampling period

Cells highlighted in green indicate that samples were not submitted for analysis.

Cells highlighted in blue indicate that hand writing on sampling log was not legible

Concentrations in italics were calculated at the method detection limit

Table A.3: TSP/PM_{10} Sampler Data – September 2008 (continued)

				(start)	(end)		Temperature (K)	Pressure (mm Hg)	(L/min)	Time Start	Time End	Duration (min)	Sampled (m^3)	(mg)	(µg)	Concentration (µg/m3)	
21-Sep-08	TL1 - PM10	4854	P9072	5	5	5	275.8	668.1	5.491	238.3	262.3	1,440	7.9	< 0.04	40.00	*5.1*	
	TL1 - TSP	4841	P9071	5	5	5	275.8	668.1	5.594	233.3	257.3	1,440	8.1	< 0.04	40.00	*5.0*	
	TL2 - PM10	4848	P9074	5	5	5	275.8	668.1	5.485	176.5	200.5	1,440	7.9	< 0.04	40.00	*5.1*	
	TL2 - TSP	4858	P9073	5	5	5	275.8	668.1	5.536	239.4	258.8	1,164	6.4	< 0.04	40.00	*6.2*	
	TL3 - PM10	4849	P8928	5	5	5	275.8	668.1	5.536	203.9	227.9	1,440	8.0	< 0.04	40.00	*5.0*	
	TL3 - TSP	4844	P8927	5	5	5	275.8	668.1	5.535	215.9	239.9	1,440	8.0	0.06	60.00	7.5	
	RC1 - PM10	4843	P9076	5	5	5	275.8	668.1	5.576	228.7	252.7	1,440	8.0	< 0.04	40.00	*5.0*	
	RC1 - TSP	4857	P9075	5	5	5	275.8	668.1	5.460	239.9	263.8	1,434	7.8	< 0.04	40.00	*5.1*	
	A1 - PM10	4845	P8926	5	5	5	275.8	668.1	5.613	239.8	263.7	1,434	8.0	< 0.04	40.00	*5.0*	
	A1 - TSP	4853	P8925	5	5	5	275.8	668.1	5.614	132.5	156.5	1,440	8.1	< 0.04	40.00	*4.9*	
	VG1 - PM10	4852	P9078	5	5	5	275.8	668.1	5.527	228.5	252.5	1,440	8.0	< 0.04	40.00	*5.0*	
	VG1 - TSP	4855	P9077	5	5	5	275.8	668.1	5.493	238.3	262.3	1,440	7.9	< 0.04	40.00	*5.1*	
	VG2 - PM10	4856	P8921	5	5	5	275.8	668.1	5.595	239.9	263.9	1,440	8.1	< 0.04	40.00	*5.0*	
	VG2 - TSP	4850	P9079	5	5	5	275.8	668.1	5.485	239.9	263.9	1,440	7.9	< 0.04	40.00	*5.1*	
	G1 - PM10	4842	P8924	5	5	5	275.8	668.1	5.584	215.9	239.9	1,440	8.0	< 0.04	40.00	*5.0*	
	G1 - TSP	4846	P8922	5	5	5	275.8	668.1	5.586	239.9	263.9	1,440	8.0	0.04	40.00	5.0	
	FA1 - PM10	4851	P8930	5	5	5	275.8	668.1	5.503	215.9	239.9	1,440	7.9	0.04	40.00	5.0	
	FA1 - TSP	4847	P8929	5	5	5	275.8	668.1	5.554	191.9	215.9	1,440	8.0	0.08	80.00	10.0	
27-Sep-08	TL1 - PM10	4854	P9034	5	5	5	275.5	664.9	5.501	262.3	286.3	1,440	7.9	< 0.04	40.00	*5.0*	
	TL1 - TSP	4841	P9035	5	5	5	275.5	664.9	5.604	257.3	281.3	1,440	8.1	< 0.04	40.00	*5.0*	
	TL2 - PM10	4848	P9070	5	5	5	275.5	664.9	5.495	200.5	224.4	1,434	7.9	< 0.04	40.00	*5.1*	
	TL2 - TSP	4858	P9033	5	5	5	275.5	664.9	5.545	258.8	282.8	1,440	8.0	< 0.04	40.00	*5.0*	
	TL3 - PM10	4849	P9058	5	5	5	275.5	664.9	5.545	227.9	251.8	1,434	8.0	< 0.04	40.00	*5.0*	
	TL3 - TSP	4844	P9057	5	5	5	275.5	664.9	5.544	239.9	263.9	1,440	8.0	< 0.04	40.00	*5.0*	
	RC1 - PM10	4843	P9068	5	5	5	275.5	664.9	5.586	252.7	276.7	1,440	8.0	< 0.04	40.00	*5.0*	
	RC1 - TSP	4857	P9069	5	5	5	275.5	664.9	5.469	263.8	287.8	1,440	7.9	< 0.04	40.00	*5.1*	
	A1 - PM10	4845	P9060	5	5	5	275.5	664.9	5.622	263.7	287.7	1,440	8.1	0.06	60.00	7.4	
	A1 - TSP	4853	P9059	5	5	5	275.5	664.9	5.624	156.5	180.5	1,440	8.1	< 0.04	40.00	*4.9*	
	VG1 - PM10	4852	P9065	5	5	5	275.5	664.9	5.537	252.5	276.5	1,440	8.0	< 0.04	40.00	*5.0*	
	VG1 - TSP	4855	P9066	5	5	5	275.5	664.9	5.502	262.3	286.3	1,440	7.9	< 0.04	40.00	*5.0*	
	VG2 - PM10	4856	P9063	5	5	5	275.5	664.9	5.604	263.9	287.9	1,440	8.1	< 0.04	40.00	*5.0*	
	VG2 - TSP	4850	P9064	5	5	5	275.5	664.9	5.495	263.9	287.8	1,434	7.9	0.04	40.00	5.1	
	G1 - PM10	4842	P9062	5	5	5	275.5	664.9	5.593	239.9	263.9	1,440	8.1	< 0.04	40.00	*5.0*	
	G1 - TSP	4846	P9061	5	5	5	275.5	664.9	5.596	263.9	287.8	1,434	8.0	< 0.04	40.00	*5.0*	
	FA1 - PM10	4851	P9056	5	5	5	275.5	664.9	5.963	239.9	263.8	1,434	8.6	< 0.04	40.00	*4.7*	
	FA1 - TSP	4847	P9067	5	5	5	275.5	664.9	5.564	215.9	239.9	1,440	8.0	0.07	70.00	8.7	
3-Oct-08	TL1 - PM10	4854	P9052	5	5	5	280.4	653.8	5.597	286.3	310.3	1,440	8.1	0.04	40.00	5.0	
	TL1 - TSP	4841	P9053	5	5	5	280.4	653.8	5.701	281.3	305.3	1,440	8.2	0.11	110.00	13.4	
	TL2 - PM10	4848	P9050	5	5	5	280.4	653.8	5.591	224.4	248.4	1,440	8.1	< 0.04	40.00	*5.0*	
	TL2 - TSP	4858	P9051	5	5	5	280.4	653.8	5.642	282.8	306.8	1,440	8.1	< 0.04	40.00	*4.9*	
	TL3 - PM10	4849	P9038	5	5	5	280.4	653.8	5.642	251.8	275.8	1,440	8.1	< 0.04	40.00	*4.9*	
	TL3 - TSP	4844	P9039	5	5	5	280.4	653.8	5.641	263.9	287.9	1,440	8.1	0.08	80.00	9.8	
	RC1 - PM10	4843	P9048	5	5	5	280.4	653.8	5.683	276.7	300.7	1,440	8.2	< 0.04	40.00	*4.9*	
	RC1 - TSP	4857	P9049	5	5	5	280.4	653.8	5.565	287.8	311.8	1,440	8.0	0.04	40.00	5.0	
	A1 - PM10	4845	P9040	5	5	5	280.4	653.8	5.720	287.7	311.7	1,440	8.2	< 0.04	40.00	*4.9*	
	A1 - TSP	4853	P9041	5	5	5	280.4	653.8	5.722	180.5	204.5	1,440	8.2	0.06	60.00	7.3	
	VG1 - PM10	4852	P9046	5	5	5	280.4	653.8	5.633	276.5	300.5	1,440	8.1	< 0.04	40.00	*4.9*	
	VG1 - TSP	4855	P9047	5	5	5	280.4	653.8	5.598	286.3	310.3	1,440	8.1	0.05	50.00	6.2	
	VG2 - PM10	4856	P9044	5	5	5	280.4	653.8	5.702	287.9	311.8	1,434	8.2	< 0.04	40.00	*4.9*	
	VG2 - TSP	4850	P9045	5	5	5	280.4	653.8	5.591	287.8	311.8	1,440	8.1	0.06	60.00	7.5	
	G1 - PM10	4842	P9042	5	5	5	280.4	653.8	5.691	263.9	263.9	0	0.0	< 0.04	40.00	#DIV/0!	Battery failure? Battery indicates o.k.; may be computer battery.
	G1 - TSP	4846	P9043	5	5	5	280.4	653.8	5.693	287.8	311.8	1,440	8.2	< 0.04	40.00	*4.9*	
	FA1 - PM10	4851	P9036	5	5	5	280.4	653.8	5.609	263.8	287.8	1,440	8.1	0.110	110.00	13.6	
	FA1 - TSP	4847	P9037	5	5	5	280.4	653.8	5.661	239.9	263.9	1,440	8.2	0.07	70.00	8.6	

Notes:

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Concentrations in italics were calculated at the method detection limit

APPENDIX B

Summary Data for Sample
Trace Inorganic Elemental Composition

	Aluminium																	
	Concentration (µg/m3)																	
Sampling Date	TL1 - TSP	TL1 - PM10	TL2 - TSP	TL2 - PM10	TL3 - TSP	TL3 - PM10	RC1 - TSP	RC1 - PM10	A1 - TSP	A1 - PM10	VG1 - TSP	VG1 - PM10	VG2 - TSP	VG2 - PM10	G1 - TSP	G1 - PM10	FA1 - TSP	FA1 - PM10
17-Jul-08	7.56E-02	9.81E-02	7.28E-02	6.47E-02	3.43E-01	7.15E-02	6.87E-02	5.63E-02	3.69E-01	5.64E-02	1.56E-01	8.56E-02	2.37E-01	9.01E-02	6.83E-02	3.22E-02	1.34E-01	8.43E-02
23-Jul-08	5.20E-02	1.00E-01	4.58E-02	5.65E-02	6.58E-02	5.86E-02	4.92E-02	5.93E-02	1.01E+00	3.95E-02	4.77E-02	5.61E-02	4.25E-02	3.57E-02	4.20E-02	ND	1.04E-01	4.63E-02
29-Jul-08	9.96E-02	2.00E-01	5.21E-02	9.14E-02	6.59E-01	1.18E-01	5.75E-02	5.14E-02	7.23E-01	4.99E-02	1.25E-01	8.47E-02	3.86E-02	3.04E-01	4.35E-02	4.78E-02	ND	ND
4-Aug-08	1.40E-01	5.30E-02	7.74E-02	ND	4.41E-01	1.19E-01	7.76E-02	9.02E-02	4.22E-01	4.29E-02	5.61E-01	1.45E-01	3.73E-01	5.65E-02	5.18E-02	9.36E-02	ND	5.90E-02
10-Aug-08	3.81E-02	3.97E-02	2.32E-02	6.14E-02	ND	ND	2.71E-02	2.71E-02	2.75E-01	3.55E-02	1.44E-01	3.34E-02	3.97E-02	3.56E-02	5.15E-02	5.09E-02	ND	ND
22-Aug-08	3.55E-02	3.99E-02	3.21E-02	3.12E-02	6.45E-02	7.98E-02	3.26E-02	3.31E-02	5.73E-02	4.90E-02	5.48E-02	3.84E-02	4.49E-02	3.69E-02	4.04E-02	3.82E-02	4.93E-02	5.10E-02
28-Aug-08	2.22E-02	2.63E-02	2.24E-02	3.64E-02	3.62E-02	2.86E-02	2.52E-02	2.34E-02	2.70E-02	2.82E-02	3.40E-02	2.23E-02	2.63E-02	2.09E-02	1.97E-02	2.10E-02	3.59E-02	3.13E-02
3-Sep-08	3.10E-02	5.30E-02	3.88E-02	4.04E-02	2.03E-01	5.76E-02	2.66E-02	3.35E-02	2.71E-02	1.97E-02	1.49E-01	2.91E-02	1.78E-01	5.57E-02	2.48E-02	1.61E-02	1.45E-01	4.66E-02
9-Sep-08	2.96E-02	2.01E-02	2.86E-02	4.40E-02	6.48E-02	2.49E-02	3.41E-02	1.85E-02	2.10E-02	2.21E-02	2.76E-02	2.00E-02	2.39E-02	1.60E-02	3.21E-02	1.73E-02	6.60E-02	2.76E-02
15-Sep-08	1.85E-02	1.64E-02	5.09E-02	2.27E-02	5.24E-02	2.12E-02	2.78E-02	2.36E-02	*3.07E-02*	*1.85E-02*	4.90E-02	2.75E-02	2.14E-02	2.47E-02	5.07E-02	6.43E-02	4.97E-02	2.76E-02
21-Sep-08	1.49E-02	1.26E-02	3.26E-02	1.27E-02	4.77E-02	1.76E-02	1.79E-02	9.96E-03	4.21E-02	2.73E-02	1.77E-02	1.26E-02	1.65E-02	1.24E-02	1.99E-02	1.24E-02	7.88E-02	3.66E-02
27-Sep-08	2.11E-02	2.02E-02	3.26E-02	1.27E-02	2.13E-02	2.39E-02	1.40E-02	1.49E-02	1.61E-02	4.08E-02	2.52E-02	1.88E-02	1.90E-02	2.35E-02	4.24E-02	1.86E-02	5.49E-02	2.57E-02
3-Oct-08	5.12E-02	2.73E-02	6.89E-02	5.96E-02	3.57E-02	2.46E-02	4.74E-02	4.64E-02	2.55E-02	1.94E-02	5.71E-02	2.47E-02	3.73E-02	2.69E-02	9.03E-02	ND	8.10E-02	3.47E-02
Arithmetic Mean	4.84E-02	5.43E-02	4.45E-02	4.45E-02	1.69E-01	5.38E-02	3.89E-02	3.75E-02	2.34E-01	3.45E-02	1.11E-01	4.60E-02	8.44E-02	5.69E-02	4.44E-02	3.75E-02	7.98E-02	4.28E-02
Geomertic Mean	3.88E-02	3.93E-02	4.10E-02	3.80E-02	9.23E-02	4.32E-02	3.46E-02	3.17E-02	8.62E-02	3.22E-02	6.84E-02	3.58E-02	4.80E-02	3.72E-02	4.06E-02	3.09E-02	7.27E-02	4.00E-02
95th Percentile	1.16E-01	1.40E-01	7.47E-02	7.67E-02	5.39E-01	1.18E-01	7.23E-02	7.17E-02	8.36E-01	5.25E-02	3.18E-01	1.09E-01	2.91E-01	1.76E-01	7.71E-02	7.90E-02	1.40E-01	7.16E-02
98th Percentile	1.30E-01	1.76E-01	7.63E-02	8.55E-02	6.11E-01	1.19E-01	7.55E-02	8.28E-02	9.37E-01	5.48E-02	4.64E-01	1.31E-01	3.40E-01	2.53E-01	8.50E-02	8.78E-02	1.43E-01	7.92E-02
Maximum	1.40E-01	2.00E-01	7.74E-02	9.14E-02	6.59E-01	1.19E-01	7.76E-02	9.02E-02	1.01E+00	5.64E-02	5.61E-01	1.45E-01	3.73E-01	3.04E-01	9.03E-02	9.36E-02	1.45E-01	8.43E-02
Minimum	1.49E-02	1.26E-02	2.24E-02	1.27E-02	2.13E-02	1.76E-02	1.40E-02	9.96E-03	1.61E-02	1.85E-02	1.77E-02	1.26E-02	1.65E-02	1.24E-02	1.97E-02	1.24E-02	3.59E-02	2.57E-02

	Antimony																	
	Concentration (µg/m3)																	
Sampling Date	TL1 - TSP	TL1 - PM10	TL2 - TSP	TL2 - PM10	TL3 - TSP	TL3 - PM10	RC1 - TSP	RC1 - PM10	A1 - TSP	A1 - PM10	VG1 - TSP	VG1 - PM10	VG2 - TSP	VG2 - PM10	G1 - TSP	G1 - PM10	FA1 - TSP	FA1 - PM10
17-Jul-08	*6.10E-04*	*6.21E-04*	*6.50E-04*	*6.22E-04*	*6.16E-04*	*1.23E-03*	*6.25E-04*	1.22E-03	*5.59E-03*	*6.55E-04*	*6.21E-04*	*6.90E-04*	*6.57E-04*	*6.44E-04*	*6.44E-04*	*6.45E-04*	*6.14E-04*	*6.20E-04*
23-Jul-08	*6.19E-04*	7.70E-04	*6.36E-04*	*6.28E-04*	*6.58E-04*	*6.37E-04*	*6.31E-04*	*6.18E-04*	*8.11E-03*	*6.17E-04*	*6.27E-04*	*6.24E-04*	*6.64E-04*	*6.16E-04*	*6.17E-04*	ND	*6.21E-04*	*6.26E-04*
29-Jul-08	*1.35E-03*	*1.85E-03*	*6.51E-04*	*1.76E-03*	*6.17E-04*	*6.17E-04*	*6.25E-04*	*6.12E-04*	*7.69E-03*	*6.08E-04*	*1.46E-03*	*1.18E-03*	*6.22E-04*	*6.23E-04*	*6.59E-04*	*6.45E-04*	ND	ND
4-Aug-08	*7.77E-04*	*5.30E-04*	*6.35E-04*	ND	*6.35E-04*	*6.24E-04*	*6.47E-04*	*1.16E-03*	*9.18E-03*	*6.13E-04*	*6.26E-04*	*6.96E-04*	*6.66E-04*	*6.28E-04*	*6.32E-04*	*6.50E-04*	ND	6.28E-04
10-Aug-08	*6.14E-04*	*6.61E-04*	*4.46E-04*	*6.26E-04*	ND	ND	*6.16E-04*	*6.16E-04*	*6.88E-03*	*6.12E-04*	*6.25E-04*	*6.95E-04*	*6.40E-04*	*6.14E-04*	*6.28E-04*	*6.52E-04*	ND	ND
22-Aug-08	*6.12E-04*	*6.23E-04*	*6.18E-04*	*6.24E-04*	*9.22E-04*	*1.25E-03*	*6.27E-04*	*6.14E-04*	*6.09E-04*	*6.12E-04*	*6.23E-04*	*6.19E-04*	*6.24E-04*	*6.14E-04*	*6.13E-04*	*6.15E-04*	*6.16E-04*	*6.22E-04*
28-Aug-08	*6.18E-04*	*6.27E-04*	*6.22E-04*	*6.27E-04*	1.12E-03	*6.22E-04*	*6.30E-04*	*6.17E-04*	*6.13E-04*	*6.13E-04*	*6.29E-04*	*6.20E-04*	*6.27E-04*	*6.15E-04*	*6.16E-04*	*6.16E-04*	*6.19E-04*	*6.25E-04*
3-Sep-08	*6.19E-04*	*6.31E-04*	*6.26E-04*	*6.31E-04*	*6.26E-04*	*6.26E-04*	*6.34E-04*	*6.21E-04*	*6.17E-04*	*6.17E-04*	*6.31E-04*	*6.32E-04*	*6.31E-04*	*6.19E-04*	*6.20E-04*	*6.20E-04*	*6.24E-04*	*6.29E-04*
9-Sep-08	*6.16E-04*	*6.28E-04*	*6.23E-04*	*6.28E-04*	*6.23E-04*	*6.23E-04*	*6.31E-04*	*6.18E-04*	*6.16E-04*	*6.14E-04*	*6.27E-04*	*6.23E-04*	*6.28E-04*	*6.16E-04*	*6.17E-04*	*6.17E-04*	*6.23E-04*	*6.26E-04*
15-Sep-08	*6.17E-04*	*6.31E-04*	*6.21E-04*	*6.29E-04*	*6.24E-04*	*6.24E-04*	*6.32E-04*	*6.22E-04*	*6.15E-04*	*6.15E-04*	*6.28E-04*	*6.25E-04*	*6.29E-04*	*6.17E-04*	*6.18E-04*	*6.18E-04*	*6.22E-04*	*6.27E-04*
21-Sep-08	*6.21E-04*	*6.32E-04*	*7.76E-04*	*6.33E-04*	*6.27E-04*	*6.27E-04*	*6.39E-04*	*6.23E-04*	*6.18E-04*	*6.21E-04*	*6.32E-04*	*6.28E-04*	*6.33E-04*	*6.21E-04*	*6.22E-04*	*6.22E-04*	*6.25E-04*	*6.31E-04*
27-Sep-08	*6.20E-04*	*6.31E-04*	*6.26E-04*	*6.35E-04*	*6.26E-04*	*6.29E-04*	*6.35E-04*	*6.22E-04*	*6.17E-04*	*6.18E-04*	*6.31E-04*	*6.27E-04*	*6.35E-04*	*6.20E-04*	*6.23E-04*	*6.21E-04*	*6.24E-04*	*5.85E-04*
3-Oct-08	*6.09E-04*	*6.20E-04*	*6.15E-04*	*6.21E-04*	*6.16E-04*	*6.15E-04*	*6.24E-04*	*6.11E-04*	*6.07E-04*	*6.07E-04*	*6.20E-04*	*6.16E-04*	*6.21E-04*	*6.11E-04*	*6.10E-04*	ND	*6.13E-04*	*6.19E-04*
Arithmetic Mean	6.84E-04	7.27E-04	6.26E-04	7.22E-04	6.93E-04	7.27E-04	6.30E-04	7.06E-04	3.26E-03	6.17E-04	6.91E-04	6.82E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Geomertic Mean	6.66E-04	6.86E-04	6.23E-04	6.84E-04	6.79E-04	7.00E-04	6.30E-04	6.83E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
95th Percentile	1.00E-03	1.20E-03	7.01E-04	1.14E-03	1.01E-03	1.24E-03	6.42E-04	1.18E-03	8.54E-03	6.35E-04	9.62E-04	8.88E-04	6.65E-04	6.34E-04	6.50E-04	6.51E-04	6.25E-04	6.30E-04
98th Percentile	1.21E-03	1.59E-03	7.46E-04	1.51E-03	1.08E-03	1.24E-03	6.45E-04	1.21E-03	8.92E-03	6.47E-04	1.26E-03	1.06E-03	6.65E-04	6.40E-04	6.56E-04	6.52E-04	6.25E-04	6.31E-04
Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	1.12E-03	1.25E-03	6.47E-04	1.22E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Arsenic																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	1.95E-03	1.74E-03	1.56E-03	1.62E-03	2.59E-03	3.94E-03	1.75E-03	2.32E-03	1.45E-02	1.18E-03	2.24E-03	1.79E-03	3.02E-03	2.06E-03	2.45E-03	2.32E-03	2.95E-03	2.97E-03
23-Jul-08	3.46E-03	2.31E-03	2.80E-03	1.88E-03	2.37E-03	2.67E-03	2.52E-03	2.72E-03	3.89E-02	2.84E-03	2.51E-03	3.12E-03	2.66E-03	2.22E-03	1.97E-03	**ND**	2.48E-03	3.13E-03
29-Jul-08	5.12E-03	7.03E-03	2.47E-03	7.38E-03	3.08E-03	2.71E-03	2.63E-03	2.69E-03	4.16E-02	1.70E-03	5.53E-03	3.76E-03	2.36E-03	2.37E-03	2.77E-03	1.81E-03	**ND**	**ND**
4-Aug-08	2.80E-03	2.01E-03	2.28E-03	**ND**	1.65E-03	1.12E-03	2.72E-03	5.78E-03	4.04E-02	3.06E-03	3.01E-03	2.92E-03	2.80E-03	3.27E-03	1.89E-03	2.47E-03	**ND**	1.00E-03
10-Aug-08	6.14E-04	1.19E-03	5.36E-04	1.25E-03	**ND**	**ND**	6.16E-04	9.86E-04	1.38E-02	9.79E-04	7.50E-04	1.11E-03	6.40E-04	6.14E-04	1.26E-03	6.52E-04	**ND**	**ND**
22-Aug-08	6.12E-04	9.97E-04	6.18E-04	6.24E-04	9.22E-04	2.74E-03	1.00E-03	9.82E-04	8.53E-04	6.12E-04	9.97E-04	6.19E-04	6.24E-04	1.23E-03	6.13E-04	8.62E-04	9.86E-04	6.22E-04
28-Aug-08	7.41E-04	1.75E-03	1.99E-03	2.26E-03	1.37E-03	7.46E-04	6.30E-04	1.60E-03	7.35E-04	6.13E-04	1.01E-03	8.68E-04	6.27E-04	1.72E-03	1.85E-03	1.60E-03	1.12E-03	6.25E-04
3-Sep-08	1.49E-03	8.83E-04	1.50E-03	1.39E-03	2.75E-03	1.75E-03	2.16E-03	1.86E-03	1.73E-03	1.11E-03	1.64E-03	1.26E-03	1.77E-03	1.61E-03	9.92E-04	7.44E-04	5.11E-03	2.90E-03
9-Sep-08	2.09E-03	2.76E-03	3.61E-03	4.65E-03	2.49E-03	2.74E-03	4.92E-03	4.70E-03	2.34E-03	2.09E-03	3.01E-03	2.74E-03	3.39E-03	2.83E-03	2.59E-03	2.22E-03	2.87E-03	2.38E-03
15-Sep-08	7.41E-04	6.31E-04	6.21E-04	6.29E-04	6.24E-04	6.24E-04	6.32E-04	7.46E-04	6.15E-04	6.15E-04	6.28E-04	6.25E-04	6.29E-04	6.17E-04	6.18E-04	8.66E-04	6.22E-04	1.00E-03
21-Sep-08	8.69E-04	6.32E-04	7.76E-04	6.33E-04	8.78E-04	1.00E-03	6.39E-04	9.96E-04	6.18E-04	8.70E-04	7.59E-04	6.28E-04	6.33E-04	6.21E-04	6.22E-04	8.71E-04	2.25E-03	2.02E-03
27-Sep-08	1.49E-03	1.26E-03	2.13E-03	1.02E-03	2.13E-03	1.26E-03	1.52E-03	1.37E-03	1.48E-03	2.84E-03	2.40E-03	1.76E-03	1.40E-03	1.24E-03	8.72E-04	2.36E-03	1.62E-03	1.87E-03
3-Oct-08	1.46E-03	1.36E-03	1.48E-03	8.70E-04	6.16E-04	1.23E-03	2.12E-03	6.11E-04	2.67E-03	6.07E-04	1.36E-03	2.59E-03	1.49E-03	6.11E-04	1.83E-03	**ND**	1.96E-03	1.36E-03
Arithmetic Mean	1.80E-03	1.89E-03	1.72E-03	2.02E-03	1.79E-03	1.88E-03	1.84E-03	2.11E-03	1.23E-02	1.47E-03	1.99E-03	1.83E-03	1.70E-03	1.62E-03	1.56E-03	1.53E-03	2.20E-03	1.81E-03
Geomertic Mean	1.44E-03	1.50E-03	1.46E-03	1.46E-03	1.55E-03	1.61E-03	1.48E-03	1.68E-03	3.91E-03	1.22E-03	1.62E-03	1.52E-03	1.38E-03	1.37E-03	1.36E-03	1.35E-03	1.87E-03	1.56E-03
95th Percentile	4.13E-03	4.47E-03	3.12E-03	5.88E-03	2.90E-03	3.28E-03	3.60E-03	5.13E-03	4.09E-02	2.93E-03	4.02E-03	3.38E-03	3.17E-03	3.01E-03	2.66E-03	2.41E-03	4.14E-03	3.05E-03
98th Percentile	4.72E-03	6.00E-03	3.42E-03	6.78E-03	3.01E-03	3.68E-03	4.39E-03	5.52E-03	4.13E-02	3.01E-03	4.93E-03	3.61E-03	3.30E-03	3.16E-03	2.73E-03	2.45E-03	4.72E-03	3.10E-03
Maximum	5.12E-03	7.03E-03	3.61E-03	7.38E-03	3.08E-03	3.94E-03	4.92E-03	5.78E-03	4.16E-02	3.06E-03	5.53E-03	3.76E-03	3.39E-03	3.27E-03	2.77E-03	2.47E-03	5.11E-03	3.13E-03
Minimum	6.12E-04	6.31E-04	5.36E-04	6.24E-04	6.16E-04	6.24E-04	6.16E-04	6.11E-04	6.15E-04	6.07E-04	6.28E-04	6.19E-04	6.24E-04	6.11E-04	6.13E-04	6.52E-04	6.22E-04	6.22E-04

	Barium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0015	0.0211	0.0008	0.0010	0.0357	0.0017	0.0022	0.0022	0.0302	0.0017	0.0061	0.0025	0.0113	0.0032	0.0052	0.0012	0.0061	0.0038
23-Jul-08	4.95E-03	2.57E-03	1.27E-03	8.80E-04	6.85E-03	2.16E-03	3.66E-03	1.48E-03	2.27E-02	2.10E-03	2.76E-03	4.12E-03	3.06E-03	9.86E-04	1.85E-03	**ND**	3.60E-03	2.00E-03
29-Jul-08	5.65E-03	4.07E-03	2.21E-03	6.68E-03	4.56E-02	6.29E-03	8.13E-03	4.04E-03	1.54E-02	3.53E-03	4.37E-03	2.82E-03	9.96E-04	1.01E-02	1.58E-03	7.74E-04	ND	ND
4-Aug-08	6.84E-03	1.80E-03	3.30E-03	ND	4.07E-02	7.74E-03	2.46E-03	2.31E-03	3.49E-02	4.53E-03	2.76E-02	5.71E-03	1.60E-02	3.64E-03	1.89E-03	7.93E-03	ND	6.03E-03
10-Aug-08	0.0017	0.0008	0.0004	0.0016	**ND**	**ND**	*0.0006*	*0.0006*	0.0193	0.0010	0.0044	0.0017	0.0013	0.0037	0.0018	0.0009	**ND**	**ND**
22-Aug-08	6.85E-03	3.99E-03	1.61E-03	1.87E-03	6.64E-03	2.74E-02	2.38E-03	2.33E-03	9.75E-04	1.71E-03	5.61E-03	7.43E-04	2.74E-03	2.95E-03	1.47E-03	1.11E-03	1.60E-03	2.11E-03
28-Aug-08	0.0052	0.0034	0.0006	*0.0006*	0.0049	0.0026	0.0006	*0.0006*	0.0013	0.0015	0.0016	0.0012	0.0011	0.0106	*0.0006*	0.0006	0.0030	0.0006
3-Sep-08	2.97E-03	7.57E-04	1.50E-03	1.39E-03	2.00E-02	5.51E-03	1.40E-03	1.37E-03	1.60E-03	1.60E-03	8.45E-03	1.01E-03	9.85E-03	2.60E-03	1.74E-03	8.69E-04	6.98E-03	2.64E-03
9-Sep-08	0.0031	0.0011	0.0015	0.0009	0.0042	0.0031	0.0009	*0.0006*	0.0012	0.0006	0.0016	0.0007	0.0013	0.0007	0.0012	*0.0006*	0.0046	0.0020
15-Sep-08	7.90E-03	2.90E-03	1.61E-03	2.64E-03	3.49E-03	1.62E-03	3.16E-03	1.49E-03	1.23E-03	8.61E-04	2.51E-03	1.50E-03	1.38E-03	1.48E-03	1.98E-03	2.84E-03	1.99E-03	3.39E-03
21-Sep-08	*0.0006*	*0.0006*	*0.0008*	*0.0006*	0.0041	0.0010	0.0011	*0.0006*	0.0011	*0.0006*	*0.0006*	*0.0006*	0.0006	*0.0006*	*0.0006*	*0.0006*	0.0175	0.0016
27-Sep-08	0.0014	*0.0006*	0.0008	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0009	0.0078	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0036	*0.0006*
3-Oct-08	0.0018	0.0022	0.0068	0.0034	0.0042	0.0012	0.0015	0.0010	0.0008	*0.0006*	0.0019	*0.0006*	0.0010	*0.0006*	0.0010	**ND**	0.0032	0.0012
Arithmetic Mean	3.88E-03	3.54E-03	1.78E-03	1.85E-03	1.48E-02	5.09E-03	2.22E-03	1.48E-03	1.01E-02	2.16E-03	5.24E-03	1.84E-03	3.94E-03	3.22E-03	1.65E-03	1.64E-03	5.22E-03	2.37E-03
Geomertic Mean	3.04E-03	2.02E-03	1.34E-03	1.38E-03	7.75E-03	2.84E-03	1.65E-03	1.22E-03	3.62E-03	1.57E-03	3.06E-03	1.39E-03	2.09E-03	2.01E-03	1.39E-03	1.09E-03	4.11E-03	1.92E-03
95th Percentile	7.27E-03	1.09E-02	4.69E-03	4.85E-03	4.29E-02	1.66E-02	5.45E-03	3.02E-03	3.21E-02	5.83E-03	1.61E-02	4.75E-03	1.32E-02	1.03E-02	3.25E-03	5.39E-03	1.28E-02	4.93E-03
98th Percentile	7.65E-03	1.70E-02	5.94E-03	5.95E-03	4.45E-02	2.31E-02	7.06E-03	3.63E-03	3.38E-02	7.00E-03	2.30E-02	5.33E-03	1.49E-02	1.05E-02	4.39E-03	6.92E-03	1.56E-02	5.59E-03
Maximum	7.90E-03	2.11E-02	6.77E-03	6.68E-03	4.56E-02	2.74E-02	8.13E-03	4.04E-03	3.49E-02	7.78E-03	2.76E-02	5.71E-03	1.60E-02	1.06E-02	5.15E-03	7.93E-03	1.75E-02	6.03E-03
Minimum	6.21E-04	6.31E-04	4.46E-04	6.27E-04	6.26E-04	6.29E-04	6.16E-04	6.16E-04	8.50E-04	6.07E-04	6.31E-04	6.16E-04	6.33E-04	6.11E-04	6.16E-04	6.16E-04	1.60E-03	5.85E-04

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Beryllium																	
	Concentration (µg/m3)																	
Sampling Date	TL1 - TSP	TL1 - PM10	TL2 - TSP	TL2 - PM10	TL3 - TSP	TL3 - PM10	RC1 - TSP	RC1 - PM10	A1 - TSP	A1 - PM10	VG1 - TSP	VG1 - PM10	VG2 - TSP	VG2 - PM10	G1 - TSP	G1 - PM10	FA1 - TSP	FA1 - PM10
17-Jul-08	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0012*	*0.0006*	*0.0006*	*0.0056*	*0.0007*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
23-Jul-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0081*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
29-Jul-08	*0.0013*	*0.0018*	*0.0007*	*0.0018*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0077*	*0.0006*	*0.0015*	*0.0012*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	**ND**	**ND**
4-Aug-08	*0.0008*	*0.0005*	*0.0006*	**ND**	*0.0006*	*0.0006*	*0.0006*	*0.0012*	*0.0092*	*0.0006*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0007*	**ND**	*0.0006*
10-Aug-08	*0.0006*	*0.0007*	*0.0004*	*0.0006*	**ND**	**ND**	*0.0006*	*0.0006*	*0.0069*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	**ND**	**ND**
22-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0009*	*0.0012*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
28-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
9-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
15-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
21-Sep-08	*0.0006*	*0.0006*	*0.0008*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
27-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Oct-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
Arithmetic Mean	6.84E-04	7.17E-04	6.26E-04	7.22E-04	6.51E-04	7.27E-04	6.30E-04	6.59E-04	3.26E-03	6.17E-04	6.91E-04	6.82E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.47E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
95th Percentile	1.00E-03	1.14E-03	7.01E-04	1.14E-03	7.77E-04	1.24E-03	6.42E-04	8.36E-04	8.54E-03	6.35E-04	9.62E-04	8.88E-04	6.65E-04	6.34E-04	6.50E-04	6.51E-04	6.25E-04	6.30E-04
98th Percentile	1.21E-03	1.56E-03	7.46E-04	1.51E-03	8.64E-04	1.24E-03	6.45E-04	1.03E-03	8.92E-03	6.47E-04	1.26E-03	1.06E-03	6.65E-04	6.40E-04	6.56E-04	6.52E-04	6.25E-04	6.31E-04
Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04

	Boron																	
	Concentration (µg/m3)																	
Sampling Date	TL1 - TSP	TL1 - PM10	TL2 - TSP	TL2 - PM10	TL3 - TSP	TL3 - PM10	RC1 - TSP	RC1 - PM10	A1 - TSP	A1 - PM10	VG1 - TSP	VG1 - PM10	VG2 - TSP	VG2 - PM10	G1 - TSP	G1 - PM10	FA1 - TSP	FA1 - PM10
17-Jul-08	*0.0305*	*0.0311*	*0.0325*	*0.0311*	*0.0308*	*0.0616*	*0.0312*	*0.0306*	*0.2795*	*0.0328*	*0.0310*	*0.0345*	*0.0329*	*0.0322*	*0.0322*	*0.0322*	*0.0307*	*0.0310*
23-Jul-08	*0.0309*	*0.0321*	*0.0318*	*0.0314*	*0.0329*	*0.0318*	*0.0316*	*0.0309*	*0.4053*	*0.0308*	*0.0314*	*0.0312*	*0.0332*	*0.0308*	*0.0308*	**ND**	*0.0310*	*0.0313*
29-Jul-08	*0.0673*	*0.0924*	*0.0325*	*0.0879*	*0.0308*	*0.0308*	*0.0313*	*0.0306*	*0.3847*	*0.0304*	*0.0728*	*0.0588*	*0.0311*	*0.0312*	*0.0330*	*0.0323*	**ND**	**ND**
4-Aug-08	*0.0388*	*0.0265*	*0.0317*	**ND**	*0.0318*	*0.0312*	*0.0323*	*0.0578*	*0.4592*	*0.0306*	*0.0313*	*0.0348*	*0.0333*	*0.0314*	*0.0316*	*0.0325*	**ND**	*0.0314*
10-Aug-08	*0.0311*	*0.0334*	*0.0226*	*0.0317*	**ND**	**ND**	*0.0308*	*0.0308*	*0.3441*	*0.0306*	*0.0313*	*0.0348*	*0.0320*	*0.0307*	*0.0314*	*0.0326*	**ND**	**ND**
22-Aug-08	*0.0306*	*0.0312*	*0.0309*	*0.0312*	*0.0461*	*0.0623*	*0.0313*	*0.0307*	*0.0305*	*0.0306*	*0.0311*	*0.0310*	*0.0312*	*0.0307*	*0.0306*	*0.0308*	*0.0308*	*0.0311*
28-Aug-08	*0.0309*	*0.0313*	*0.0311*	*0.0314*	*0.0312*	*0.0311*	*0.0315*	*0.0309*	*0.0306*	*0.0307*	*0.0315*	*0.0310*	*0.0314*	*0.0308*	*0.0308*	*0.0308*	*0.0310*	*0.0313*
3-Sep-08	*0.0310*	*0.0315*	*0.0313*	*0.0316*	*0.0313*	*0.0313*	*0.0317*	*0.0311*	*0.0308*	*0.0309*	*0.0315*	*0.0316*	*0.0316*	*0.0310*	*0.0310*	*0.0310*	*0.0312*	*0.0315*
9-Sep-08	*0.0308*	*0.0314*	*0.0311*	*0.0314*	*0.0311*	*0.0311*	*0.0316*	*0.0309*	*0.0308*	*0.0307*	*0.0314*	*0.0312*	*0.0314*	*0.0308*	*0.0308*	*0.0309*	*0.0312*	*0.0313*
15-Sep-08	*0.0309*	*0.0316*	*0.0310*	*0.0315*	*0.0312*	*0.0312*	*0.0316*	*0.0311*	*0.0307*	*0.0308*	*0.0314*	*0.0312*	*0.0315*	*0.0309*	*0.0309*	*0.0309*	*0.0311*	*0.0314*
21-Sep-08	*0.0310*	*0.0316*	*0.0388*	*0.0316*	*0.0314*	*0.0314*	*0.0319*	*0.0311*	*0.0309*	*0.0311*	*0.0316*	*0.0314*	*0.0316*	*0.0310*	*0.0311*	*0.0311*	*0.0313*	*0.0315*
27-Sep-08	*0.0310*	*0.0316*	*0.0313*	*0.0317*	*0.0313*	*0.0314*	*0.0317*	*0.0311*	*0.0309*	*0.0309*	*0.0316*	*0.0314*	*0.0317*	*0.0310*	*0.0312*	*0.0310*	*0.0312*	*0.0292*
3-Oct-08	*0.0305*	*0.0310*	*0.0308*	*0.0311*	*0.0308*	*0.0308*	*0.0312*	*0.0305*	*0.0303*	*0.0303*	*0.0310*	*0.0308*	*0.0311*	*0.0306*	*0.0305*	**ND**	*0.0307*	*0.0310*
Arithmetic Mean	3.42E-02	3.59E-02	3.13E-02	3.61E-02	3.26E-02	3.63E-02	3.15E-02	3.29E-02	1.63E-01	3.09E-02	3.45E-02	3.41E-02	3.18E-02	3.10E-02	3.12E-02	3.15E-02	3.10E-02	3.11E-02
Geomertic Mean	3.33E-02	3.39E-02	3.12E-02	3.42E-02	3.23E-02	3.50E-02	3.15E-02	3.24E-02	7.99E-02	3.09E-02	3.34E-02	3.36E-02	3.18E-02	3.10E-02	3.12E-02	3.15E-02	3.10E-02	3.11E-02
95th Percentile	5.02E-02	5.70E-02	3.50E-02	5.70E-02	3.88E-02	6.19E-02	3.21E-02	4.18E-02	4.27E-01	3.17E-02	4.81E-02	4.44E-02	3.32E-02	3.17E-02	3.25E-02	3.26E-02	3.12E-02	3.15E-02
98th Percentile	6.05E-02	7.83E-02	3.73E-02	7.55E-02	4.32E-02	6.22E-02	3.22E-02	5.14E-02	4.46E-01	3.24E-02	6.29E-02	5.31E-02	3.33E-02	3.20E-02	3.28E-02	3.26E-02	3.12E-02	3.15E-02
Maximum	6.73E-02	9.24E-02	3.88E-02	8.79E-02	4.61E-02	6.23E-02	3.23E-02	5.78E-02	4.59E-01	3.28E-02	7.28E-02	5.88E-02	3.33E-02	3.22E-02	3.30E-02	3.26E-02	3.13E-02	3.15E-02
Minimum	3.05E-02	2.65E-02	2.26E-02	3.11E-02	3.08E-02	3.08E-02	3.08E-02	3.05E-02	3.03E-02	3.03E-02	3.10E-02	3.08E-02	3.11E-02	3.06E-02	3.05E-02	3.08E-02	3.07E-02	2.92E-02

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Cadmium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0004	0.0002	0.0003	0.0004	0.0002	0.0005	0.0002	0.0004	0.0022	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0001	0.0004	0.0005
23-Jul-08	3.71E-04	3.85E-04	2.54E-04	6.28E-04	1.71E-03	6.37E-04	3.79E-04	2.47E-04	3.24E-03	1.36E-03	1.25E-04	2.49E-04	2.66E-04	1.23E-04	2.47E-04	**ND**	2.48E-04	2.51E-04
29-Jul-08	1.08E-03	3.70E-04	2.60E-04	1.05E-03	3.70E-04	3.70E-04	2.50E-04	3.67E-04	3.08E-03	2.43E-04	2.91E-04	4.71E-04	3.73E-04	3.74E-04	2.64E-04	1.29E-04	ND	ND
4-Aug-08	4.66E-04	1.06E-04	2.54E-04	ND	1.27E-04	1.25E-04	2.46E-03	9.25E-04	3.67E-03	1.23E-04	6.26E-04	2.78E-04	3.99E-04	2.51E-04	2.53E-04	2.60E-04	ND	2.51E-04
10-Aug-08	*0.0001*	0.0003	0.0004	0.0003	**ND**	**ND**	0.0009	0.0006	*0.0014*	0.0002	*0.0001*	0.0001	0.0003	*0.0001*	0.0003	0.0003	**ND**	**ND**
22-Aug-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0002*	*0.0002*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
28-Aug-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	0.0000	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*		*0.0001*
3-Sep-08	*0.0001*	0.0003	*0.0001*	*0.0001*	0.0001	*0.0001*	*0.0001*	*0.0001*	*0.0001*	0.0001	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
9-Sep-08	0.0001	0.0001	0.0001	0.0004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
15-Sep-08	*0.0001*	*0.0001*	0.0006	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	0.0017	*0.0001*	*0.0001*	*0.0001*	*0.0001*
21-Sep-08	*0.0001*	*0.0001*	*0.0002*	*0.0001*	*0.0001*	0.0004	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	0.0003	0.0001	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
27-Sep-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
3-Oct-08	0.0004	*0.0001*	*0.0001*	0.0001	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	0.0002	0.0001	0.0005	*0.0001*	*0.0001*	**ND**	*0.0001*	0.0004
Arithmetic Mean	2.80E-04	1.92E-04	2.24E-04	2.97E-04	2.93E-04	2.42E-04	4.00E-04	2.70E-04	1.12E-03	2.67E-04	2.05E-04	2.06E-04	2.36E-04	2.96E-04	1.84E-04	1.50E-04	1.65E-04	2.03E-04
Geomertic Mean	2.08E-04	1.73E-04	1.94E-04	2.18E-04	1.86E-04	1.81E-04	2.22E-04	2.04E-04	3.96E-04	1.84E-04	1.73E-04	1.81E-04	2.03E-04	1.90E-04	1.68E-04	1.43E-04	1.51E-04	1.77E-04
95th Percentile	7.10E-04	3.76E-04	4.63E-04	8.20E-04	9.74E-04	5.58E-04	1.50E-03	7.40E-04	3.41E-03	8.57E-04	4.74E-04	4.37E-04	4.38E-04	9.23E-04	3.13E-04	2.60E-04	3.20E-04	4.34E-04
98th Percentile	9.30E-04	3.81E-04	5.58E-04	9.61E-04	1.42E-03	6.05E-04	2.07E-03	8.51E-04	3.57E-03	1.16E-03	5.65E-04	4.57E-04	4.73E-04	1.41E-03	3.57E-04	2.61E-04	3.49E-04	4.71E-04
Maximum	1.08E-03	3.85E-04	6.21E-04	1.05E-03	1.71E-03	6.37E-04	2.46E-03	9.25E-04	3.67E-03	1.36E-03	6.26E-04	4.71E-04	4.97E-04	1.73E-03	3.87E-04	2.61E-04	3.68E-04	4.96E-04
Minimum	1.22E-04	1.06E-04	1.23E-04	1.24E-04	1.23E-04	3.11E-05	1.23E-04	1.22E-04	1.21E-04	1.21E-04	1.23E-04	1.23E-04	1.23E-04	1.22E-04	1.22E-04	1.23E-04	1.23E-04	1.17E-04

	Calcium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.1463	0.1863	0.1430	0.1492	0.6163	0.2957	0.1374	0.1223	1.2300	0.1180	0.2235	0.1381	0.3550	0.1545	0.1289	0.0903	0.2211	0.1487
23-Jul-08	0.0990	0.1283	0.1526	0.0880	0.1448	0.0891	0.1262	0.2225	1.4590	0.1233	0.1255	0.1496	0.1727	0.1109	0.0864	**ND**	0.1737	0.1002
29-Jul-08	0.5385	0.3328	0.1041	0.2812	0.9746	0.2097	0.1125	0.1224	1.2311	0.1095	0.4367	0.1882	0.1494	0.2119	0.1055	0.1162	**ND**	**ND**
4-Aug-08	0.1864	0.0954	0.1396	**ND**	0.6098	0.1373	0.1293	0.1851	1.1020	0.1226	0.6513	0.1949	0.3196	0.1507	0.1137	0.1561	**ND**	0.1130
10-Aug-08	0.0614	0.0661	0.1875	0.1002	**ND**	**ND**	0.0493	0.0493	0.6882	0.0734	0.2251	0.0834	0.0896	0.0860	0.1131	0.1043	**ND**	**ND**
22-Aug-08	0.0734	0.0748	0.0865	0.0873	0.1106	0.1745	0.0752	0.0736	0.0975	0.0980	0.0748	0.0743	0.0873	0.0737	0.0980	0.0738	0.0862	0.0871
28-Aug-08	0.0618	0.1128	0.0870	0.0753	0.0999	0.0622	0.0882	0.0864	0.0981	0.0613	0.0755	0.0496	0.0753	0.0615	0.0616	0.0740	0.0991	0.0500
3-Sep-08	0.0076	0.0142	0.0109	0.0095	0.0125	0.0078	0.0112	0.0107	0.0121	0.0076	0.0095	0.0063	0.0095	0.0076	0.0076	0.0092	0.0124	0.0063
9-Sep-08	0.1109	0.0879	0.1121	0.0880	0.1619	0.0996	0.1389	0.0989	0.0986	0.0860	0.0878	0.0998	0.0880	0.0862	0.1234	0.0864	0.1869	0.1127
15-Sep-08	0.0741	0.0758	0.1987	0.1133	0.1372	0.1122	0.1897	0.0870	0.1230	0.0861	0.1257	0.0999	0.1007	0.0864	0.0989	0.1855	0.1367	0.1506
21-Sep-08	0.0745	0.0759	0.1242	0.0886	0.1255	0.1004	0.1022	0.0623	0.0990	0.1118	0.0885	0.0879	0.1013	0.0869	0.0746	0.0871	0.2250	0.2145
27-Sep-08	0.0620	0.1515	0.1378	0.0761	0.1002	0.1509	0.0889	0.1119	0.0864	0.0865	0.0883	0.0878	0.0635	0.1239	0.1620	0.1117	0.1623	0.1169
3-Oct-08	0.1583	0.1365	0.2339	0.2360	0.1108	0.0985	0.1373	0.2077	0.1092	0.0850	0.1737	0.1479	0.1615	0.1101	0.1464	**ND**	0.2208	0.1114
Arithmetic Mean	1.27E-01	1.18E-01	1.32E-01	1.16E-01	2.67E-01	1.28E-01	1.07E-01	1.11E-01	4.95E-01	8.99E-02	1.84E-01	1.08E-01	1.36E-01	1.04E-01	1.02E-01	9.95E-02	1.52E-01	1.10E-01
Geomertic Mean	8.79E-02	9.65E-02	1.12E-01	9.20E-02	1.57E-01	1.01E-01	9.12E-02	9.01E-02	2.16E-01	7.80E-02	1.23E-01	8.71E-02	1.03E-01	8.61E-02	8.64E-02	8.33E-02	1.24E-01	8.71E-02
95th Percentile	3.27E-01	2.45E-01	2.13E-01	2.56E-01	7.78E-01	2.48E-01	1.59E-01	2.14E-01	1.32E+00	1.23E-01	5.23E-01	1.91E-01	3.34E-01	1.77E-01	1.53E-01	1.71E-01	2.23E-01	1.83E-01
98th Percentile	4.54E-01	2.98E-01	2.25E-01	2.71E-01	8.96E-01	2.77E-01	1.77E-01	2.19E-01	1.40E+00	1.23E-01	6.00E-01	1.93E-01	3.47E-01	1.98E-01	1.58E-01	1.80E-01	2.24E-01	2.02E-01
Maximum	5.38E-01	3.33E-01	2.34E-01	2.81E-01	9.75E-01	2.96E-01	1.90E-01	2.23E-01	1.46E+00	1.23E-01	6.51E-01	1.95E-01	3.55E-01	2.12E-01	1.62E-01	1.85E-01	2.25E-01	2.15E-01
Minimum	7.65E-03	1.42E-02	1.09E-02	9.51E-03	1.25E-02	7.78E-03	1.12E-02	1.07E-02	1.21E-02	7.57E-03	9.52E-03	6.27E-03	9.51E-03	7.62E-03	7.64E-03	9.18E-03	1.24E-02	6.30E-03

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Chromium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0683	0.0547	0.0715	0.0696	0.0752	0.1553	0.0762	0.0673	0.6038	0.0747	0.0969	0.0773	0.0802	0.0734	0.0928	0.1019	0.0700	0.0855
23-Jul-08	0.0767	0.0834	0.0992	0.0578	0.0619	0.0751	0.0858	0.1001	1.0375	0.0826	0.0577	0.0786	0.0558	0.0579	0.0518	**ND**	0.0583	0.0827
29-Jul-08	0.2612	0.2514	0.0807	0.3268	0.0913	0.1270	0.1125	0.1139	0.8156	0.1253	0.1456	0.1153	0.0597	0.2606	0.0607	0.0594	**ND**	**ND**
4-Aug-08	0.1041	0.0583	0.0597	**ND**	0.0521	0.0549	0.0711	0.1295	1.1571	0.0539	0.1202	0.0585	0.0826	0.0616	0.1036	0.0923	**ND**	0.0803
10-Aug-08	0.0540	0.0846	0.0536	0.0726	**ND**	**ND**	0.0542	0.0517	0.6056	0.0808	0.0500	0.0556	0.0499	0.0565	0.0553	0.0704	**ND**	**ND**
22-Aug-08	0.0673	0.0798	0.0692	0.0661	0.1401	0.1596	0.0777	0.0687	0.0768	0.0612	0.0760	0.0731	0.0649	0.0614	0.0735	0.0677	0.0517	0.0672
28-Aug-08	0.0568	0.0702	0.0634	0.0790	0.0674	0.0721	0.0693	0.0839	0.0821	0.0711	0.0654	0.0595	0.0828	0.0640	0.0702	0.0801	0.0632	0.0513
3-Sep-08	0.0619	0.0757	0.0751	0.0619	0.0551	0.0701	0.0622	0.0658	0.0543	0.0753	0.0542	0.0543	0.0530	0.0557	0.0620	0.0372	0.0649	0.0441
9-Sep-08	0.0752	0.0665	0.0585	0.0704	0.0548	0.0510	0.0745	0.0569	0.0641	0.0712	0.0577	0.0623	0.0679	0.0788	0.0790	0.0790	0.0548	0.0526
15-Sep-08	0.0666	0.0745	0.0671	0.0931	0.0661	0.0599	0.1024	0.0746	0.0738	0.0713	0.0553	0.0512	0.0680	0.0716	0.0507	0.0482	0.0547	0.0740
21-Sep-08	0.0571	0.0594	0.0900	0.0848	0.0803	0.0627	0.0792	0.0635	0.0594	0.0683	0.0683	0.0666	0.0684	0.0633	0.0522	0.0634	0.0713	0.0669
27-Sep-08	0.0545	0.0656	0.0601	0.0609	0.0852	0.0729	0.0609	0.0522	0.0605	0.0519	0.0669	0.0602	0.0596	0.0719	0.0760	0.0807	0.0774	0.0655
3-Oct-08	0.0658	0.0558	0.0566	0.0571	0.0554	0.0554	0.0587	0.0868	0.0485	0.0607	0.0918	0.0641	0.0559	0.0501	0.0488	**ND**	0.0675	0.0718
Arithmetic Mean	8.23E-02	8.31E-02	6.96E-02	9.17E-02	7.37E-02	8.47E-02	7.58E-02	7.81E-02	3.65E-01	7.30E-02	7.74E-02	6.74E-02	6.53E-02	7.90E-02	6.74E-02	7.09E-02	6.34E-02	6.74E-02
Geomertic Mean	7.36E-02	7.55E-02	6.85E-02	7.91E-02	7.08E-02	7.80E-02	7.42E-02	7.50E-02	1.70E-01	7.12E-02	7.33E-02	6.59E-02	6.44E-02	7.06E-02	6.56E-02	6.85E-02	6.29E-02	6.61E-02
95th Percentile	1.67E-01	1.51E-01	9.37E-02	1.98E-01	1.13E-01	1.57E-01	1.06E-01	1.20E-01	1.09E+00	9.97E-02	1.30E-01	9.33E-02	8.27E-02	1.52E-01	9.71E-02	9.71E-02	7.46E-02	8.41E-02
98th Percentile	2.23E-01	2.11E-01	9.70E-02	2.75E-01	1.29E-01	1.59E-01	1.10E-01	1.26E-01	1.13E+00	1.15E-01	1.39E-01	1.06E-01	8.27E-02	2.17E-01	1.01E-01	1.00E-01	7.63E-02	8.50E-02
Maximum	2.61E-01	2.51E-01	9.92E-02	3.27E-01	1.40E-01	1.60E-01	1.13E-01	1.30E-01	1.16E+00	1.25E-01	1.46E-01	1.15E-01	8.28E-02	2.61E-01	1.04E-01	1.02E-01	7.74E-02	8.55E-02
Minimum	5.40E-02	5.47E-02	5.36E-02	5.71E-02	5.21E-02	5.10E-02	5.42E-02	5.17E-02	4.85E-02	5.19E-02	5.00E-02	5.12E-02	4.99E-02	5.01E-02	4.88E-02	3.72E-02	5.17E-02	4.41E-02

	Cobalt																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**	
17-Jul-08	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0012*	*0.0006*	*0.0006*	*0.0056*	*0.0007*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	0.0011	
23-Jul-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0081*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	**ND**	*0.0006*	*0.0006*	
29-Jul-08	*0.0013*	*0.0018*	*0.0007*	*0.0018*	0.0007	*0.0006*	*0.0006*	*0.0006*	*0.0077*	*0.0006*	*0.0015*	*0.0012*	*0.0006*	*0.0007*	*0.0006*	**ND**	**ND**	
4-Aug-08	*0.0008*	*0.0005*	*0.0006*	**ND**	*0.0006*	*0.0006*	*0.0006*	*0.0012*	*0.0092*	*0.0006*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0007*	**ND**	*0.0006*	
10-Aug-08	*0.0006*	*0.0007*	*0.0004*	*0.0006*	**ND**	**ND**	*0.0006*	*0.0006*	*0.0069*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0007*	**ND**	**ND**	
22-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0009*	*0.0012*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	
28-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	
3-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	
9-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	
15-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	
21-Sep-08	*0.0006*	*0.0006*	*0.0008*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0006	*0.0006*	*0.0006*	*0.0006*	*0.0006*	
27-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	
3-Oct-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*	
Arithmetic Mean	6.84E-04	7.17E-04	6.26E-04	7.22E-04	6.61E-04	7.27E-04	6.30E-04	6.59E-04	3.26E-03	6.17E-04	6.91E-04	6.82E-04	6.37E-04	6.24E-04	6.29E-04	6.20E-04	6.67E-04	
Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.57E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.24E-04	6.29E-04	6.20E-04	6.56E-04	
95th Percentile	1.00E-03	1.14E-03	7.01E-04	1.14E-03	8.22E-04	1.24E-03	6.42E-04	8.36E-04	8.54E-03	6.35E-04	9.62E-04	8.88E-04	6.65E-04	6.50E-04	6.51E-04	6.25E-04	8.73E-04	
98th Percentile	1.21E-03	1.56E-03	7.46E-04	1.51E-03	8.82E-04	1.24E-03	6.45E-04	1.03E-03	8.92E-03	6.47E-04	1.26E-03	1.06E-03	6.65E-04	6.56E-04	6.52E-04	6.25E-04	1.02E-03	
Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.59E-04	6.52E-04	6.25E-04	1.12E-03	
Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04	

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Copper																	
	(µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0024	0.0248	0.0055	0.1554	0.0069	0.1355	0.0612	0.0044	0.0302	0.0068	0.0045	0.0052	0.0060	0.0033	0.0075	0.0039	0.0087	0.0071
23-Jul-08	0.0032	0.0049	0.0036	0.0028	0.0145	0.0023	0.0045	0.3226	0.2432	0.0048	0.0054	0.0036	0.0027	0.0604	0.0048	**ND**	0.0035	0.0034
29-Jul-08	0.1035	0.0048	0.0155	0.0026	0.4773	0.0136	0.0033	0.0035	0.0027	0.0323	0.0096	0.0093	0.0100	0.0034	0.0053	0.0046	**ND**	**ND**
4-Aug-08	0.0054	0.0159	0.0037	**ND**	0.0057	0.0030	0.0036	0.0083	0.0459	0.0245	0.0093	0.0167	0.0072	0.0050	0.0032	0.0031	**ND**	0.0151
10-Aug-08	0.0020	0.0022	0.0027	0.0029	**ND**	**ND**	0.0026	0.0022	0.0165	0.0021	0.0021	0.0028	0.0040	0.0016	0.0026	0.0020	**ND**	**ND**
22-Aug-08	0.0012	0.0021	0.0014	0.0011	0.0065	0.0020	0.0016	0.0014	0.0023	0.0012	0.0007	0.0011	0.0019	0.0023	0.0010	0.0011	0.0014	0.0012
28-Aug-08	*0.0006*	0.0010	0.0007	*0.0006*	0.0014	0.0009	0.0030	0.0017	0.0007	0.0006	0.0013	*0.0006*	0.0008	0.0006	0.0010	0.0007	0.0012	*0.0006*
3-Sep-08	*0.0006*	0.0010	0.0025	0.0009	0.0029	0.0010	0.0006	*0.0006*	0.0021	0.0023	0.0015	*0.0006*	0.0013	0.0028	0.0007	*0.0006*	0.0019	0.0006
9-Sep-08	0.0015	0.0008	0.0009	0.0008	0.0025	0.0026	0.0010	0.0006	0.0009	0.0012	0.0008	0.0020	0.0006	*0.0006*	0.0030	0.0012	0.0046	0.0024
15-Sep-08	0.0012	0.0034	0.0094	0.0024	0.0012	0.0012	0.0038	0.0011	0.0015	*0.0006*	0.0068	0.0032	0.0019	0.0027	0.0046	0.0121	0.0017	0.0011
21-Sep-08	0.0016	0.0013	0.0033	0.0009	0.0023	0.0015	0.0018	*0.0006*	0.0011	0.0010	0.0019	0.0009	0.0008	0.0009	0.0026	0.0009	0.0026	0.0013
27-Sep-08	0.0010	0.0014	0.0083	0.0008	0.0011	0.0008	0.0011	0.0012	0.0007	0.0012	0.0014	0.0013	*0.0006*	0.0011	0.0025	0.0007	0.0019	0.0009
3-Oct-08	0.1048	0.0011	0.0017	0.0016	0.0011	0.0021	0.0015	0.0016	0.0011	0.0007	0.0032	0.0010	0.0022	0.0011	0.0059	**ND**	0.0015	0.0012
Arithmetic Mean	1.76E-02	4.98E-03	4.54E-03	1.44E-02	4.36E-02	1.39E-02	6.91E-03	2.69E-02	2.68E-02	6.12E-03	3.73E-03	3.72E-03	3.07E-03	6.61E-03	3.43E-03	2.82E-03	2.90E-03	3.18E-03
Geomertic Mean	2.94E-03	2.58E-03	3.14E-03	1.99E-03	4.45E-03	2.73E-03	2.65E-03	2.45E-03	3.97E-03	2.34E-03	2.63E-03	2.18E-03	2.04E-03	2.26E-03	2.78E-03	1.77E-03	2.37E-03	1.81E-03
95th Percentile	1.04E-01	1.95E-02	1.18E-02	7.15E-02	2.23E-01	6.85E-02	2.72E-02	1.34E-01	1.25E-01	2.76E-02	9.42E-03	1.23E-02	8.30E-03	2.72E-02	6.50E-03	8.37E-03	6.87E-03	1.11E-02
98th Percentile	1.04E-01	2.27E-02	1.40E-02	1.22E-01	3.75E-01	1.09E-01	4.76E-02	2.47E-01	1.96E-01	3.04E-02	9.56E-03	1.49E-02	9.31E-03	4.71E-02	7.09E-03	1.06E-02	7.98E-03	1.35E-02
Maximum	1.05E-01	2.48E-02	1.55E-02	1.55E-01	4.77E-01	1.36E-01	6.12E-02	3.23E-01	2.43E-01	3.23E-02	9.65E-03	1.67E-02	9.97E-03	6.04E-02	7.47E-03	1.21E-02	8.72E-03	1.51E-02
Minimum	6.18E-04	7.53E-04	7.46E-04	6.27E-04	1.11E-03	7.55E-04	6.34E-04	6.18E-04	7.35E-04	6.13E-04	7.48E-04	6.20E-04	6.28E-04	6.15E-04	7.44E-04	6.20E-04	1.24E-03	6.25E-04

	Iron																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.1463	0.2609	0.1561	0.1368	0.7272	0.1725	0.1749	0.1468	0.8945	0.1311	0.3229	0.1795	0.4997	0.2060	0.1933	0.0903	0.2825	0.2107
23-Jul-08	1.24E-01	1.03E-01	1.14E-01	1.26E-01	1.45E-01	1.53E-01	1.01E-01	9.89E-02	1.30E+00	1.11E-01	1.76E-01	1.12E-01	1.06E-01	1.72E-01	8.64E-02	**ND**	1.74E-01	1.50E-01
29-Jul-08	2.69E-01	4.07E-01	1.56E-01	3.87E-01	1.39E+00	2.47E-01	1.63E-01	1.59E-01	1.23E+00	2.43E-01	3.49E-01	1.88E-01	9.96E-02	1.73E+00	1.32E-01	9.04E-02	ND	ND
4-Aug-08	3.11E-01	1.38E-01	1.65E-01	ND	1.05E+00	2.37E-01	1.29E-01	2.08E-01	1.47E+00	1.23E-01	1.18E+00	3.06E-01	6.92E-01	1.51E-01	1.26E-01	1.69E-01	ND	2.89E-01
10-Aug-08	0.1378	0.0860	**ND**	0.0446	0.06160326	**ND**	0.1346	0.0493	0.0834	0.6882	0.0737	0.2877	0.0913	0.0896	**ND**	0.1131		**ND**
22-Aug-08	0.0856	0.0748	0.0618	0.0499	0.1290	0.1247	0.1128	0.0491	0.0488	0.0612	0.0748	0.0619	0.0749	0.0860	0.0613	0.0615	0.0862	0.0871
28-Aug-08	0.0741	0.0627	0.0497	0.0753	0.1124	0.0622	0.0504	0.0494	0.0368	0.0490	0.0755	*0.0310*	0.0878	0.0492	*0.0308*	0.0370	0.0619	0.0375
3-Sep-08	0.0495	0.0378	0.0751	0.0379	0.4381	0.1251	0.7359	0.0497	0.0617	0.0494	0.2649	0.0506	0.3915	0.1362	0.0620	*0.0310*	0.3492	0.1385
9-Sep-08	0.3697	0.0502	0.0623	0.0503	0.1370	0.0747	0.0631	0.0494	0.0493	0.0491	0.0627	0.0499	0.0628	0.0493	0.0740	0.0494	0.1495	0.0752
15-Sep-08	0.1111	0.0884	0.1366	0.0503	0.1247	0.0748	0.0759	0.0622	0.0615	0.0369	0.1257	0.0749	0.0378	0.0494	0.0989	0.1113	0.1243	0.0753
21-Sep-08	0.0372	0.0379	0.0621	0.0380	0.1004	0.0376	0.0383	0.0374	0.0618	0.0994	0.0759	0.0377	0.0760	0.0372	0.0497	0.0373	0.2000	0.0883
27-Sep-08	0.0744	0.0631	0.0877	0.0381	0.0501	0.0503	0.0381	0.0497	0.0494	0.0494	0.0631	0.0376	0.0381	0.0496	0.0748	0.0372	0.0998	0.0585
3-Oct-08	0.0974	0.0496	0.0862	0.0745	0.0862	0.0492	0.0624	0.1100	0.0607	0.0486	0.1116	0.0616	0.0745	0.0734	0.0732	**ND**	0.1717	0.0743
Arithmetic Mean	1.45E-01	1.12E-01	1.01E-01	9.23E-02	3.51E-01	1.17E-01	1.45E-01	8.61E-02	4.16E-01	1.34E-01	2.27E-01	1.14E-01	1.79E-01	2.22E-01	8.85E-02	7.52E-02	1.70E-01	1.17E-01
Geomertic Mean	1.16E-01	8.50E-02	9.31E-02	6.89E-02	1.91E-01	9.79E-02	9.93E-02	7.34E-02	1.43E-01	8.81E-02	1.43E-01	8.41E-02	1.12E-01	1.04E-01	7.96E-02	6.48E-02	1.50E-01	9.90E-02
95th Percentile	3.34E-01	3.19E-01	1.60E-01	2.49E-01	1.19E+00	2.41E-01	3.99E-01	1.79E-01	1.37E+00	4.21E-01	6.81E-01	2.95E-01	5.77E-01	8.17E-01	1.60E-01	1.41E-01	3.19E-01	2.50E-01
98th Percentile	3.55E-01	3.72E-01	1.63E-01	3.32E-01	1.31E+00	2.45E-01	6.01E-01	1.96E-01	1.43E+00	5.81E-01	9.79E-01	3.02E-01	6.46E-01	1.37E+00	1.80E-01	1.58E-01	3.37E-01	2.73E-01
Maximum	3.70E-01	4.07E-01	1.65E-01	3.87E-01	1.39E+00	2.47E-01	7.36E-01	2.08E-01	1.47E+00	6.88E-01	1.18E+00	3.06E-01	6.92E-01	1.73E+00	1.93E-01	1.69E-01	3.49E-01	2.89E-01
Minimum	3.72E-02	3.78E-02	4.97E-02	3.79E-02	5.01E-02	3.76E-02	3.81E-02	3.74E-02	3.68E-02	3.69E-02	6.27E-02	3.10E-02	3.78E-02	3.72E-02	3.08E-02	3.10E-02	6.19E-02	3.75E-02

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Lead																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0011	0.0076	0.0012	0.0009	0.0456	0.0039	0.0027	0.0017	0.0212	0.0033	0.0046	0.0028	0.0068	0.0031	0.0045	0.0017	0.0020	0.0042
23-Jul-08	0.0001	0.0010	0.0001	0.0001	0.0060	0.0005	0.0003	0.0002	0.0344	0.0004	0.0006	0.0003	0.0009	0.0004	0.0006	**ND**	0.0002	0.0005
29-Jul-08	0.0035	0.0181	0.0027	0.0039	0.0839	0.0160	0.0163	0.0097	0.0554	0.0064	0.0058	0.0031	0.0017	0.0079	0.0040	0.0021	**ND**	**ND**
4-Aug-08	0.0037	0.0022	0.0028	**ND**	0.0737	0.0200	0.0043	0.0051	0.0624	0.0067	0.0238	0.0107	0.0123	0.0038	0.0019	0.0026	**ND**	0.0054
10-Aug-08	0.0017	0.0017	0.0008	0.0023	**ND**	**ND**	0.0012	0.0011	0.0151	0.0016	0.0051	0.0017	0.0026	0.0016	0.0025	0.0014	**ND**	**ND**
22-Aug-08	0.0053	0.0029	0.0015	0.0015	0.0090	0.0080	0.0016	0.0037	0.0009	0.0031	0.0015	*0.0006*	0.0012	0.0018	*0.0006*	*0.0006*	0.0023	0.0039
28-Aug-08	0.0026	0.0024	0.0007	0.0006	0.0050	0.0025	0.0009	*0.0006*	0.0027	0.0053	0.0026	0.0016	0.0021	0.0010	*0.0006*	0.0007	0.0040	0.0009
3-Sep-08	*0.0006*	*0.0006*	0.0013	0.0006	0.0501	0.0213	0.0013	0.0007	0.0014	*0.0006*	0.0047	0.0008	0.0062	0.0035	0.0051	0.0020	0.0015	0.0014
9-Sep-08	0.0015	0.0009	0.0007	*0.0006*	0.0061	0.0010	0.0008	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0012	*0.0006*
15-Sep-08	0.0028	0.0014	*0.0006*	*0.0006*	0.0087	0.0031	*0.0006*	*0.0006*	0.0006	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0006
21-Sep-08	*0.0006*	*0.0006*	*0.0008*	*0.0006*	0.0011	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0006	*0.0006*	*0.0006*	*0.0006*	0.0001	*0.0006*
27-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0010	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0026	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0007	*0.0006*	*0.0006*	*0.0006*
3-Oct-08	0.0029	*0.0006*	*0.0006*	*0.0006*	0.0037	0.0009	0.0006	*0.0006*	0.0008	*0.0006*	0.0014	*0.0006*	0.0006	*0.0006*	0.0015	**ND**	0.0012	*0.0006*
Arithmetic Mean	2.09E-03	3.13E-03	1.12E-03	1.08E-03	2.45E-02	6.53E-03	2.46E-03	2.00E-03	1.51E-02	2.50E-03	4.05E-03	1.90E-03	2.85E-03	2.01E-03	1.83E-03	1.24E-03	1.38E-03	1.76E-03
Geomertic Mean	1.46E-03	1.65E-03	8.85E-04	7.77E-04	9.84E-03	2.85E-03	1.25E-03	1.09E-03	3.56E-03	1.56E-03	1.99E-03	1.11E-03	1.63E-03	1.30E-03	1.27E-03	1.05E-03	8.89E-04	1.16E-03
95th Percentile	4.34E-03	1.18E-02	2.76E-03	2.98E-03	7.83E-02	2.06E-02	9.06E-03	6.92E-03	5.82E-02	6.56E-03	1.30E-02	6.12E-03	9.00E-03	5.40E-03	4.74E-03	2.33E-03	3.23E-03	4.81E-03
98th Percentile	4.89E-03	1.56E-02	2.78E-03	3.51E-03	8.16E-02	2.10E-02	1.34E-02	8.57E-03	6.08E-02	6.67E-03	1.95E-02	8.88E-03	1.10E-02	6.87E-03	4.95E-03	2.49E-03	3.67E-03	5.16E-03
Maximum	5.26E-03	1.81E-02	2.79E-03	3.87E-03	8.39E-02	2.13E-02	1.63E-02	9.67E-03	6.24E-02	6.74E-03	2.38E-02	1.07E-02	1.23E-02	7.85E-03	5.08E-03	2.60E-03	3.96E-03	5.40E-03
Minimum	1.36E-04	6.20E-04	1.49E-04	1.09E-04	1.00E-03	5.02E-04	3.47E-04	2.12E-04	6.15E-04	4.04E-04	5.77E-04	3.44E-04	6.21E-04	3.81E-04	5.56E-04	6.15E-04	7.77E-05	5.28E-04

	Magnesium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0366	*0.0311*	0.0390	0.0373	0.2588	*0.0616*	0.0375	0.0367	0.3354	0.0393	0.1118	0.0552	0.1972	0.0644	0.0387	*0.0322*	0.0860	0.0496
23-Jul-08	*0.0309*	*0.0321*	*0.0318*	*0.0314*	0.0395	*0.0318*	*0.0316*	*0.0309*	*0.4053*	*0.0308*	*0.0314*	*0.0312*	0.0399	*0.0308*	*0.0308*	**ND**	0.0621	*0.0313*
29-Jul-08	0.0808	*0.0924*	*0.0325*	*0.0879*	0.4935	0.0863	*0.0313*	*0.0306*	*0.3847*	*0.0304*	0.1165	*0.0588*	0.0373	0.4862	*0.0330*	*0.0323*	**ND**	**ND**
4-Aug-08	0.0777	0.0318	0.0508	**ND**	0.4192	0.0874	0.0388	*0.0578*	*0.4592*	0.0368	0.6262	0.1253	0.3462	0.0377	*0.0316*	*0.0325*	**ND**	*0.0314*
10-Aug-08	*0.0307*	*0.0330*	*0.0223*	*0.0313*	**ND**	**ND**	*0.0308*	*0.0308*	*0.3441*	*0.0306*	0.1501	*0.0348*	*0.0320*	*0.0307*	*0.0314*	*0.0326*	**ND**	**ND**
22-Aug-08	*0.0306*	*0.0312*	*0.0309*	*0.0312*	*0.0461*	0.0748	*0.0313*	*0.0307*	*0.0305*	*0.0306*	0.0374	*0.0310*	0.0374	*0.0307*	0.0368	*0.0308*	0.0370	0.0373
28-Aug-08	*0.0309*	*0.0313*	*0.0311*	*0.0314*	*0.0312*	*0.0311*	*0.0315*	*0.0309*	*0.0306*	*0.0307*	*0.0315*	*0.0310*	*0.0314*	*0.0308*	*0.0308*	*0.0308*	*0.0310*	*0.0313*
3-Sep-08	*0.0310*	*0.0315*	*0.0313*	0.0379	0.1752	0.0501	*0.0317*	*0.0311*	*0.0308*	*0.0309*	0.1387	*0.0316*	0.1768	0.0743	*0.0310*	*0.0310*	0.1372	0.0378
9-Sep-08	*0.0308*	*0.0314*	*0.0311*	*0.0314*	0.0498	*0.0311*	*0.0316*	*0.0309*	*0.0308*	*0.0307*	*0.0314*	*0.0312*	*0.0314*	*0.0308*	*0.0308*	*0.0309*	0.0623	*0.0313*
15-Sep-08	*0.0309*	*0.0316*	0.0006	*0.0315*	*0.0312*	*0.0312*	*0.0316*	*0.0311*	*0.0307*	*0.0308*	*0.0314*	*0.0312*	*0.0315*	*0.0309*	*0.0309*	*0.0309*	*0.0311*	*0.0314*
21-Sep-08	*0.0310*	*0.0316*	*0.0388*	*0.0316*	*0.0314*	*0.0314*	*0.0319*	*0.0311*	*0.0309*	*0.0311*	*0.0316*	*0.0314*	*0.0316*	*0.0310*	*0.0311*	*0.0311*	0.0500	*0.0315*
27-Sep-08	*0.0310*	*0.0316*	*0.0313*	*0.0317*	*0.0313*	*0.0314*	*0.0317*	*0.0311*	*0.0309*	*0.0309*	*0.0316*	*0.0314*	*0.0317*	*0.0310*	*0.0312*	*0.0310*	*0.0312*	*0.0292*
3-Oct-08	0.0487	*0.0310*	*0.0308*	0.0373	*0.0308*	*0.0308*	*0.0312*	*0.0305*	*0.0303*	*0.0303*	*0.0310*	*0.0308*	*0.0311*	*0.0306*	*0.0305*	**ND**	0.0613	*0.0310*
Arithmetic Mean	4.01E-02	3.63E-02	3.09E-02	3.77E-02	1.37E-01	4.82E-02	3.25E-02	3.34E-02	1.67E-01	3.18E-02	1.08E-01	4.27E-02	8.12E-02	7.23E-02	3.22E-02	3.15E-02	5.89E-02	3.39E-02
Geomertic Mean	3.74E-02	3.43E-02	2.42E-02	3.58E-02	7.35E-02	4.39E-02	3.24E-02	3.28E-02	8.11E-02	3.17E-02	6.18E-02	3.84E-02	5.21E-02	4.38E-02	3.21E-02	3.15E-02	5.24E-02	3.35E-02
95th Percentile	7.89E-02	5.68E-02	4.37E-02	6.04E-02	4.53E-01	8.68E-02	3.80E-02	4.52E-02	4.27E-01	3.78E-02	3.41E-01	8.54E-02	2.57E-01	2.39E-01	3.75E-02	3.26E-02	1.14E-01	4.37E-02
98th Percentile	8.00E-02	7.82E-02	4.79E-02	7.69E-02	4.77E-01	8.71E-02	3.85E-02	5.28E-02	4.46E-01	3.87E-02	5.12E-01	1.09E-01	3.10E-01	3.87E-01	3.82E-02	3.26E-02	1.28E-01	4.72E-02
Maximum	8.08E-02	9.24E-02	5.08E-02	8.79E-02	4.93E-01	8.74E-02	3.88E-02	5.78E-02	4.59E-01	3.93E-02	6.26E-01	1.25E-01	3.46E-01	4.86E-01	3.87E-02	3.26E-02	1.37E-01	4.96E-02
Minimum	3.06E-02	3.10E-02	6.21E-04	3.12E-02	3.08E-02	3.08E-02	3.08E-02	3.05E-02	3.03E-02	3.03E-02	3.10E-02	3.08E-02	3.11E-02	3.06E-02	3.05E-02	3.08E-02	3.10E-02	2.92E-02

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Manganese																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0022	0.0026	0.0023	0.0019	0.0106	0.0020	0.0024	0.0021	0.0112	0.0024	0.0046	0.0026	0.0079	0.0031	0.0028	0.0010	0.0061	0.0036
23-Jul-08	1.48E-03	1.15E-03	1.40E-03	1.01E-03	2.24E-03	1.53E-03	1.39E-03	1.48E-03	1.62E-02	1.48E-03	1.63E-03	1.50E-03	1.86E-03	1.48E-03	1.23E-03	**ND**	3.72E-03	1.88E-03
29-Jul-08	3.23E-03	4.81E-03	1.95E-03	3.51E-03	2.10E-02	3.58E-03	2.63E-03	2.08E-03	1.23E-02	1.46E-03	7.86E-03	2.12E-03	2.49E-03	7.11E-03	1.71E-03	1.03E-03	ND	ND
4-Aug-08	4.19E-03	1.91E-03	2.16E-03	ND	1.65E-02	3.99E-03	2.20E-03	2.54E-03	1.47E-02	1.96E-03	1.63E-02	4.59E-03	1.17E-02	2.39E-03	1.64E-03	1.69E-03	ND	5.02E-03
10-Aug-08	0.0015	0.0016	0.0010	0.0020	**ND**	**ND**	0.0009	0.0010	0.0110	0.0011	0.0043	0.0010	0.0012	0.0012	0.0019	0.0016	**ND**	**ND**
22-Aug-08	0.0013	0.0014	0.0015	0.0009	0.0018	0.0025	0.0023	0.0011	0.0012	0.0011	0.0015	0.0011	0.0016	0.0012	0.0013	0.0011	0.0016	0.0016
28-Aug-08	*0.0006*	0.0002	0.0002	0.0001	0.0002	0.0003	0.0003	0.0001	0.0001	0.0001	0.0002	*0.0006*	0.0002	0.0002	*0.0006*	*0.0006*	0.0002	0.0002
3-Sep-08	*0.0006*	*0.0006*	0.0013	*0.0006*	0.0068	0.0018	0.0032	0.0009	0.0007	*0.0006*	0.0039	0.0006	0.0062	0.0020	0.0010	*0.0006*	0.0080	0.0026
9-Sep-08	0.0014	*0.0006*	0.0011	*0.0006*	0.0024	0.0012	0.0010	*0.0006*	0.0010	0.0007	0.0011	0.0006	0.0009	*0.0006*	0.0014	0.0007	0.0034	0.0013
15-Sep-08	0.0009	0.0048	0.0137	0.0011	0.0012	0.0007	0.0011	*0.0006*	0.0007	0.0007	0.0033	0.0019	0.0011	0.0010	0.0011	0.0037	0.0022	0.0011
21-Sep-08	*0.0006*	*0.0006*	*0.0008*	*0.0006*	0.0002	*0.0006*	*0.0006*	*0.0006*	0.0001	0.0001	*0.0006*	*0.0006*	0.0006	*0.0006*	*0.0006*	*0.0006*	0.0003	0.0001
27-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0016	0.0007
3-Oct-08	0.0021	0.0009	0.0017	0.0016	0.0010	*0.0006*	0.0012	0.0017	*0.0006*	*0.0006*	0.0020	0.0010	0.0014	0.0011	0.0007	**ND**	0.0032	0.0012
Arithmetic Mean	1.59E-03	1.68E-03	2.28E-03	1.22E-03	5.38E-03	1.62E-03	1.53E-03	1.19E-03	5.43E-03	1.00E-03	3.68E-03	1.45E-03	2.91E-03	1.74E-03	1.29E-03	1.21E-03	3.03E-03	1.77E-03
Geomertic Mean	1.30E-03	1.16E-03	1.37E-03	9.20E-04	2.08E-03	1.24E-03	1.26E-03	9.53E-04	1.73E-03	7.37E-04	2.07E-03	1.17E-03	1.62E-03	1.18E-03	1.16E-03	1.02E-03	1.91E-03	1.16E-03
95th Percentile	3.62E-03	4.80E-03	6.87E-03	2.68E-03	1.85E-02	3.76E-03	2.84E-03	2.27E-03	1.53E-02	2.12E-03	1.12E-02	3.41E-03	9.42E-03	4.70E-03	2.26E-03	2.70E-03	7.15E-03	4.31E-03
98th Percentile	3.96E-03	4.80E-03	1.09E-02	3.18E-03	2.00E-02	3.90E-03	3.04E-03	2.43E-03	1.58E-02	2.26E-03	1.43E-02	4.12E-03	1.08E-02	6.14E-03	2.61E-03	3.31E-03	7.65E-03	4.74E-03
Maximum	4.19E-03	4.81E-03	1.37E-02	3.51E-03	2.10E-02	3.99E-03	3.17E-03	2.54E-03	1.62E-02	2.36E-03	1.63E-02	4.59E-03	1.17E-02	7.11E-03	2.83E-03	3.71E-03	7.98E-03	5.02E-03
Minimum	6.18E-04	1.72E-04	1.84E-04	1.10E-04	1.57E-04	3.10E-04	2.84E-04	1.36E-04	9.13E-05	9.17E-05	1.88E-04	6.20E-04	2.03E-04	1.51E-04	6.16E-04	6.16E-04	1.98E-04	1.42E-04

	Molybdenum																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	0.0004	*0.0006*	0.0004	*0.0003*	*0.0028*	0.0004	0.0004	*0.0003*	0.0005	*0.0003*	0.0005	*0.0003*	*0.0003*	*0.0003*
23-Jul-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	0.0004	*0.0003*	*0.0041*	0.0004	0.0008	*0.0003*	*0.0003*	*0.0003*	*0.0003*	**ND**	*0.0003*	*0.0003*
29-Jul-08	*0.0007*	*0.0009*	*0.0003*	*0.0009*	0.0011	*0.0003*	*0.0003*	*0.0003*	*0.0038*	*0.0003*	*0.0007*	*0.0006*	*0.0003*	0.0004	0.0004	*0.0003*	**ND**	**ND**
4-Aug-08	*0.0004*	0.0003	*0.0003*	**ND**	*0.0003*	*0.0003*	*0.0003*	*0.0006*	*0.0046*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	**ND**	0.0004
10-Aug-08	*0.0003*	*0.0003*	*0.0002*	*0.0003*	**ND**	**ND**	*0.0003*	*0.0003*	*0.0034*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	**ND**	**ND**
22-Aug-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0005*	*0.0006*	0.0005	0.0005	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*
28-Aug-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*
3-Sep-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*
9-Sep-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*
15-Sep-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*
21-Sep-08	*0.0003*	*0.0003*	*0.0004*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*
27-Sep-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*
3-Oct-08	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	**ND**	*0.0003*	*0.0003*
Arithmetic Mean	3.42E-04	3.63E-04	3.13E-04	3.61E-04	3.98E-04	3.63E-04	3.39E-04	3.43E-04	1.63E-03	3.18E-04	3.84E-04	3.41E-04	3.34E-04	3.15E-04	3.32E-04	3.15E-04	3.10E-04	3.17E-04
Geomertic Mean	3.33E-04	3.43E-04	3.11E-04	3.42E-04	3.65E-04	3.50E-04	3.36E-04	3.36E-04	7.99E-04	3.17E-04	3.63E-04	3.36E-04	3.30E-04	3.14E-04	3.28E-04	3.15E-04	3.10E-04	3.16E-04
95th Percentile	5.02E-04	5.68E-04	3.50E-04	5.70E-04	7.53E-04	6.19E-04	4.28E-04	5.26E-04	4.27E-03	3.79E-04	7.38E-04	4.44E-04	4.10E-04	3.43E-04	4.44E-04	3.26E-04	3.12E-04	3.46E-04
98th Percentile	6.05E-04	7.82E-04	3.73E-04	7.55E-04	9.67E-04	6.22E-04	4.72E-04	5.57E-04	4.46E-03	3.88E-04	7.47E-04	5.31E-04	4.80E-04	3.61E-04	4.87E-04	3.26E-04	3.12E-04	3.64E-04
Maximum	6.73E-04	9.24E-04	3.88E-04	8.79E-04	1.11E-03	6.23E-04	5.01E-04	5.78E-04	4.59E-03	3.93E-04	7.53E-04	5.88E-04	5.26E-04	3.74E-04	5.15E-04	3.26E-04	3.13E-04	3.77E-04
Minimum	3.05E-04	3.10E-04	2.23E-04	3.11E-04	3.08E-04	3.08E-04	3.08E-04	3.05E-04	3.03E-04	3.03E-04	3.10E-04	3.08E-04	3.11E-04	3.06E-04	3.05E-04	3.08E-04	3.07E-04	2.92E-04

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Nickel																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0044	0.0027	0.0046	0.0046	0.0041	0.0042	0.0049	0.0037	0.0224	0.0042	0.0036	0.0033	0.0049	0.0030	0.0028	0.0028	0.0034	0.0033
23-Jul-08	0.0022	0.0024	0.0034	0.0019	0.0026	0.0036	0.0029	0.0022	0.0308	0.0041	0.0024	0.0019	0.0021	0.0018	0.0022	**ND**	0.0026	0.0031
29-Jul-08	0.0057	0.0085	0.0039	0.0074	0.0085	0.0027	0.0025	0.0040	0.0200	0.0035	0.0099	0.0035	0.0034	0.0052	0.0040	0.0021	**ND**	**ND**
4-Aug-08	0.0026	0.0024	0.0023	**ND**	0.0038	0.0026	0.0022	0.0039	0.0294	0.0029	0.0036	0.0042	0.0039	0.0025	0.0035	0.0027	**ND**	0.0029
10-Aug-08	0.0020	0.0048	0.0026	0.0029	**ND**	**ND**	0.0026	0.0022	0.0248	0.0029	0.0026	0.0022	0.0026	0.0017	0.0023	0.0020	**ND**	**ND**
22-Aug-08	0.0007	0.0012	0.0019	*0.0006*	0.0013	0.0015	0.0078	0.0010	0.0012	*0.0006*	0.0006	*0.0006*	0.0009	*0.0006*	0.0007	0.0007	0.0007	0.0007
28-Aug-08	0.0007	0.0013	0.0016	0.0016	0.0006	*0.0006*	0.0008	0.0006	*0.0006*	0.0010	0.0009	0.0006	*0.0006*	0.0017	0.0007	0.0007	0.0007	*0.0006*
3-Sep-08	0.0006	0.0009	0.0009	0.0008	0.0011	0.0010	0.0009	0.0006	*0.0006*	0.0006	0.0013	*0.0006*	0.0013	0.0010	0.0007	*0.0006*	0.0011	0.0008
9-Sep-08	0.0009	*0.0006*	*0.0006*	*0.0006*	0.0026	0.0006	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0006	*0.0006*	*0.0006*	0.0007	0.0006	0.0009	0.0010
15-Sep-08	*0.0006*	*0.0006*	*0.0006*	0.0011	*0.0006*	0.0009	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0016	*0.0006*	0.0010	0.0006	0.0012	*0.0006*
21-Sep-08	*0.0006*	0.0009	*0.0008*	*0.0006*	0.0006	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0011	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0011	*0.0006*
27-Sep-08	*0.0006*	0.0008	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0019	*0.0006*	*0.0006*	*0.0006*	0.0006	0.0010	*0.0006*	*0.0006*	0.0048
3-Oct-08	0.0058	*0.0006*	0.0007	0.0006	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0014	0.0006	0.0006	*0.0006*	*0.0006*	**ND**	0.0007	*0.0006*
Arithmetic Mean	2.12E-03	2.14E-03	1.88E-03	1.95E-03	2.26E-03	1.63E-03	2.13E-03	1.65E-03	1.02E-02	1.90E-03	2.21E-03	1.55E-03	1.82E-03	1.59E-03	1.61E-03	1.29E-03	1.33E-03	1.74E-03
Geomertic Mean	1.44E-03	1.47E-03	1.46E-03	1.31E-03	1.49E-03	1.24E-03	1.43E-03	1.19E-03	2.70E-03	1.42E-03	1.45E-03	1.13E-03	1.37E-03	1.21E-03	1.27E-03	1.04E-03	1.12E-03	1.26E-03
95th Percentile	5.73E-03	6.26E-03	4.16E-03	5.85E-03	6.07E-03	3.85E-03	6.03E-03	3.98E-03	3.00E-02	4.12E-03	6.14E-03	3.79E-03	4.26E-03	3.87E-03	3.70E-03	2.78E-03	3.06E-03	4.07E-03
98th Percentile	5.80E-03	7.61E-03	4.40E-03	6.77E-03	7.53E-03	4.05E-03	7.08E-03	4.01E-03	3.05E-02	4.16E-03	8.39E-03	4.02E-03	4.62E-03	4.69E-03	3.86E-03	2.82E-03	3.29E-03	4.51E-03
Maximum	5.85E-03	8.50E-03	4.55E-03	7.38E-03	8.51E-03	4.19E-03	7.77E-03	4.04E-03	3.08E-02	4.20E-03	9.90E-03	4.18E-03	4.87E-03	5.24E-03	3.96E-03	2.84E-03	3.44E-03	4.79E-03
Minimum	6.17E-04	6.20E-04	6.21E-04	6.21E-04	6.16E-04	6.15E-04	6.24E-04	6.11E-04	6.07E-04	6.07E-04	6.23E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.17E-04	6.24E-04	6.19E-04

	Phosphorus																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.1341	0.1242	0.1300	0.1368	0.1356	0.1972	0.1249	0.1223	0.8945	0.1049	0.1242	0.1243	0.1315	0.1287	0.1417	0.1290	0.1228	0.1240
23-Jul-08	1.24E-01	1.28E-01	1.27E-01	1.13E-01	1.18E-01	1.27E-01	1.26E-01	1.73E-01	1.46E+00	1.23E-01	1.25E-01	1.25E-01	1.46E-01	1.23E-01	1.23E-01	**ND**	1.37E-01	1.50E-01
29-Jul-08	2.69E-01	3.33E-01	1.30E-01	3.16E-01	1.48E-01	1.73E-01	1.25E-01	9.80E-02	1.39E+00	1.09E-01	2.91E-01	2.35E-01	1.37E-01	1.37E-01	1.58E-01	1.42E-01	ND	ND
4-Aug-08	0.1398	0.0954	0.1523	**ND**	0.1016	*0.0936*	0.1552	0.2313	1.6530	0.1471	0.1252	0.1253	0.1465	0.1256	0.1137	0.1561	**ND**	*0.0942*
10-Aug-08	0.1597	*0.0991*	*0.0670*	*0.0939*	**ND**	**ND**	*0.0924*	*0.0924*	*1.0323*	*0.0918*	*0.0938*	*0.1043*	*0.0960*	*0.0921*	*0.0942*	*0.0978*	**ND**	**ND**
22-Aug-08	*0.0918*	*0.0935*	*0.0927*	*0.0936*	0.1475	*0.1870*	*0.0940*	*0.0920*	*0.0914*	*0.0918*	*0.0934*	*0.0929*	0.0998	*0.0921*	*0.0919*	*0.0923*	0.0986	*0.0933*
28-Aug-08	*0.0927*	*0.0940*	0.0994	*0.0941*	*0.0936*	*0.0932*	0.1008	*0.0926*	*0.0919*	*0.0920*	*0.0944*	*0.0930*	0.1004	0.0984	*0.0924*	0.0986	0.0991	*0.0938*
3-Sep-08	0.0991	*0.0946*	*0.0939*	*0.0947*	0.1127	*0.0939*	*0.0952*	0.1118	*0.0925*	*0.0926*	0.1009	*0.0948*	0.1010	*0.0929*	*0.0930*	*0.0931*	0.1372	*0.0944*
9-Sep-08	0.1232	0.1130	0.1121	0.1257	0.1245	0.1121	0.1136	0.1236	0.1110	0.1105	0.1255	0.1247	0.1131	0.0986	0.1234	0.1111	0.1246	0.1127
15-Sep-08	*0.0926*	*0.0947*	*0.0931*	*0.0944*	*0.0936*	*0.0935*	*0.0948*	*0.0933*	*0.0922*	*0.0923*	*0.0943*	*0.0937*	*0.0944*	*0.0926*	*0.0927*	*0.0927*	*0.0932*	*0.0941*
21-Sep-08	*0.0931*	*0.0948*	*0.1164*	*0.0949*	*0.0941*	*0.0941*	*0.0958*	*0.0934*	*0.0928*	*0.0932*	*0.0948*	*0.0942*	*0.0949*	*0.0931*	*0.0932*	*0.0933*	*0.0938*	*0.0946*
27-Sep-08	0.0991	0.1010	0.1002	*0.0952*	0.1002	0.1006	*0.0952*	0.0995	0.1111	0.1112	0.1010	0.1003	0.1142	0.0991	0.1122	0.0993	0.0998	0.0936
3-Oct-08	0.1218	*0.0931*	0.1108	0.1366	*0.0923*	0.1108	0.1123	0.1711	0.0971	0.0971	0.1240	0.0986	0.1242	*0.0917*	0.1098	**ND**	0.1227	0.0991
Arithmetic Mean	1.26E-01	1.20E-01	1.10E-01	1.24E-01	1.14E-01	1.23E-01	1.10E-01	1.23E-01	5.54E-01	1.04E-01	1.22E-01	1.16E-01	1.15E-01	1.05E-01	1.11E-01	1.10E-01	1.13E-01	1.04E-01
Geomertic Mean	1.20E-01	1.11E-01	1.08E-01	1.15E-01	1.12E-01	1.18E-01	1.08E-01	1.17E-01	2.60E-01	1.03E-01	1.16E-01	1.12E-01	1.14E-01	1.04E-01	1.09E-01	1.08E-01	1.12E-01	1.03E-01
95th Percentile	2.03E-01	2.10E-01	1.39E-01	2.18E-01	1.48E-01	1.92E-01	1.38E-01	1.96E-01	1.54E+00	1.33E-01	1.92E-01	1.69E-01	1.46E-01	1.32E-01	1.48E-01	1.49E-01	1.37E-01	1.37E-01
98th Percentile	2.43E-01	2.84E-01	1.47E-01	2.77E-01	1.48E-01	1.95E-01	1.48E-01	2.17E-01	1.61E+00	1.41E-01	2.51E-01	2.09E-01	1.46E-01	1.35E-01	1.54E-01	1.53E-01	1.37E-01	1.45E-01
Maximum	2.69E-01	3.33E-01	1.52E-01	3.16E-01	1.48E-01	1.97E-01	1.55E-01	2.31E-01	1.65E+00	1.47E-01	2.91E-01	2.35E-01	1.46E-01	1.37E-01	1.58E-01	1.56E-01	1.37E-01	1.50E-01
Minimum	9.18E-02	9.31E-02	6.70E-02	9.36E-02	9.23E-02	9.32E-02	9.24E-02	9.20E-02	9.14E-02	9.18E-02	9.34E-02	9.29E-02	9.44E-02	9.17E-02	9.19E-02	9.23E-02	9.32E-02	9.33E-02

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Potassium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0610*	*0.0621*	*0.0650*	*0.0622*	0.0986	*0.1232*	*0.0625*	*0.0612*	*0.5591*	*0.0655*	0.0621	*0.0690*	0.0789	*0.0644*	*0.0644*	*0.0645*	0.0982	*0.0620*
23-Jul-08	*0.0619*	*0.0641*	*0.0636*	*0.0628*	*0.0658*	*0.0637*	*0.0631*	*0.0618*	*0.8106*	*0.0617*	*0.0627*	*0.0624*	*0.0664*	*0.0616*	*0.0617*	**ND**	0.0621	*0.0626*
29-Jul-08	*0.1346*	*0.1849*	*0.0651*	*0.1757*	0.1727	*0.0617*	*0.0625*	*0.0612*	*0.7695*	*0.0608*	*0.1456*	*0.1176*	*0.0622*	0.0873	*0.0659*	*0.0645*	**ND**	**ND**
4-Aug-08	*0.0777*	*0.0530*	*0.0635*	**ND**	0.1397	*0.0624*	*0.0647*	*0.1157*	*0.9183*	*0.0613*	0.1753	0.0835	*0.0666*	*0.0628*	*0.0632*	*0.0650*	**ND**	0.1004
10-Aug-08	0.0860	*0.0661*	0.0982	0.0626	**ND**	**ND**	0.1356	0.0739	0.8258	0.0857	0.1626	*0.0695*	0.0896	0.0982	0.0879	0.0913	**ND**	**ND**
22-Aug-08	0.1223	0.1246	0.1360	0.1123	0.1659	0.1995	0.2005	0.1473	0.0731	0.0612	0.1744	0.1733	0.1497	0.1106	0.1225	0.1231	0.1232	0.1492
28-Aug-08	0.1730	0.1253	0.1119	0.1004	0.1373	0.1119	0.1008	0.1234	0.1226	0.0858	0.0881	0.0744	0.1004	0.0861	0.0739	0.0986	0.1487	0.1000
3-Sep-08	0.0991	*0.0631*	0.1377	0.1389	0.0876	0.1377	0.1015	0.1118	0.0864	0.0987	*0.0631*	0.1011	0.1010	0.0619	*0.0620*	0.0869	0.0748	*0.0629*
9-Sep-08	*0.0616*	*0.0628*	*0.0623*	*0.0628*	*0.0623*	*0.0623*	*0.0631*	*0.0618*	*0.0616*	*0.0614*	*0.0627*	*0.0623*	*0.0628*	*0.0616*	0.0740	*0.0617*	*0.0623*	*0.0626*
15-Sep-08	*0.0617*	*0.0631*	*0.0621*	*0.0629*	*0.0624*	*0.0624*	*0.0632*	*0.0622*	*0.0615*	*0.0615*	*0.0628*	*0.0625*	*0.0629*	*0.0617*	*0.0618*	*0.0618*	*0.0622*	*0.0627*
21-Sep-08	*0.0621*	*0.0632*	*0.0776*	*0.0633*	*0.0627*	*0.0627*	*0.0639*	*0.0623*	*0.0618*	*0.0621*	*0.0632*	*0.0628*	*0.0633*	*0.0621*	*0.0622*	*0.0622*	*0.0625*	*0.0631*
27-Sep-08	*0.0620*	*0.0631*	*0.0626*	*0.0635*	*0.0626*	*0.0629*	*0.0635*	*0.0622*	*0.0617*	*0.0618*	*0.0631*	*0.0627*	*0.0635*	*0.0620*	*0.0623*	*0.0621*	*0.0624*	*0.0585*
3-Oct-08	0.4385	*0.0620*	*0.0615*	*0.0621*	*0.0616*	*0.0615*	*0.0624*	*0.0611*	*0.0607*	*0.0607*	*0.0620*	*0.0616*	*0.0621*	*0.0611*	*0.0610*	**ND**	*0.0613*	*0.0619*
Arithmetic Mean	1.15E-01	8.13E-02	8.21E-02	8.58E-02	9.83E-02	8.93E-02	8.52E-02	8.20E-02	3.44E-01	6.83E-02	9.60E-02	8.18E-02	7.92E-02	7.24E-02	7.10E-02	7.65E-02	8.18E-02	7.69E-02
Geomertic Mean	9.41E-02	7.53E-02	7.82E-02	7.98E-02	9.03E-02	8.16E-02	7.87E-02	7.75E-02	1.78E-01	6.74E-02	8.65E-02	7.75E-02	7.62E-02	7.08E-02	6.95E-02	7.43E-02	7.74E-02	7.33E-02
95th Percentile	2.79E-01	1.49E-01	1.37E-01	1.55E-01	1.69E-01	1.65E-01	1.62E-01	1.33E-01	8.63E-01	9.10E-02	1.75E-01	1.40E-01	1.21E-01	1.03E-01	1.02E-01	1.11E-01	1.37E-01	1.25E-01
98th Percentile	3.75E-01	1.71E-01	1.37E-01	1.68E-01	1.71E-01	1.86E-01	1.85E-01	1.42E-01	8.96E-01	9.56E-02	1.75E-01	1.60E-01	1.38E-01	1.08E-01	1.14E-01	1.18E-01	1.44E-01	1.39E-01
Maximum	4.39E-01	1.85E-01	1.38E-01	1.76E-01	1.73E-01	1.99E-01	2.01E-01	1.47E-01	9.18E-01	9.87E-02	1.75E-01	1.73E-01	1.50E-01	1.11E-01	1.23E-01	1.23E-01	1.49E-01	1.49E-01
Minimum	6.10E-02	5.30E-02	6.15E-02	6.21E-02	6.16E-02	6.15E-02	6.24E-02	6.11E-02	6.07E-02	6.07E-02	6.20E-02	6.16E-02	6.21E-02	6.11E-02	6.10E-02	6.17E-02	6.13E-02	5.85E-02

	Selenium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0006*	*0.0006211*	*0.0007*	*0.0006*	*0.0006*	*0.0012*	*0.0006*	*0.0006*	*0.0056*	*0.0007*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
23-Jul-08	*0.0006*	*0.00064138*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0081*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
29-Jul-08	*0.0013*	*0.00184869*	*0.0007*	*0.0018*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0077*	*0.0006*	*0.0015*	*0.0012*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	**ND**	**ND**
4-Aug-08	*0.0008*	*0.00052974*	*0.0006*	**ND**	*0.0006*	*0.0006*	*0.0006*	*0.0012*	*0.0092*	*0.0006*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0007*	**ND**	*0.0006*
10-Aug-08	*0.0006*	*0.00066098*	*0.0004*	*0.0006*	**ND**	**ND**	*0.0006*	*0.0006*	*0.0069*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	**ND**	**ND**
22-Aug-08	*0.0006*	*0.00062314*	*0.0006*	*0.0006*	*0.0009*	*0.0012*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
28-Aug-08	*0.0006*	*0.0006266*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Sep-08	*0.0006*	*0.00063077*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
9-Sep-08	*0.0006*	*0.00062759*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
15-Sep-08	*0.0006*	*0.00063127*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
21-Sep-08	*0.0006*	*0.00063231*	*0.0008*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
27-Sep-08	*0.0006*	*0.00063122*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Oct-08	*0.0006*	*0.0006204*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
Arithmetic Mean	6.84E-04	7.17E-04	6.26E-04	7.22E-04	6.51E-04	7.27E-04	6.30E-04	6.59E-04	3.26E-03	6.17E-04	6.91E-04	6.82E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.47E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
95th Percentile	1.00E-03	1.14E-03	7.01E-04	1.14E-03	7.77E-04	1.24E-03	6.42E-04	8.36E-04	8.54E-03	6.35E-04	9.62E-04	8.88E-04	6.65E-04	6.34E-04	6.50E-04	6.51E-04	6.25E-04	6.30E-04
98th Percentile	1.21E-03	1.56E-03	7.46E-04	1.51E-03	8.64E-04	1.24E-03	6.45E-04	1.03E-03	8.92E-03	6.47E-04	1.26E-03	1.06E-03	6.65E-04	6.40E-04	6.56E-04	6.52E-04	6.25E-04	6.31E-04
Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Silver																	
	Concentrations (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0002*	*0.0002*	*0.0002*	0.0002	*0.0002*	*0.0003*	*0.0002*	0.0002	0.0022	*0.0002*	0.0004	0.0003	*0.0002*	0.0003	*0.0002*	0.0003	0.0004	0.0009
23-Jul-08	1.55E-04	1.60E-04	1.59E-04	1.57E-04	1.65E-04	1.59E-04	2.52E-04	1.55E-04	2.03E-03	1.54E-04	1.57E-04	1.56E-04	1.66E-04	3.70E-04	1.54E-04	ND	1.55E-04	1.57E-04
29-Jul-08	*0.0003*	*0.0005*	*0.0002*	*0.0004*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0019*	*0.0002*	0.0006	*0.0003*	0.0002	*0.0002*	0.0003	*0.0002*	**ND**	**ND**
4-Aug-08	*0.0002*	*0.0001*	*0.0002*	**ND**	*0.0002*	*0.0002*	*0.0002*	0.0005	*0.0023*	0.0004	*0.0002*	0.0003	0.0007	0.0005	0.0006	*0.0002*	**ND**	*0.0002*
10-Aug-08	0.0002	*0.0002*	*0.0001*	*0.0002*	**ND**	**ND**	*0.0002*	*0.0002*	*0.0017*	*0.0002*	*0.0003*	*0.0002*	*0.0009*	*0.0002*	*0.0005*	*0.0002*	**ND**	**ND**
22-Aug-08	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0003*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	0.0002	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
28-Aug-08	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	0.0002	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
3-Sep-08	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
9-Sep-08	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
15-Sep-08	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
21-Sep-08	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
27-Sep-08	0.0002	0.0002	0.0002	*0.0002*	0.0002	0.0002	*0.0002*	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001
3-Oct-08	0.0002	*0.0002*	0.0002	0.0002	*0.0002*	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	*0.0002*	0.0002	**ND**	0.0002	0.0002
Arithmetic Mean	1.71E-04	1.79E-04	1.57E-04	1.88E-04	1.63E-04	1.82E-04	1.65E-04	1.85E-04	8.79E-04	1.71E-04	2.13E-04	1.94E-04	2.69E-04	2.06E-04	2.27E-04	1.66E-04	1.77E-04	2.20E-04
Geomertic Mean	1.66E-04	1.69E-04	1.56E-04	1.78E-04	1.62E-04	1.75E-04	1.63E-04	1.74E-04	4.14E-04	1.65E-04	1.92E-04	1.87E-04	2.17E-04	1.88E-04	1.97E-04	1.64E-04	1.69E-04	1.82E-04
95th Percentile	2.51E-04	2.84E-04	1.75E-04	3.34E-04	1.94E-04	3.10E-04	1.98E-04	3.32E-04	2.26E-03	2.45E-04	4.56E-04	2.85E-04	7.58E-04	4.23E-04	5.54E-04	2.10E-04	2.73E-04	5.13E-04
98th Percentile	3.02E-04	3.91E-04	1.86E-04	3.97E-04	2.16E-04	3.11E-04	2.31E-04	4.10E-04	2.28E-03	3.19E-04	5.32E-04	2.90E-04	8.41E-04	4.71E-04	6.01E-04	2.39E-04	3.30E-04	7.26E-04
Maximum	3.37E-04	4.62E-04	1.94E-04	4.39E-04	2.30E-04	3.12E-04	2.52E-04	4.63E-04	2.30E-03	3.68E-04	5.82E-04	2.94E-04	8.96E-04	5.02E-04	6.32E-04	2.58E-04	3.68E-04	8.68E-04
Minimum	1.52E-04	1.32E-04	1.12E-04	1.55E-04	1.54E-04	1.54E-04	1.54E-04	1.53E-04	1.52E-04	1.52E-04	1.55E-04	1.54E-04	1.55E-04	1.53E-04	1.52E-04	1.54E-04	1.53E-04	1.46E-04

	Sodium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	7.7434	2.3850	8.6999	8.0582	6.6925	12.1251	8.5828	8.2819	74.1331	8.6391	7.7619	9.4159	8.8495	8.7788	8.6332	8.3818	7.0616	7.5986
23-Jul-08	6.4840	6.8371	7.1096	6.1951	6.5037	8.5296	7.2590	7.0338	83.9753	7.2886	5.5594	6.4099	6.8563	5.4704	5.4292	**ND**	6.1430	6.3131
29-Jul-08	14.9967	20.3356	6.8337	18.9432	6.5755	6.6727	7.0153	6.4040	72.1747	7.1774	13.0135	10.9645	5.8129	6.2337	5.9483	6.1051	**ND**	**ND**
4-Aug-08	7.8447	5.1173	6.2323	**ND**	6.0852	5.9899	6.5188	10.8026	79.3437	5.4175	6.9135	5.6669	7.9765	5.2883	8.2478	8.0628	**ND**	7.6701
10-Aug-08	2.6651	7.6541	4.9725	7.2391	**ND**	**ND**	5.7068	5.5443	66.4799	6.7078	5.3533	6.4242	5.8123	5.9680	5.8159	5.5949	**ND**	**ND**
22-Aug-08	0.1468	0.1371	0.1113	0.0998	0.1659	0.1745	0.1128	0.1105	0.1097	0.0857	0.0997	0.1114	0.1497	0.0983	0.1103	0.1108	0.0862	0.1244
28-Aug-08	0.0865	0.1128	0.1243	0.1631	0.0999	0.1119	0.1008	0.2962	0.0858	0.0858	0.0881	0.0744	0.1631	0.0984	0.0986	0.1109	0.0991	0.1000
3-Sep-08	0.1115	0.1262	0.1001	0.1137	0.1001	0.1126	0.1015	0.1242	0.1111	0.0987	0.1261	0.1011	0.1137	0.0867	0.1240	0.0620	0.1123	0.0755
9-Sep-08	0.0137	0.0158	0.0125	0.0143	0.0125	0.0140	0.0128	0.0154	0.0137	0.0121	0.0158	0.0126	0.0143	0.0107	0.0153	0.0077	0.0140	0.0095
15-Sep-08	0.2839	0.2020	0.1490	0.1133	0.0499	0.0499	0.1012	0.0746	0.0615	0.2829	0.0754	0.0625	0.0629	0.0494	0.0989	0.0866	0.0622	0.0502
21-Sep-08	0.0745	0.0632	0.0931	0.0633	0.0878	0.0627	0.0894	0.0872	0.0742	0.0621	0.0885	0.0879	0.0760	0.0621	0.0746	0.0746	0.0750	0.0757
27-Sep-08	0.0496	0.0631	0.1503	0.0635	0.1127	0.1006	0.0635	0.0746	0.0864	0.0988	0.1010	0.0878	0.1015	0.1239	0.1246	0.0869	0.1623	0.1052
3-Oct-08	0.7917	0.1985	0.2339	0.4099	0.1354	0.1354	0.1997	0.4032	0.0971	0.1214	0.2233	0.2342	0.2112	0.2201	0.0976	**ND**	0.1472	0.1362
Arithmetic Mean	3.18E+00	3.33E+00	2.68E+00	3.46E+00	2.22E+00	2.84E+00	2.76E+00	3.02E+00	2.90E+01	2.78E+00	3.03E+00	3.05E+00	2.78E+00	2.50E+00	2.68E+00	2.61E+00	1.40E+00	2.02E+00
Geomertic Mean	5.29E-01	4.76E-01	4.96E-01	4.24E-01	3.40E-01	3.64E-01	4.46E-01	5.32E-01	1.02E+00	4.49E-01	4.70E-01	4.47E-01	4.77E-01	4.02E-01	4.42E-01	3.42E-01	1.91E-01	2.43E-01
95th Percentile	1.07E+01	1.27E+01	7.75E+00	1.30E+01	6.63E+00	1.01E+01	7.79E+00	9.29E+00	8.12E+01	7.83E+00	9.86E+00	1.00E+01	8.33E+00	7.25E+00	8.40E+00	8.22E+00	6.65E+00	7.63E+00
98th Percentile	1.33E+01	1.73E+01	8.32E+00	1.65E+01	6.67E+00	1.13E+01	8.27E+00	1.02E+01	8.29E+01	8.31E+00	1.18E+01	1.06E+01	8.64E+00	8.17E+00	8.54E+00	8.32E+00	6.90E+00	7.66E+00
Maximum	1.50E+01	2.03E+01	8.70E+00	1.89E+01	6.69E+00	1.21E+01	8.58E+00	1.08E+01	8.40E+01	8.64E+00	1.30E+01	1.10E+01	8.85E+00	8.78E+00	8.63E+00	8.38E+00	7.06E+00	7.67E+00
Minimum	1.37E-02	1.58E-02	1.25E-02	1.43E-02	1.25E-02	1.40E-02	1.28E-02	1.54E-02	1.37E-02	1.21E-02	1.58E-02	1.26E-02	1.43E-02	1.07E-02	1.53E-02	7.66E-03	1.40E-02	9.46E-03

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Strontium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0006*	0.0007	*0.0007*	*0.0006*	0.0022	*0.0012*	*0.0006*	*0.0006*	*0.0056*	*0.0007*	0.0007	*0.0007*	0.0011	*0.0006*	*0.0006*	*0.0006*	0.0007	*0.0006*
23-Jul-08	*0.0006*	*0.00064138*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0081*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
29-Jul-08	*0.0013*	*0.0018*	*0.0007*	*0.0018*	0.0042	0.0006	*0.0006*	*0.0006*	*0.0077*	*0.0006*	*0.0015*	*0.0012*	*0.0006*	0.0011	*0.0007*	*0.0006*	**ND**	**ND**
4-Aug-08	*0.0008*	*0.0005*	*0.0006*	**ND**	0.0028	0.0006	*0.0006*	*0.0012*	*0.0092*	*0.0006*	0.0033	0.0008	0.0013	*0.0006*	*0.0006*	*0.0007*	**ND**	*0.0006*
10-Aug-08	*0.0006*	*0.0007*	*0.0004*	*0.0006*	**ND**	**ND**	*0.0006*	*0.0006*	*0.0069*	*0.0006*	0.0004	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	**ND**	**ND**
22-Aug-08	*0.0006*	*0.00062314*	*0.0006*	*0.0006*	*0.0009*	*0.0012*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
28-Aug-08	*0.0006*	*0.0006266*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0015	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0010	*0.0006*	0.0008	*0.0006*	*0.0006*	*0.0006*	0.0014	*0.0006*
9-Sep-08	*0.0006*	*0.00062759*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
15-Sep-08	*0.0006*	*0.00063127*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
21-Sep-08	*0.0006*	*0.00063231*	*0.0008*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0006	*0.0006*
27-Sep-08	*0.0006*	*0.00063122*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0007	*0.0006*
3-Oct-08	*0.0006*	*0.0006*	0.0015	0.0012	*0.0006*	*0.0006*	0.0006	0.0007	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
Arithmetic Mean	6.84E-04	7.27E-04	6.93E-04	7.74E-04	1.34E-03	7.27E-04	6.30E-04	6.68E-04	3.26E-03	6.17E-04	9.15E-04	6.93E-04	7.28E-04	6.58E-04	6.24E-04	6.29E-04	7.20E-04	6.22E-04
Geomertic Mean	6.66E-04	6.86E-04	6.66E-04	7.25E-04	1.03E-03	7.00E-04	6.30E-04	6.57E-04	1.60E-03	6.17E-04	7.72E-04	6.81E-04	7.06E-04	6.48E-04	6.24E-04	6.29E-04	6.96E-04	6.22E-04
95th Percentile	1.00E-03	1.19E-03	1.06E-03	1.47E-03	3.42E-03	1.24E-03	6.42E-04	9.03E-04	8.54E-03	6.35E-04	2.18E-03	9.72E-04	1.16E-03	8.35E-04	6.50E-04	6.51E-04	1.09E-03	6.30E-04
98th Percentile	1.21E-03	1.58E-03	1.31E-03	1.64E-03	3.89E-03	1.24E-03	6.45E-04	1.05E-03	8.92E-03	6.47E-04	2.82E-03	1.09E-03	1.26E-03	1.01E-03	6.56E-04	6.52E-04	1.26E-03	6.31E-04
Maximum	1.35E-03	1.85E-03	1.48E-03	1.76E-03	4.19E-03	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	3.26E-03	1.18E-03	1.33E-03	1.12E-03	6.59E-04	6.52E-04	1.37E-03	6.31E-04
Minimum	6.09E-04	5.30E-04	4.46E-04	6.22E-04	6.16E-04	6.15E-04	6.16E-04	6.12E-04	6.07E-04	6.07E-04	4.07E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04

	Telurium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0012*	*0.0006*	*0.0006*	*0.0056*	*0.0007*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
23-Jul-08	*6.19E-04*	*6.41E-04*	*6.36E-04*	*6.28E-04*	*6.58E-04*	*6.37E-04*	*6.31E-04*	*6.18E-04*	*8.11E-03*	*6.17E-04*	*6.27E-04*	*6.24E-04*	*6.64E-04*	*6.16E-04*	*6.17E-04*	*ND*	*6.21E-04*	*6.26E-04*
29-Jul-08	*0.0013*	*0.0018*	*0.0007*	*0.0018*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0077*	*0.0006*	*0.0015*	*0.0012*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	**ND**	**ND**
4-Aug-08	*0.0008*	*0.0005*	*0.0006*	**ND**	*0.0006*	*0.0006*	*0.0006*	*0.0012*	*0.0092*	*0.0006*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0007*	**ND**	*0.0006*
10-Aug-08	*0.0006*	*0.0007*	*0.0004*	*0.0006*	**ND**	**ND**	*0.0006*	*0.0006*	*0.0069*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	**ND**	**ND**
22-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0009*	*0.0012*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
28-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
9-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
15-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
21-Sep-08	*0.0006*	*0.0006*	*0.0008*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
27-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Oct-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
Arithmetic Mean	6.84E-04	7.17E-04	6.26E-04	7.22E-04	6.51E-04	7.27E-04	6.30E-04	6.59E-04	3.26E-03	6.17E-04	6.91E-04	6.82E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Geomertic Mean	6.66E-04	6.77E-04	6.23E-04	6.84E-04	6.47E-04	7.00E-04	6.30E-04	6.48E-04	1.60E-03	6.17E-04	6.69E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
95th Percentile	1.00E-03	1.14E-03	7.01E-04	1.14E-03	7.77E-04	1.24E-03	6.42E-04	8.36E-04	8.54E-03	6.35E-04	9.62E-04	8.88E-04	6.65E-04	6.34E-04	6.50E-04	6.51E-04	6.25E-04	6.30E-04
98th Percentile	1.21E-03	1.56E-03	7.46E-04	1.51E-03	8.64E-04	1.24E-03	6.45E-04	1.03E-03	8.92E-03	6.47E-04	1.26E-03	1.06E-03	6.65E-04	6.40E-04	6.56E-04	6.52E-04	6.25E-04	6.31E-04
Maximum	1.35E-03	1.85E-03	7.76E-04	1.76E-03	9.22E-04	1.25E-03	6.47E-04	1.16E-03	9.18E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Thallium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0003	0.0004	0.0002	0.0002	0.0001	0.0002	0.0001	0.0001	0.0007	0.0001	0.0001	0.0002	*0.0001*	*0.0001*	*0.0001*	0.0001	*0.0001*	*0.0001*
23-Jul-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	0.0001	0.0001	*0.0008*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	**ND**	*0.0001*	0.0001
29-Jul-08	*0.0001*	*0.0002*	*0.0001*	*0.0002*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0008*	*0.0001*	*0.0001*	0.0002	*0.0001*	*0.0001*	*0.0001*	*0.0001*	**ND**	**ND**
4-Aug-08	*0.0001*	*0.0001*	*0.0001*	**ND**	*0.0001*	*0.0001*	*0.0001*	0.0002	*0.0009*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	**ND**	*0.0001*
10-Aug-08	*0.0001*	*0.0001*	*0.0000*	*0.0001*	**ND**	**ND**	0.0001	*0.0001*	*0.0007*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	**ND**	**ND**
22-Aug-08	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0001	*0.0001*	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
28-Aug-08	0.0001	0.0001	0.0001	*0.0001*	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
3-Sep-08	*0.0001*	*0.0001*	0.0001	0.0001	*0.0001*	0.0001	0.0001	0.0001	*0.0001*	*0.0001*	0.0009	0.0001	0.0001	0.0001	*0.0001*	*0.0001*	*0.0001*	*0.0001*
9-Sep-08	0.0003	0.0001	0.0001	0.0001	*0.0001*	0.0001	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
15-Sep-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
21-Sep-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
27-Sep-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
3-Oct-08	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	**ND**	*0.0001*	*0.0001*
Arithmetic Mean	1.15E-04	1.07E-04	7.83E-05	8.78E-05	7.38E-05	8.72E-05	8.43E-05	8.24E-05	3.36E-04	6.55E-05	1.44E-04	9.05E-05	6.94E-05	6.77E-05	6.81E-05	7.08E-05	6.69E-05	7.12E-05
Geomertic Mean	9.38E-05	8.76E-05	7.32E-05	7.99E-05	7.10E-05	7.96E-05	7.96E-05	7.63E-05	1.66E-04	6.51E-05	9.02E-05	8.09E-05	6.76E-05	6.59E-05	6.63E-05	6.81E-05	6.58E-05	6.91E-05
95th Percentile	2.99E-04	2.70E-04	1.50E-04	1.86E-04	1.21E-04	1.73E-04	1.48E-04	1.50E-04	8.54E-04	8.15E-05	4.58E-04	1.92E-04	9.48E-05	9.27E-05	9.35E-05	1.06E-04	8.91E-05	1.12E-04
98th Percentile	3.27E-04	3.46E-04	1.62E-04	1.94E-04	1.37E-04	1.74E-04	1.57E-04	1.85E-04	8.92E-04	8.41E-05	7.36E-04	1.96E-04	1.20E-04	1.18E-04	1.18E-04	1.31E-04	1.02E-04	1.20E-04
Maximum	3.45E-04	3.98E-04	1.69E-04	1.99E-04	1.47E-04	1.75E-04	1.63E-04	2.08E-04	9.18E-04	8.58E-05	9.21E-04	1.98E-04	1.37E-04	1.35E-04	1.35E-04	1.48E-04	1.11E-04	1.24E-04
Minimum	6.09E-05	5.30E-05	4.46E-05	6.21E-05	6.16E-05	6.15E-05	6.24E-05	6.11E-05	6.07E-05	6.07E-05	6.20E-05	6.16E-05	6.21E-05	6.11E-05	6.10E-05	6.16E-05	6.13E-05	5.85E-05

	Tin																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0020	0.0040	0.0014	0.0029	0.0016	0.0032	0.0020	0.0024	0.0145	0.0018	0.0014	0.0019	0.0026	0.0013	0.0019	0.0010	0.0023	0.0038
23-Jul-08	0.0016	0.00230896	0.0018	0.0023	0.0014	0.0024	0.0035	0.0022	0.0340	0.0148	0.0015	0.0015	0.0021	0.0020	0.0015	**ND**	0.0019	0.0018
29-Jul-08	0.0030	0.0030	0.0012	0.0049	0.0036	0.0015	0.0031	0.0012	0.0123	0.0069	0.0049	0.0031	0.0012	0.0027	0.0018	0.0015	**ND**	**ND**
4-Aug-08	0.0019	0.0012	0.0024	**ND**	0.0009	0.0015	0.0019	0.0032	0.0863	0.0028	0.0021	0.0068	0.0017	0.0019	0.0013	0.0014	**ND**	0.0028
10-Aug-08	0.0028	0.0019	0.0018	0.0018	**ND**	**ND**	0.0010	0.0018	0.0151	0.0013	0.0023	0.0021	0.0028	0.0016	0.0021	0.0013	**ND**	**ND**
22-Aug-08	0.0015	0.001246271	0.0014	0.0012	0.0018	0.0040	0.0015	0.0014	0.0020	0.0016	0.0012	0.0010	0.0019	0.0011	0.0013	0.0012	0.0010	0.0009
28-Aug-08	0.0009	0.001503838	0.0016	0.0010	0.0011	0.0009	0.0011	0.0010	0.0011	0.0007	0.0013	0.0007	0.0013	0.0049	0.0009	0.0009	0.0010	0.0015
3-Sep-08	0.0009	0.0011	0.0015	0.0013	0.0011	0.0013	0.0014	0.0010	0.0014	0.0011	0.0108	0.0010	0.0013	0.0009	0.0011	0.0011	0.0009	0.0008
9-Sep-08	0.0014	0.000753106	0.0009	0.0011	0.0009	0.0010	0.0014	0.0010	0.0032	0.0010	0.0011	0.0014	0.0010	0.0010	0.0015	0.0007	0.0108	0.0016
15-Sep-08	0.0015	0.000883772	0.0007	0.0006	0.0006	0.0015	0.0019	0.0007	0.0006	0.0006	0.0006	0.0006	0.0011	0.0006	0.0011	0.0009	0.0006	0.0010
21-Sep-08	0.0002	*0.0006*	*0.0008*	0.0001	0.0001	0.0002	0.0002	*0.0006*	0.0001	*0.0006*	0.0001	*0.0006*	*0.0006*	0.0001	*0.0006*	0.0001	0.0001	0.0001
27-Sep-08	*0.0006*	*0.0006*	0.0009	*0.0006*	*0.0006*	*0.0006*	*0.0006*	0.0009	0.0017	0.0007	*0.0006*	*0.0006*	0.0008	0.0056	0.0010	*0.0006*	*0.0006*	0.0008
3-Oct-08	0.0095	0.0009	0.0007	0.0011	0.0006	*0.0006*	0.0006	0.0007	*0.0006*	*0.0006*	0.0007	0.0060	0.0007	*0.0006*	0.0010	**ND**	0.0007	0.0006
Arithmetic Mean	2.12E-03	1.53E-03	1.31E-03	1.58E-03	1.20E-03	1.55E-03	1.57E-03	1.41E-03	1.33E-02	2.67E-03	2.21E-03	2.11E-03	1.48E-03	1.86E-03	1.32E-03	9.87E-04	1.99E-03	1.43E-03
Geomertic Mean	1.44E-03	1.29E-03	1.22E-03	1.11E-03	9.00E-04	1.19E-03	1.28E-03	1.23E-03	3.20E-03	1.48E-03	1.27E-03	1.50E-03	1.33E-03	1.24E-03	1.25E-03	8.42E-04	9.89E-04	1.06E-03
95th Percentile	5.58E-03	3.36E-03	2.04E-03	3.79E-03	2.62E-03	3.56E-03	3.29E-03	2.76E-03	5.50E-02	1.01E-02	7.31E-03	6.35E-03	2.70E-03	5.18E-03	2.01E-03	1.49E-03	7.01E-03	3.30E-03
98th Percentile	7.93E-03	3.73E-03	2.26E-03	4.47E-03	3.20E-03	3.82E-03	3.44E-03	3.05E-03	7.38E-02	1.29E-02	9.43E-03	6.63E-03	2.77E-03	5.42E-03	2.09E-03	1.53E-03	9.31E-03	3.63E-03
Maximum	9.50E-03	3.98E-03	2.41E-03	4.92E-03	3.58E-03	3.99E-03	3.53E-03	3.24E-03	8.63E-02	1.48E-02	1.08E-02	6.82E-03	2.82E-03	5.58E-03	2.14E-03	1.55E-03	1.08E-02	3.84E-03
Minimum	1.84E-04	6.31E-04	7.38E-04	7.97E-05	7.83E-05	1.88E-04	2.42E-04	6.23E-04	7.61E-05	6.07E-04	7.95E-05	6.25E-04	6.33E-04	7.66E-05	6.22E-04	1.08E-04	7.77E-05	1.27E-04

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Titanium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0055	0.0053	0.0064	0.0052	0.0160	0.0079	0.0064	0.0053	0.0391	0.0056	0.0087	0.0066	0.0076	0.0058	0.0059	0.0043	0.0075	0.0058
23-Jul-08	4.33E-03	4.23E-03	3.94E-03	3.64E-03	4.21E-03	4.46E-03	4.67E-03	3.83E-03	5.35E-02	4.19E-03	4.02E-03	4.61E-03	4.25E-03	4.07E-03	3.70E-03	ND	5.09E-03	5.01E-03
29-Jul-08	0.0089	0.0144	0.0051	0.0130	0.0271	0.0070	0.0043	0.0038	0.0569	0.0043	0.0099	0.0071	0.0037	0.0199	0.0040	0.0037	**ND**	**ND**
4-Aug-08	0.0079	0.0039	0.0055	**ND**	0.0203	0.0057	0.0054	0.0072	0.0514	0.0043	0.0200	0.0071	0.0083	0.0043	0.0043	0.0057	**ND**	0.0033
10-Aug-08	0.0033	0.0036	0.0019	0.0036	**ND**	**ND**	0.0016	0.0021	0.0248	0.0027	0.0073	0.0025	0.0029	0.0025	0.0036	0.0037	**ND**	**ND**
22-Aug-08	0.0037	0.0041	0.0038	0.0039	0.0059	0.0087	0.0038	0.0041	0.0038	0.0040	0.0042	0.0056	0.0047	0.0042	0.0042	0.0039	0.0042	0.0045
28-Aug-08	0.0040	0.0044	0.0041	0.0041	0.0044	0.0041	0.0042	0.0041	0.0039	0.0037	0.0040	0.0036	0.0038	0.0041	0.0031	0.0039	0.0037	0.0043
3-Sep-08	0.0050	0.0034	0.0048	0.0038	0.0104	0.0055	0.0044	0.0055	0.0041	0.0038	0.0095	0.0043	0.0061	0.0045	0.0037	0.0024	0.0097	0.0050
9-Sep-08	0.0062	0.0049	0.0055	0.0052	0.0072	0.0062	0.0049	0.0049	0.0059	0.0049	0.0055	0.0047	0.0054	0.0058	0.0057	0.0049	0.0077	0.0056
15-Sep-08	0.0044	0.0049	0.0075	0.0045	0.0060	0.0052	0.0056	0.0046	0.0052	0.0042	0.0067	0.0049	0.0052	0.0046	0.0058	0.0063	0.0073	0.0054
21-Sep-08	0.0048	0.0046	0.0070	0.0048	0.0058	0.0044	0.0050	0.0047	0.0051	0.0047	0.0053	0.0050	0.0062	0.0051	0.0046	0.0041	0.0073	0.0057
27-Sep-08	0.0050	0.0047	0.0053	0.0049	0.0054	0.0057	0.0048	0.0052	0.0052	0.0054	0.0053	0.0050	0.0053	0.0051	0.0056	0.0051	0.0060	0.0058
3-Oct-08	0.0062	0.0051	0.0057	0.0060	0.0055	0.0053	0.0055	0.0061	0.0050	0.0049	0.0058	0.0052	0.0057	0.0051	0.0052	**ND**	0.0070	0.0057
Arithmetic Mean	5.32E-03	5.19E-03	5.10E-03	5.23E-03	9.86E-03	5.85E-03	4.65E-03	4.72E-03	2.03E-02	4.36E-03	7.40E-03	5.09E-03	5.32E-03	5.76E-03	4.57E-03	4.37E-03	6.55E-03	5.10E-03
Geomertic Mean	5.11E-03	4.81E-03	4.85E-03	4.88E-03	8.05E-03	5.71E-03	4.46E-03	4.55E-03	1.11E-02	4.30E-03	6.64E-03	4.92E-03	5.12E-03	5.03E-03	4.48E-03	4.24E-03	6.31E-03	5.03E-03
95th Percentile	8.31E-03	8.97E-03	7.17E-03	9.13E-03	2.34E-02	8.26E-03	5.89E-03	6.53E-03	5.49E-02	5.52E-03	1.40E-02	7.08E-03	7.88E-03	1.15E-02	5.86E-03	6.01E-03	8.83E-03	5.84E-03
98th Percentile	8.65E-03	1.22E-02	7.34E-03	1.15E-02	2.56E-02	8.54E-03	6.18E-03	6.92E-03	5.61E-02	5.59E-03	1.76E-02	7.09E-03	8.11E-03	1.66E-02	5.90E-03	6.19E-03	9.37E-03	5.84E-03
Maximum	8.88E-03	1.44E-02	7.45E-03	1.30E-02	2.71E-02	8.73E-03	6.37E-03	7.17E-03	5.69E-02	5.64E-03	2.00E-02	7.10E-03	8.26E-03	1.99E-02	5.93E-03	6.31E-03	9.73E-03	5.85E-03
Minimum	3.32E-03	3.41E-03	1.87E-03	3.63E-03	4.21E-03	4.10E-03	1.60E-03	2.09E-03	3.78E-03	2.69E-03	4.02E-03	2.50E-03	2.94E-03	2.46E-03	3.08E-03	2.36E-03	3.72E-03	3.26E-03

	Vanadium																	
	Concentrations (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0006*	*0.0006*	0.0008	*0.0006*	0.0007	*0.0012*	*0.0006*	*0.0006*	*0.0056*	*0.0007*	*0.0006*	*0.0007*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
23-Jul-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0081*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
29-Jul-08	*0.0013*	*0.0018*	*0.0007*	*0.0018*	0.0015	*0.0006*	*0.0006*	*0.0006*	0.0092	*0.0006*	*0.0015*	*0.0012*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	**ND**	**ND**
4-Aug-08	*0.0008*	*0.0005*	*0.0006*	**ND**	0.0006	*0.0006*	*0.0006*	*0.0012*	*0.0092*	*0.0006*	0.0009	*0.0007*	0.0007	*0.0006*	*0.0006*	*0.0007*	**ND**	*0.0006*
10-Aug-08	*0.0006*	*0.0007*	*0.0004*	*0.0006*	**ND**	**ND**	*0.0006*	*0.0006*	*0.0069*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0006*	*0.0006*	*0.0007*	**ND**	**ND**
22-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0009*	*0.0012*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
28-Aug-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
9-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
15-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
21-Sep-08	*0.0006*	*0.0006*	*0.0008*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
27-Sep-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*
3-Oct-08	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	*0.0006*	**ND**	*0.0006*	*0.0006*
Arithmetic Mean	6.84E-04	7.17E-04	6.36E-04	7.22E-04	7.33E-04	7.27E-04	6.30E-04	6.59E-04	3.38E-03	6.17E-04	7.10E-04	6.82E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
Geomertic Mean	6.66E-04	6.77E-04	6.32E-04	6.84E-04	7.07E-04	7.00E-04	6.30E-04	6.48E-04	1.62E-03	6.17E-04	6.86E-04	6.71E-04	6.37E-04	6.20E-04	6.24E-04	6.29E-04	6.20E-04	6.22E-04
95th Percentile	1.00E-03	1.14E-03	7.78E-04	1.14E-03	1.17E-03	1.24E-03	6.42E-04	8.36E-04	9.20E-03	6.35E-04	1.11E-03	8.88E-04	6.65E-04	6.34E-04	6.50E-04	6.51E-04	6.25E-04	6.30E-04
98th Percentile	1.21E-03	1.56E-03	7.79E-04	1.51E-03	1.36E-03	1.24E-03	6.45E-04	1.03E-03	9.22E-03	6.47E-04	1.32E-03	1.06E-03	6.65E-04	6.40E-04	6.56E-04	6.52E-04	6.25E-04	6.31E-04
Maximum	1.35E-03	1.85E-03	7.80E-04	1.76E-03	1.48E-03	1.25E-03	6.47E-04	1.16E-03	9.23E-03	6.55E-04	1.46E-03	1.18E-03	6.66E-04	6.44E-04	6.59E-04	6.52E-04	6.25E-04	6.31E-04
Minimum	6.09E-04	5.30E-04	4.46E-04	6.21E-04	6.16E-04	6.15E-04	6.16E-04	6.11E-04	6.07E-04	6.07E-04	6.20E-04	6.16E-04	6.21E-04	6.11E-04	6.10E-04	6.15E-04	6.13E-04	5.85E-04

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

	Zinc																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	0.0171	0.0199	0.0377	0.0137	0.0555	0.0271	0.0112	0.0171	0.1342	0.0144	0.0410	0.0083	0.0408	0.0322	0.0142	0.0129	0.0184	0.0136
23-Jul-08	0.0021	0.002549502	0.0048	0.0017	0.0073	0.0035	0.0014	0.0021	0.2175	0.0018	0.0051	0.0010	0.0054	0.0040	0.0017	**ND**	0.0023	0.0017
29-Jul-08	0.0754	0.0666	0.0091	0.0984	0.1012	0.0666	0.0400	0.0208	0.1539	0.0243	0.0262	0.0259	0.0224	0.0199	0.0132	0.0129	**ND**	**ND**
4-Aug-08	0.0202	0.0117	0.0178	**ND**	0.0927	0.0349	0.0116	0.0278	0.6796	0.0233	0.0802	0.0251	0.0306	0.0251	0.0253	0.0143	**ND**	0.0339
10-Aug-08	0.0111	0.0159	0.0196	0.0664	**ND**	**ND**	0.0394	0.0715	0.0963	0.0196	0.0188	0.0153	0.0090	0.0086	0.0201	0.0313	**ND**	**ND**
22-Aug-08	0.0049	0.003738814	0.0049	0.0037	0.0111	0.0150	0.0038	0.0061	0.0049	0.0073	0.0050	0.0037	0.0050	0.0061	0.0061	0.0037	0.0062	0.0099
28-Aug-08	0.0037	0.0088	0.0062	*0.0031*	0.0075	0.0037	0.0063	0.0037	0.0037	0.0061	0.0063	0.0037	0.0063	0.0049	0.0049	0.0037	0.0173	*0.0031*
3-Sep-08	0.0062	0.0050	0.0075	0.0101	0.0388	0.0125	0.0076	0.0050	0.0037	*0.0031*	0.0416	0.0051	0.0164	0.0074	0.0161	0.0037	0.0050	0.0038
9-Sep-08	0.0136	*0.0031*	*0.0031*	0.0038	0.0075	0.0050	0.0050	0.0099	0.0049	0.0037	0.0038	0.0062	0.0038	0.0074	0.0037	0.0037	0.0050	0.0088
15-Sep-08	*0.0031*	*0.0032*	0.0050	*0.0031*	0.0112	0.0050	0.0038	0.0149	*0.0031*	*0.0031*	*0.0031*	*0.0031*	*0.0031*	0.0062	*0.0031*	0.0037	*0.0031*	*0.0031*
21-Sep-08	*0.0031*	0.0089	*0.0039*	*0.0032*	0.0113	*0.0031*	0.0038	*0.0031*	*0.0031*	*0.0031*	0.0202	0.0088	0.0076	*0.0031*	*0.0031*	*0.0031*	0.0063	0.0063
27-Sep-08	*0.0031*	*0.0032*	*0.0031*	*0.0032*	0.0063	*0.0031*	*0.0032*	*0.0031*	*0.0031*	0.0037	*0.0032*	*0.0031*	*0.0032*	0.0050	0.0050	*0.0031*	0.0112	0.0035
3-Oct-08	0.0004	*0.0031*	*0.0031*	*0.0031*	*0.0031*	*0.0031*	*0.0031*	*0.0031*	*0.0030*	*0.0030*	*0.0031*	*0.0031*	*0.0031*	*0.0031*	0.0006	**ND**	*0.0031*	*0.0031*
Arithmetic Mean	1.26E-02	1.20E-02	9.68E-03	1.78E-02	2.94E-02	1.52E-02	1.08E-02	1.45E-02	1.01E-01	8.97E-03	1.98E-02	8.65E-03	1.20E-02	1.02E-02	9.01E-03	8.74E-03	7.78E-03	8.26E-03
Geomertic Mean	5.89E-03	6.95E-03	6.88E-03	6.59E-03	1.57E-02	8.35E-03	6.52E-03	8.18E-03	1.68E-02	6.08E-03	1.07E-02	5.87E-03	8.07E-03	7.56E-03	5.82E-03	6.18E-03	6.13E-03	5.61E-03
95th Percentile	4.23E-02	3.85E-02	2.69E-02	8.08E-02	9.65E-02	4.92E-02	3.97E-02	4.52E-02	4.02E-01	2.37E-02	5.70E-02	2.54E-02	3.47E-02	2.79E-02	2.22E-02	2.28E-02	1.79E-02	2.38E-02
98th Percentile	6.21E-02	5.54E-02	3.34E-02	9.14E-02	9.93E-02	5.96E-02	3.99E-02	6.10E-02	5.69E-01	2.41E-02	7.09E-02	2.57E-02	3.83E-02	3.05E-02	2.40E-02	2.79E-02	1.82E-02	2.98E-02
Maximum	7.54E-02	6.66E-02	3.77E-02	9.84E-02	1.01E-01	6.66E-02	4.00E-02	7.15E-02	6.80E-01	2.43E-02	8.02E-02	2.59E-02	4.08E-02	3.22E-02	2.53E-02	3.13E-02	1.84E-02	3.39E-02
Minimum	3.77E-04	2.55E-03	3.08E-03	1.72E-03	3.08E-03	3.08E-03	1.42E-03	2.12E-03	3.03E-03	1.78E-03	3.10E-03	1.03E-03	3.11E-03	3.06E-03	6.08E-04	3.10E-03	2.29E-03	1.71E-03

	Zirconium																	
	Concentration (µg/m3)																	
Sampling Date	**TL1 - TSP**	**TL1 - PM10**	**TL2 - TSP**	**TL2 - PM10**	**TL3 - TSP**	**TL3 - PM10**	**RC1 - TSP**	**RC1 - PM10**	**A1 - TSP**	**A1 - PM10**	**VG1 - TSP**	**VG1 - PM10**	**VG2 - TSP**	**VG2 - PM10**	**G1 - TSP**	**G1 - PM10**	**FA1 - TSP**	**FA1 - PM10**
17-Jul-08	*0.0061*	*0.0062*	*0.0065*	*0.0062*	*0.0062*	*0.0123*	*0.0062*	*0.0061*	*0.0559*	*0.0066*	*0.0062*	*0.0069*	*0.0066*	*0.0064*	*0.0064*	*0.0064*	*0.0061*	*0.0062*
23-Jul-08	*6.19E-03*	*6.41E-03*	*6.36E-03*	*6.28E-03*	*6.58E-03*	*6.37E-03*	*6.31E-03*	*6.18E-03*	*8.11E-02*	*6.17E-03*	*6.27E-03*	*6.24E-03*	*6.64E-03*	*6.16E-03*	*6.17E-03*	*ND*	*6.21E-03*	*6.26E-03*
29-Jul-08	*0.0135*	*0.0185*	*0.0065*	*0.0176*	*0.0062*	*0.0062*	*0.0063*	*0.0061*	*0.0769*	*0.0061*	*0.0146*	*0.0118*	*0.0062*	*0.0062*	*0.0066*	*0.0065*	**ND**	**ND**
4-Aug-08	*0.0078*	*0.0053*	*0.0063*	**ND**	*0.0064*	*0.0062*	*0.0065*	*0.0116*	*0.0918*	*0.0061*	*0.0063*	*0.0070*	*0.0067*	*0.0063*	*0.0063*	*0.0065*	**ND**	*0.0063*
10-Aug-08	*0.0061*	*0.0066*	*0.0045*	*0.0063*	**ND**	**ND**	*0.0062*	*0.0062*	*0.0688*	*0.0061*	*0.0063*	*0.0070*	*0.0064*	*0.0061*	*0.0063*	*0.0065*	**ND**	**ND**
22-Aug-08	*0.0061*	*0.0062*	*0.0062*	*0.0062*	*0.0092*	*0.0125*	*0.0063*	*0.0061*	*0.0061*	*0.0061*	*0.0062*	*0.0062*	*0.0062*	*0.0061*	*0.0061*	*0.0062*	*0.0062*	*0.0062*
28-Aug-08	*0.0062*	*0.0063*	*0.0062*	*0.0063*	*0.0062*	*0.0062*	*0.0063*	*0.0062*	*0.0061*	*0.0061*	*0.0063*	*0.0062*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0063*
3-Sep-08	*0.0062*	*0.0063*	*0.0063*	*0.0063*	*0.0063*	*0.0063*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0063*	*0.0063*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0063*
9-Sep-08	*0.0062*	*0.0063*	*0.0062*	*0.0101*	*0.0062*	*0.0062*	*0.0063*	*0.0062*	*0.0062*	*0.0061*	*0.0063*	*0.0062*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0063*
15-Sep-08	*0.0062*	*0.0063*	*0.0062*	*0.0063*	*0.0062*	*0.0062*	*0.0063*	*0.0062*	*0.0061*	*0.0062*	*0.0063*	*0.0062*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0063*
21-Sep-08	*0.0062*	*0.0063*	*0.0078*	*0.0063*	*0.0063*	*0.0063*	*0.0064*	*0.0062*	*0.0062*	*0.0062*	*0.0063*	*0.0063*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0063*	*0.0063*
27-Sep-08	*0.0062*	*0.0063*	*0.0063*	*0.0063*	*0.0063*	*0.0063*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0063*	*0.0063*	*0.0063*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0058*
3-Oct-08	*0.0061*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0062*	*0.0061*	*0.0061*	*0.0061*	*0.0062*	*0.0062*	*0.0062*	*0.0061*	*0.0061*	**ND**	*0.0061*	*0.0062*
Arithmetic Mean	6.84E-03	7.17E-03	6.26E-03	7.53E-03	6.51E-03	7.27E-03	6.30E-03	6.59E-03	3.26E-02	6.17E-03	6.91E-03	6.82E-03	6.37E-03	6.20E-03	6.24E-03	6.29E-03	6.20E-03	6.22E-03
Geomertic Mean	6.66E-03	6.77E-03	6.23E-03	7.11E-03	6.47E-03	7.00E-03	6.30E-03	6.48E-03	1.60E-02	6.17E-03	6.69E-03	6.71E-03	6.37E-03	6.20E-03	6.24E-03	6.29E-03	6.20E-03	6.22E-03
95th Percentile	1.00E-02	1.14E-02	7.01E-03	1.34E-02	7.77E-03	1.24E-02	6.42E-03	8.36E-03	8.54E-02	6.35E-03	9.62E-03	8.88E-03	6.65E-03	6.34E-03	6.50E-03	6.51E-03	6.25E-03	6.30E-03
98th Percentile	1.21E-02	1.56E-02	7.46E-03	1.59E-02	8.64E-03	1.24E-02	6.45E-03	1.03E-02	8.92E-02	6.47E-03	1.26E-02	1.06E-02	6.65E-03	6.40E-03	6.56E-03	6.52E-03	6.25E-03	6.31E-03
Maximum	1.35E-02	1.85E-02	7.76E-03	1.76E-02	9.22E-03	1.25E-02	6.47E-03	1.16E-02	9.18E-02	6.55E-03	1.46E-02	1.18E-02	6.66E-03	6.44E-03	6.59E-03	6.52E-03	6.25E-03	6.31E-03
Minimum	6.09E-03	5.30E-03	4.46E-03	6.21E-03	6.16E-03	6.15E-03	6.16E-03	6.11E-03	6.07E-03	6.07E-03	6.20E-03	6.16E-03	6.21E-03	6.11E-03	6.10E-03	6.15E-03	6.13E-03	5.85E-03

Notes:

ND = No data

Concentrations in italics were calculated at the method detection limit

Appendix 6F
Hydrology Baseline Report

Draft

Hydrology Baseline Report
Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 6, 2014

CH2MHILL®

309 Strickland Street, Suite 301
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Acronyms and Abbreviations

%	percent
°C	degree Celsius
AMP	Adaptive Management Plan
BGC	BGC Engineering Inc.
CH2M HILL	CH2M HILL Canada Limited
CVD	Cross Valley Dam
DA	daily average
DES	Denison Environmental Services
ET	evapotranspiration
ETA	Emergency Tailings Area
Faro A	Faro Airport Climate Station
FCD	Faro Creek Diversion
FMC	Faro Mine Complex
ha	hectares
HEC-HMS	Hydrologic Engineering Center–Hydrologic Modeling System (U.S. Army Corps of Engineers)
ICAP	Integrated and Comprehensive Abandonment Plan
ID	identifier
IW	Interim Works
IWPP	Interim Works Project Proposal
km	kilometre
km^2	square kilometre(s)
LiDAR	Light Detection and Radar
m	metre(s)
m^2	square metre
m^3/sec	cubic metres per second
MAR	Mean Annual Runoff
masl	metre above sea level
mm	millimetre
N/A	not applicable
NFRC	North Fork Rose Creek
NFRD	North Fork Rose Creek Rock Drain
NHC	Northwest Hydraulics Consultants Inc.
NHRI	National Hydrology Research Institute

PMF	probable maximum flood
PMP	probable maximum precipitation
QA	quality assurance
QC	quality control
RCD	Rose Creek Diversion
RGC	Robertson Geoconsultants Inc.
SFRC	South Fork Rose Creek
SRK	SRK Consulting Engineers and Scientists
TEES	Tlicho Engineering and Environmental Services
VCD	Vangorda Creek Diversion
WMC	Water Management Consultants Inc.
WRD	waste rock dump
YT	Yukon Territory

SECTION 1

Introduction

This report provides detailed descriptions of the existing hydrological conditions at the Faro Mine Complex (FMC) and assesses the information and data used to characterize surface water flow regimes in natural channels and stream diversions. During mining and post-mining operations, considerable effort was exerted to monitor stream flow and meteorological conditions at the FMC. Data continue to be collected from existing monitoring locations, to maintain an active database of hydrological conditions. These monitoring locations are being maintained to monitor hydrological and meteorological variables that will support future remediation efforts at the FMC and will form a critical part of an active Adaptive Management Plan (AMP). The relevant baseline hydrology-related data consist primarily of stream flow data and meteorological data, collected over various intervals, as part of FMC monitoring programs or other regional or federal data collection programs.

This document also summarizes additional supporting data sets that were collected as part of the FMC site characterization efforts, consisting of physical data related to watershed and subwatershed catchments at the FMC; it also incorporates available information from ongoing hydrological studies. Many of the historical data included in this baseline report were collected and reviewed as part of previous studies at the FMC, to determine the requirements for managing surface water and directing other site activities. This report also describes surface water management activities at the FMC. These are a significant component of the overall site hydrology; they include diverting surface water and managing potentially contaminated surface water, via containment and pumping for treatment.

Lastly, this report discusses the analysis methods used to characterize hydrology at the FMC and describes the hydrological and meteorological conditions at the FMC, based on available data and the results of previous and ongoing studies.

SECTION 2

Methods

Various forms of relevant climate- and hydrology-related site information and monitoring data were collected from a variety of sources to assess baseline hydrological site conditions, including:

- Historical data collection reports
- Design study reports for various site activities
- Site characterization reports and assessments

Raw data sets, as well as data that had already been compiled and assessed for quality assurance/quality control (QA/QC) purposes, were reviewed to identify gaps and errors. Most of these data sets comprised FMC related data collected through post-mining monitoring programs. Additional data were collected from long term monitoring sites established as part of Environment Canada's climate monitoring network. Supportive site characterization data (i.e, those developed through Light Detection and Radar [LiDAR]) surveys were also used to develop watershed and subwatershed topographical characteristics and boundaries.

Section 2 describes the sources of hydrologically relevant information, including hydrological and meteorological data sets and information from previous studies and reports, and summarizes the sources of information. It also defines the study area that is relevant to baseline hydrology for the Faro Mine Interim Works (IW).

2.1 Study Area

The FMC is located within the regional Vangorda Creek and Rose/Anvil Creek watersheds. The watercourses within these basins are tributaries of the Pelly River. Figure 6F-1 illustrates the hydrology study area for the IW, which includes the Vangorda Creek Watershed and the Rose Creek Watershed to a location downstream of the FMC. This report defines the baseline hydrology conditions within the study area by evaluating conditions in subwatersheds within the FMC that are interconnected with the larger regional watersheds. Baseline conditions within the FMC study area subwatersheds are examined in the context of these broader watershed areas.

2.1.1 Faro Mine Complex Major Hydrological Features

A number of hydrological features within the FMC are important from a surface water hydrological perspective, and are monitored as part of ongoing remediation efforts. These include pre-mining sections of local watercourses, stream diversions, and surface water impoundments that were developed to facilitate mining operations. Table 6F-1 lists these features, which are also illustrated in Figures 6F-2 and 6F-3.

TABLE 6F-1
FMC Hydrology-related Features
Faro Mine Interim Works

FMC Feature	Description	Hydrological Relevance
Faro Pit	Main excavated pit in Faro Mine Area	Receives local surface water and pumped water from the ETA, Intermediate Dam Pond and groundwater from the Zone 2 wells and S-wells
		No direct contribution to surface water hydrology
Various WRDs	Waste rock from pit excavation	Potential surface water runoff during extreme rainfall events; contributes to surface flow quantity
Intermediate Dam Pond	Containment of contaminated surface water behind intermediate dam	Water pumped to the Faro Pit. Spillway from dam is being upgraded as part of IW
Various seepage collection systems	Collect potentially contaminated seepage	Contained and pumped for treatment

TABLE 6F-1
FMC Hydrology-related Features
Faro Mine Interim Works

FMC Feature	Description	Hydrological Relevance
Cross Valley Pond and CVD	Surface water containment area behind CVD	Pond acts as a water treatment polishing pond
RCD	Diversion of Rose Creek uncontaminated water around tailings area	Requires minor upgrades to convey 1:500 year design rainfall event
NFRC	Undisturbed section of Rose Creek conveying uncontaminated surface water and seepage from WRDs	Conveyance of regional flows
North Wall Interceptor Ditch	Collects uncontaminated surface water from north side of Rose Valley	Conveyance of local runoff
NFRD	Haul road crossing of Rose Creek	Creates a surface water retention area upstream of drain and limits flow
Upper Guardhouse Creek	Collects local uncontaminated surface water and directs to North Wall Interceptor Ditch	Conveyance of local runoff
Lower Guardhouse Creek	Collects potentially contaminated mill area surface water	Collected in the Intermediate Pond and pumped for treatment
Faro Zone II Pit	Collects potentially contaminated groundwater	Collected and pumped to Faro Pit
Faro Creek	Undisturbed section of Faro Creek collecting uncontaminated surface water	Conveyance of regional flows
Faro Creek Diversion	Diversion of Faro Creek around Faro Pit	Conveys uncontaminated surface water around Faro Pit
Pumphouse Pond and Dam	Collects uncontaminated surface water	Discharges into Rose Creek
Vangorda Pit	Excavated mine pit in Vangorda/Grum Area	Receives local surface water and seepage No direct contribution to surface water hydrology under operations of Vangorda Diversion within design parameters. Also receives pumped water from Little Creek Pond, Grum Pit, Grum V15, and Grum Sulphide Cell Surface Water Collection Ponds.
Grum Pit	Excavated mine pit in Vangorda/Grum Area	Collects local surface water
Vangorda Creek	Undisturbed section of Vangorda Creek collecting uncontaminated surface water	Conveyance of regional flows
VCD	Diversion of Vangorda Creek around Vangorda Pit	Conveys uncontaminated surface water around Vangorda Pit
Moose Pond	Small pond collecting local surface water	Connected to Vangorda Creek system
Sheep Pad Ponds	Collect Grum Northeast Interceptor Ditch (Grum Interceptor Ditch) water for solids settling	Connected to Vangorda Creek system
Grum Northeast Interceptor Ditch (Grum Interceptor Ditch)	Collects uncontaminated surface water and discharges to Vangorda Creek	Collects local surface water and receives discharge from Vangorda water treatment plant

TABLE 6F-1
FMC Hydrology-related Features
Faro Mine Interim Works

FMC Feature	Description	Hydrological Relevance
Little Creek Pond and Dam	Collects water from Vangorda Waste Dump	Pond water is pumped to Vangorda Pit
Dixon Creek	Conveys local uncontaminated surface water	Connected to Vangorda Creek system

Notes:
CVD = Cross Valley Dam
ETA = Emergency Tailings Area
NFRC = North Fork Rose Creek
NFRD = North Fork Rock Drain
RCD = Rose Creek Diversion
VCD = Vangorda Creek Diversion
WRD = waste rock dump

2.1.2 Climatic Conditions

The FMC is located in the Anvil Range Mountains, within the Macmillan Highlands of the Yukon Plateau-North ecoregion that is within the Boreal Cordillera Ecozone (AECOM, 2009). Climate in this ecozone is represented by long, cold winters and short, warm summers, with ranges in humidity from sub-humid to semi-arid. The climate is classified as sub-Arctic continental and characterized by a large annual range in temperature and relatively moderate amounts of annual precipitation. The strong seasonal variation in temperature is further accentuated by elevation difference. Winter temperatures can be 10 degrees Celsius (°C) lower in valley bottoms than in uplands, because of temperature inversions. During the summer months, temperatures adhere more closely to the environmental lapse rate, with valley bottom temperatures higher than upland areas (Janowicz et al., 2006).

2.2 Sources of Data and Information

The majority of site-specific data was collected during the post-mining maintenance period. These data are available through a variety of compiled sources, including annual reports generated through care and maintenance activities.

Meteorological and flow data for the regional area relevant to but outside of the FMC are available from government agency monitoring locations. Climate data are available through the Environment Canada Climate Archive (http://climate.weather.gc.ca/). Flow monitoring data are available through the Environment Canada water survey database (http://www.ec.gc.ca/eau-water).

2.2.1 Flow Data

2.2.1.1 FMC Continuous Flow Monitoring

Flow-monitoring stations have been established at a number of locations within the FMC, to monitor flows in various stream systems and creek diversions. Data from the stations were historically used to develop water balances for the FMC, support water quality studies, and track seasonal variability in flow. The information collected at these stations provides sufficient data to form an understanding of the baseline FMC hydrology. The available data identified in Table 6F-2 was reviewed; the findings of this review can be found in Section 2.3.

Figure 6F-4 presents the locations of the continuous flow monitoring stations, and Figure 6F-5 illustrates the available flow data and gaps, compared with the available meteorological data. Table 6F-2 summarizes the availability of continuous flow monitoring data from surface water monitoring stations.

TABLE 6F-2
Summary of Continuous Flow Monitoring Locations and Available Data
Faro Mine Interim Works

Station ID	Available Range	% Complete Data Set [a]	% Complete Years [b]	Data Interval
Faro Mine Area				
R7	2001-2007 2009-2011	42%	9%	Daily; every 15 or 30 minutes during select years
X2	2011	45%	0%	Every 15 minutes
X14	2001-2002 2004-2011	58%	0%	Every 30 minutes from 2004 to 2007; every 15 minutes for 2009 to 2011
X23/FCS-1	2005-2008	33%	20%	Daily; every 10 minutes for 2005 to 2008
Vangorda/Grum Area				
V1	2008-2011	43%	0%	Daily for 2010; every 15 minutes for 2008, 2009, and 2011
V8	2008-2011	45%	0%	Daily for 2008 – 2009; every 15 minutes for 2010-2011
29BC003	1977-1985, 1989 - present	33%	0%	Daily, Monthly

[a] Represents a comparison of the number of actual data points to the number of expected data points based on 365 days a year and the measurement frequency.

[b] Represents how many years within the data set are complete based on 365 days a year and measurement frequency.

Notes:

% = Percent
ID = identifier

2.2.2 Meteorological and Climate Data

Meteorological and climate data relevant to this baseline hydrology assessment are available from five sources: three Environment Canada stations (the Faro A Station and the Faro AUT Station at the Faro Airport and the Faro Station in the Faro town site) and two FMC stations (the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations, which are currently maintained by the site care and maintenance contractor) (Figure 6F-6). Environment Canada publishes data from their three Faro stations through the Environment Canada Climate Achieve. The Environment Canada Faro Station includes recorded data from 1972 to 1977, but the station is no longer in operation. The Faro A and the Faro AUT stations include recorded data from 1978 to present and 1994 to present, respectively. The Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations were established in December 2003 and include recorded data to present day.

The station at the Grum Overburden Dump is representational of the Vangorda/Grum Area (Janowicz et al., 2006). The Faro Valley Waste Dump meteorological station is representative of the Faro Mine Area. The elevation of the Grum Overburden Dump station is 1,250 metres above sea level (masl), and the elevation of the Faro Valley Waste Dump station is 1,200 masl (Janowicz et al., 2006); these are approximately 500 metres (m) higher than the

Faro A Station and the Faro AUT Station at 716 masl (AECOM, 2009). These stations measure the following conditions:

- Air temperature
- Relative humidity
- Incoming, outgoing, and net radiation
- Wind speed and direction
- Rainfall
- Snowfall
- Snow depth
- Soil moisture
- Temperature and soil heat flux

Attachment 6F-1 summarizes the relevant available climate data, tabulated by parameter and source.

2.2.2.1 Snow Data Collection Programs

The first snow data collection conducted near the FMC was carried out as a snow pack survey at a regional snow course, located near Rose Creek, and measured snowpack and snow density in recorded intervals from 1975 through to 1985 and again from 2005 to 2007 (AECOM, 2009). The FMC Meteorological Stations (located at the Faro Valley Waste Dump and Grum Overburden Dump) have measured snow depth on a continuous basis since 2003 (AECOM, 2009). Detailed snow pack monitoring, as part of the care and maintenance contract at the FMC, began in February 2010. As part of the snow pack monitoring efforts, snow course surveys have been carried out twice a year during 2010, 2011, and 2012 to determine snow core weights and snow water equivalents (Denison Environmental Services [DES], 2011, 2012). Also as a component of the snow pack monitoring, data are collected from the snow depth gauges that were installed on the north, south, east, and west portions of the Faro Valley Waste Dump and on the south and west portions of the Vangorda WRD as part of an earlier revegetation cover trial study (DES, 2011, 2012).

2.2.2.2 Icing Conditions

Icing, or Aufeis, develops in valley systems or stream channels in arctic or sub-arctic regions, when groundwater or surface water that overflows ice dams freezes. This type of icing can build up in streams and diversions during the winter months at the FMC and cause flooding and slope erosion or failure. As part of the RCD upgrade study completed by CH2M HILL (2012a), Matrix Solutions Inc. completed an Icings White Paper that describes the potential for, and causes of, icing at the FMC in relation to the RCD. This White Paper is considered a basis for potential icing conditions to develop on the RCD. It also describes the potential for icing to occur at other onsite stream and diversion locations.

2.2.2.3 Evaporation and Evapotranspiration Estimates

Evaporation is measured as the loss of water from free water surfaces, and is usually represented as a rate of water loss in monthly or annual millimetres (mm) of depth. Evapotranspiration is the loss of water from land surfaces. It is also normally expressed in terms of monthly or annual mm, and represents a combination of evaporation from the ground surface and transpiration by vegetation. Estimates of evaporation and evapotranspiration rates for the FMC have been calculated from meteorological data collected at onsite climate stations, and from regional climate stations, using the Environment Canada National Hydrology Research Institute (NHRI) WREVAP Model (NHRI, 1985). Relevant monthly and annual evaporation and evapotranspiration rates for the climate stations were compiled in the *Faro Mine Complex Closure and Reclamation – Project Proposal* (AECOM, 2009) and are attached in Attachment 6F-2.

2.2.2.4 Faro Mine Complex Field Data Collection Programs

In addition to data from continuous monitoring stations, spot measurement records for flow velocity and weather conditions are collected as part of the care and maintenance activities, and are maintained as part of the overall FMC database. Field measurements are typically collected on a monthly basis during the ice-free period.

2.3 Data Analysis Methods

A number of studies used the available FMC hydrological, meteorological, and physical site data to determine baseline hydrological conditions. The available data were reviewed and integrated into the baseline analysis through a quality assurance/quality control (QA/QC) process that determined the most suitable data for inclusion in the analysis. The data analysis carried out to develop baseline hydrological data and the steps applied during the review and QA/QC process for each relevant data set are discussed in this section.

2.3.1 Flow Data

2.3.1.1 Faro Mine Complex Continuous Flow Monitoring

CH2M HILL compiled historical flow data from archived FMC data records, from records maintained as part of previous FMC studies, and from regional flow monitoring stations maintained by Environment Canada. For historical data and data collected at the regional flow monitoring stations, CH2M HILL conducted a QA/QC review to ensure they were representative of site or regional conditions. In addition, a number of past stream gauging efforts carried out as part of the site care and maintenance contract included QA/QC inspections at flow monitoring installations. These inspections were conducted when required during data collection field seasons. These efforts included regular equipment maintenance and spot flow measurements to update rating curves for the continuous flow monitoring locations. The hydrological analyses provide the necessary characterizations to support the IW.

2.3.2 Down Valley Interim Hydraulic Upgrades

Hydrological and hydraulic analyses took place during the Down Valley Interim Hydraulic Upgrades Study and were reported in *Down Valley Interim Hydraulic Upgrades Phase 2 – Basis of Design Report* (CH2M HILL, 2014). The report presents a summary of previous work and describes current efforts to verify the flows (discharge) for various flood events, including the 1-in-500-year design flood event. These flows were determined separately for the South Fork Rose Creek (SFRC) and the NFRC. The task included the following hydraulic/hydrological modelling components:

- Estimate the attenuation of flood flows in the NFRC at the NFRD and incorporate them into the estimate of flood flows entering the RCD.
- Evaluate the probable maximum flood (PMF) flood retardation in the NFRD.
- Determine the 1-in-50-, -100-, and -500-year flood flows into the RCD.

Previous Hydrologic Studies

Previous hydrological studies for the FMC reported in CH2M HILL (2014) generally focused on determining instantaneous peak flows for a range of recurrence interval events. The studies have relied on regional analyses to determine discharge yield based on catchment area for a range of flood events. Northwest Hydraulic consultants. (NHC) and BGC Engineering, Inc. (BGC) (2004) conducted a regional analysis based on data obtained from seven regional gauges. During the study, the period of record represented by the gauges ranged from 14 years to 40 years. The catchment areas for the gauges ranged from 91 square kilometres (km^2) to 7,250 km^2. Instantaneous peak discharges were estimated for the mean annual event and for the 1-in-50-, 1-in-100-, 1-in-200-, 1-in-500-, and 1-in-1,000-year return period. The 2003 Alternative Assessment for the Vangorda Creek Diversion by SRK Consulting Engineers and Scientists (SRK) also referenced regional analysis as the source for the peak instantaneous flow identified for the diversion design (SRK, 2003). This design report (SRK, 2003) identifies the 1-in-500 year, PMF, and ½ PMF as the potential alternatives for design flows. The results of the historical SRK regional flow analysis from 2003 as well as the SRK Getechnical/Hydraulic design flow analysis of the VCD (SRK, 1990) and the flow analysis from the VCD design report (SRK, 2010) are included in Section 3.2 of this report.

2.3.3 HEC-HMS Hydrologic Modelling

The Hydrologic Engineering Center–Hydrologic Modeling System (HEC-HMS) (U.S. Army Corps of Engineers, 2000) was used to characterize the hydrological conditions at the FMC (CH2M HILL, 2012b) and enhance the

understanding of FMC hydrology baseline conditions. Using the continuous monitoring records, monthly base flow estimates were developed to create the site-wide HEC-HMS hydrological model. This method of accounting for base flow in the model was selected based on the availability of continuous flow records. The continuous flow data sets for monitoring locations R7 and V1 were examined, and representative base flow values were then applied to the respective tributary catchments (RC1 and VC1, respectively). These patterns were factored to the other catchments according to where they were located, relative to RC1 and VC1. The base flow rates and monthly distributions were selected for model input based on the analysis of many years of low-flow data at various flow monitoring stations. The HEC-HMS model development and results are part of the CH2M HILL Fiscal Year 2012 Water Modelling Analysis Report (CH2M HILL, 2012b). Section 2, the Hydrology Modelling section of that report, is provided in Attachment 6F-3.

2.3.4 HEC-HMS Model Calibration

Attachment 6F-3 discusses the hydrological model development and calibration in detail. This attachment also compares the observed versus modelled hydrographs at flow monitoring stations R7, X2, and X14 (for the Rose Creek Model) and V1 and V8 (for the Vangorda Creek model). Attachment 6F-3 also includes separate figures for each flow monitoring station.

2.3.5 Regional Analysis

Previous FMC study efforts have applied regional analysis to support FMC hydrology characterization. AECOM (2009) documents the most recent efforts, and refines the regional analysis developed for the 1996 Integrated and Comprehensive Abandonment Plan (ICAP) report (Robertson GeoConsultants Inc. [RGC], 1996). Regional analysis examines available data to develop empirical relationships that can be used to estimate flow at ungauged locations. These empirical relationships relate a flow statistic (e.g., Mean Annual Runoff [MAR]) to a catchment characteristic (e.g., drainage area).

In AECOM (2009), the regional analysis methodology was applied to develop a site-wide water balance and relationships for mean annual runoff and low flows. A brief review of the data used in the regional analysis indicated there are more recent data available which could further refine this analysis.

A four-step algorithm was used by AECOM to estimate long-term average flows for the FMC. AECOM (2009) summarizes the algorithm as follows:

1. Identify a point of interest on a topographical map and determine the catchment area tributary to that point.
2. Determine the drainage area and median catchment elevation.
3. Determine the corresponding MAR value from the median elevation from Figure 6F-7 (excerpted from AECOM [2009, with Government of Yukon's permission]).
4. Multiply the MAR by the drainage area to estimate the long-term average annual flow for the point of interest.

The following equations from AECOM (2009) can be applied to predict absolute flow values, to better understand low-flow FMC hydrology:

2-year annual minimum 7-day flow	$7Q2 = 0.034\ A \cdot MAR^{0.605}$
10-year annual minimum 7-day flow	$7Q10 = 0.030\ A \cdot MAR^{0.553}$
50-year annual minimum 7-day flow	$7Q50 = 0.032\ A \cdot MAR^{0.481}$
2-year low annual flow	$365Q2 = 0.026\ A \cdot MAR^{1.034}$
10-year low annual flow	$365Q10 = 0.0081\ A \cdot MAR^{1.188}$
50-year low annual flow	$365Q50 = 0.0040\ A \cdot MAR^{1.277}$

Where catchment area is A (in km^2), the MAR is in mm, and the resulting low flow is in litres per second (AECOM, 2009).

SRK (2006) performed an independent regional analysis in 2006, building on previous work performed by NHC (2001). The purpose of this regional analysis was to develop the design hydrograph for the ETA and examine 1-in-100-year flood events. In this case, the regional analysis developed empirical relationships that can transpose flood event data to the ETA. SRK (2003) also applied regional analysis to determine the appropriate peak instantaneous design flow (1-in-500-year return period event) for the Vangorda Creek Diversion Design (SRK, 2003). These analyses and study also reference the relationship between MAR and elevation developed for RGC (1996), and indicates these relationships can also be used to estimate peak instantaneous flow volumes at ungauged locations within the FMC.

2.3.6 Probable Maximum Flood

The probable maximum precipitation (PMP) and PMF are events that occur with less frequency than once in every 1,000 years. The PMF is a key design event for the components of the Rose Creek system at the FMC. A study performed by Water Management Consultants and a committee of the Faro Mine Closure Planning Office (2006a) examined the FMC PMF event in detail. This study was conducted in two steps: the first developed the PMP event and the second used the PMP to develop the PMF event. The PMP development process was also peer-reviewed to ensure valid assumptions were used and the outcomes were realistic. The PMP report (Taylor and Hale, 2006) and PMF reports (Water Management Consultants, 2006a and 2006b) are attached to the *Down Valley Interim Hydraulic Upgrades Phase 2 – Basis of Design Report t* (CH2M HILL, 2014).

CH2M HILL has reviewed the reports and has found the assumptions and peer-reviewed work to be appropriately conservative.

2.3.7 Faro Mine Complex Surface Water Catchment Delineation

The existing surface water catchment delineations (AECOM, 2009) were reviewed to determine their suitability for the development of current baseline hydrology. This review determined the original FMC catchments needed to be re-delineated as previous efforts emphasized catchment boundaries by significant site features rather than site topography.

To support the revision of catchment delineations, CH2M HILL reviewed recent LiDAR data. LiDAR data were collected for the FMC on two separate occasions in 2012. These data provide a high-resolution data set for the FMC (1 square metre [m^2] per pixel). Only standard topographic information was available for the surrounding regional area. The preliminary catchments developed through the review of the LiDAR and topographic information were compared with available data, including aerial photographs, culvert survey data, previous catchment delineations, and accumulated site observation knowledge. Figure 6F-1 shows the combined local and regional catchments that were developed through this analysis, including the tributary areas for Rose Creek and Vangorda Creek. The Rose Creek catchment has an area of 26,129 hectares and consists of eight subcatchments. The Vangorda Creek catchment has an area of 8,815 hectares and consists of five subcatchments. Figure 6F-8 shows the subcatchments within the watersheds. Table 6F-3 summarizes the catchments delineated for the FMC.

TABLE 6F-3
Surface Water Catchments
Faro Mine Interim Works

Catchment ID	Description	Area (hectares)	Mean Elevation (masl)
Rose Creek Regional Catchment (Tributary to X14 monitoring location)			
RC1	NFRC (Upper) – includes the extent of the NFRC to the confluence with the FCD. The flow contributed to the FMC hydrology is monitored by the R7 station.	9,874	1,480
RC2	Faro Creek and FCD –includes both the Faro Creek and FCD to its confluence with the NFRC.	1,589	1,540
RC3	NFRC (Lower) – includes the area tributary to the NFRD at the Haul Road.	992	1,110

TABLE 6F-3
Surface Water Catchments
Faro Mine Interim Works

Catchment ID	Description	Area (hectares)	Mean Elevation (masl)
RC4	SFRC – includes the extent of the area tributary to the SFRC to the confluence with the NFRC (just south of the NFRD) and is bound by the Vangorda Creek catchment to the east.	7,253	1,450
RC5	RCD – RC5 is tributary to RC6 and represents the NFRC between the NFRD and confluence with the SFRC. RC6 represents the RCD around the tailings area.	124	1,220
RC6		1,842	1,310
RC7	Upper Guardhouse Creek and North Wall Interceptor Ditch – includes the extent of the area tributary to the Upper Guardhouse Creek and North Water Interceptor Ditch before the confluence with Rose Creek.	637	1,290
RC8a	Faro Pit –includes the area tributary to the Faro Pit. The pit is considered a water storage location in the context of surface water hydrology.	305	1,140
RC8b	Tailings Area – includes the tailings area and the area between the Faro Pit and tailings area; the flow within this area is monitored by the X23 station. This catchment outlets to the Rose Creek Catchment by the Siphon at the CVD.	539	1,130
RC9	Rose Creek west of the FMC – includes the remaining area tributary to the Rose Creek, upstream of the X14 monitoring location. Water exiting this catchment flows to Anvil Creek and, eventually, the Pelly River.	2,974	1,380
Vangorda Creek Regional Catchment			
VC1	Vangorda Creek and VCD – includes the extent of the area tributary to Vangorda Creek and VCD; flow through this catchment is represented by the V1 monitoring location.	2,007	1,460
VC2	Vangorda Creek and Shrimp Creek – includes the area tributary to the Vangorda Creek between the VCD and downstream of the confluence with Shrimp/Dixon Creek.	842	1,180
VC3	Grum Pit – represents the area tributary to the Grum Pit.	176	1,310
VC4	Shrimp Creek/Dixon Creek – includes the extent of the area tributary to Shrimp/Dixon Creek upstream of the confluence with Vangorda Creek and the V27 monitoring location.	1,360	1,210
VC5	Vangorda Creek – includes the remaining areas tributary to Vangorda Creek upstream of the V8 monitoring location.	4,430	1,240

Notes:
FCD = Faro Creek Diversion
ha = hectares

Figure 6F-9 illustrates the general surface water flow regime through the FMC, based on the delineation of subcatchment areas.

2.3.8 Meteorological and Climate Data

2.3.8.1 Environment Canada

Environment Canada performs preliminary QA/QC on the meteorological and climate data collected at their network of stations before it is available on the online climate archive. Data from the archive indicates the level of quality review performed by Environment Canada, as well as flags for each parameter, indicating where there may be questionable measurements.

CH2M HILL reviewed the Environment Canada data as well as the rainfall analysis provided in AECOM (2009) to determine whether the analysis approach used by AECOM was suitable to fill data gaps in the climate readings at

the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations. This review found that the analysis provided a suitable methodology to augment data from at the FMC meteorological stations.

2.3.8.2 Faro Mine Complex Meteorological Stations

AECOM originally reviewed and processed the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Station records for 2003 to 2008 (AECOM, 2009). This review was limited to the rainfall and temperature records, as the purpose of this effort was to support the development of the site-wide water balance. The data recorded at the FMC stations do not include flags to indicate potential data quality issues. The level of QA/QC performed on these data by the care and maintenance staff is unknown; therefore CH2M HILL reviewed them for quality before surface water modelling took place in 2012 and 2013 (CH2M HILL, 2013a).

Data recorded after 2008 are available through annual reports produced by the FMC care and maintenance contractors. The purpose of this review was to develop the meteorological database required for the CH2M HILL site-wide HEC-HMS hydrologic model and to identify data gaps and potential data errors.

2.3.9 Precipitation Record

CH2M HILL developed estimated precipitation data sets for the Faro Valley Waste Dump and Grum Overburden Dump to complete the site-wide HEC-HMS hydrological model. The *Fiscal Year 2012 Water Modelling Analysis Report* (CH2M HILL, 2013a) describes the development of these data sets in detail. Section 2 of that report is presented in Attachment 6F-3.

The precipitation data sets were developed using the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Station rainfall measurements and precipitation measurements collected at the Environment Canada Faro A and Faro AUT climate stations. Linear regressions, developed in 2009 by AECOM, were applied to the rainfall records to form a complete data set. The resulting data set is a total daily precipitation record for 2000 to 2011, except for 2002 and 2003, where there was not enough data to develop estimates.

2.3.10 Air Temperature

To develop a temperature data set for the HEC-HMS hydrological model, CH2M HILL developed a patched or augmented temperature record for the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations using several data sources to fill in data gaps and form a contiguous daily temperature data set. The Fiscal Year 2012 Water Modelling Analysis Report (CH2M HILL, 2013a) and Attachment 6F-3 describe the development of these data sets in detail.

The air temperature record utilizes the Faro Valley Waste Dump and Grum Overburden Dump meteorological data as well as data collected at the Environment Canada Faro A and Faro AUT climate stations. Faro A and Faro AUT are located at the Faro Airport, approximately 145 m apart. The record includes an average daily temperature record for all years from 2000 to 2011, except for 2002 and 2003, where there was not enough data to develop a patched record.

The temperature record for input to the hydrological model must represent a continuous daily record for an entire calendar year. Data gaps identified during the review process were patched using several methods and a number of steps, depending on the type of data gap.

The first step involved filling gaps in the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations' air temperature records using air temperature data recorded at the Faro Airport Stations. Where there were gaps in the FMC meteorological station records, and there was no coincident data recorded at the Faro Airport Stations, data gaps were filled as follows:

1. Data gaps with between 1 week and 1 month of consecutive missing data were patched using average daily air temperature over the available period of record. Review of the patched data sets was carried out to verify that this approach preserved existing trends and matched climate normals for the region.
2. Data gaps with no more than 6 consecutive days of missing data were patched using the air temperature from adjacent days, keeping the trend before and after the missing data point(s). For example, if one data point is missing and the air temperature trend was increasing before and after the missing data point, the higher of

the two adjacent data points was used to fill the data gap. For consecutive data gaps, between 2 and 6 days, the observed trend is maintained by filling the gap evenly with the adjacent temperature readings.

2.3.10.1 Snow Records

Total snow depth data from the FMC snow monitoring program at the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations were processed through a QA/QC procedure in an effort to eliminate gaps and errors in the record. It was determined that the historical data were not sufficiently reliable for use in the CH2M HILL HEC-HMS hydrological modelling efforts. AECOM (2009) compared snow pack water content at the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations to snowfall records at the Faro Airport Stations and determined that the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations received approximately 25 percent more snowfall (as a water equivalent) than the Faro Airport Stations. This is consistent with the altitude differences between the two locations. Therefore, to construct a snow record for the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations, snow depth at the Faro Airport Stations was increased by 25 percent and applied to the two FMC Stations. Due to the lack of recorded snowfall data at the FMC stations, it was not possible to account for days when snow occurred at the Faro Airport and not at the FMC.

2.3.10.2 Evaporation and Evapotranspiration Analysis

Evaporation and evapotranspiration rates were calculated for the FMC using the Environment Canada NHRI Model WREVAP (NHRI, 1985) and presented in AECOM (2009). The evaporation and evapotranspiration rates defined in AECOM (2009) were used by CH2M HILL to complete the recent site-wide HEC-HMS hydrological modelling (CH2M HILL, 2013a). AECOM (2009) (Attachment 6F-2) describes the WREVAP model and the calculations of evaporation and evapotranspiration carried out by AECOM.

2.3.10.3 Climate Change

It is difficult to differentiate between natural variability and longer term trends related to climate change in meteorological and flow conditions over the 10-year period for which the baseline analysis has been prepared. The 10-year period associated with the IWPP is not significant in the context of the rate of change anticipated for climate change impacts. This baseline analysis has, therefore, not considered the effects of climate change.

2.3.11 Surface Water Management

Surface water management at the FMC affects the site's baseline hydrological characteristics, and takes place to meet a number of objectives:

- Separate uncontaminated surface water from potential contaminant sources.
- Contain contaminated surface water and direct it to treatment facilities.
- Manage the quantities of available surface water during a range of hydrological conditions to prevent damage from erosion or dam/dike failures.

To meet these objectives, surface water is managed to maintain water levels within various hydrological features at or below defined threshold levels. The threshold levels were selected to protect surface water features from excessive quantities of flow that may cause containment failures and from potential overflows of contaminated water that may cause impacts to surface water quality. Attachment 6F-4 includes two technical memoranda (CH2M HILL, 2013b) that summarize the analysis of these water management strategies.

SECTION 3

Results

The FMC hydrological data analysis provides a characterization of existing hydrological conditions at the FMC to support the effects assessment for the IW. The hydrological characterization has also supported planning and design for interim activities like the Down Valley Interim Hydraulic Upgrades and will support planning and design for remediation activities that will be part of the Faro Mine Remediation Project. This section assesses the results of the various analyses and databases that support the characterization.

3.1 Down Valley Interim Hydraulic Upgrades

Characterization of hydrological conditions in Rose Creek and the risks associated with conveyance of flows through the Rose Creek Tailings Area have been addressed in planning for the Down Valley Interim Hydraulic Upgrades that are part of the IW. The *Down Valley Interim Hydraulic Upgrades Phase 2 – Basis of Design Report* (CH2M HILL, 2014) describes the hydraulic analysis carried out to assess the Down Valley Dam interim hydraulic upgrade requirements. The report provides the detailed hydraulic results of the analysis and also describes additional analysis results from previous hydrological studies, including the following:

- FMC Flood Hydrograph Development
- FMC Design Flood Hydrographs
- NFRD Flow Attenuation Characteristics

3.2 Previous Hydrological Studies

Previous hydrological studies for the FMC reported in CH2M HILL (2014) have generally focused on determining instantaneous peak flows for a range of recurrence interval events. The studies have relied on regional analyses to determine discharge yield, based on catchment area for a range of flood events. NHC and BGC (2004) conducted a regional analysis based on data obtained from seven regional gauges. During the study, the period of record represented by the gauges ranged from 14 years to 40 years. The catchment areas for the gauges ranged from 91 km^2 to 7,250 km^2. Instantaneous peak discharges were estimated for the mean annual event and for the 1-in-50-, 1-in-100-, 1-in-200-, 1-in-500-, and 1-in-1,000-year return period floods. Table 6F-4 summarizes the peak discharge estimates at the R7 gauge (NFRC, upstream of the FMC), NFRD, SFRC, and X14 gauge (Rose Creek downstream of FMC) locations and indicates recurrence interval peak discharge values that were selected for this study.

CH2M HILL (2013a and 2014) describe the hydrology analysis of previous studies in detail.

TABLE 6F-4
Summary of Peak Discharge Hydrology (Previous Studies)
Faro Mine Interim Works

				Discharge (m^3/sec)							
Reference	**Location**	**DA (km^2)**	**Instantaneous, Daily, or Hydrograph**	**Mean Annual**	**1-in-2-year**	**1-in-50-year**	**1-in-100-year**	**1-in-200-year**	**1-in-500-year**	**1-in-1,000-year**	**PMF**
NHC/BGC (2004)	R7 gauge	95	Instantaneous	9.2	N/A	37	45	54	67	77	N/A
NHC/BGC (2004)	29BC003	91	Instantaneous	4.27	N/A	14.2	18.6	24.0	33.1	43	N/A
SRK (2010)	R7 gauge	99[a]	Instantaneous	N/A	10	N/A	42	50	63[b]	N/A	N/A
SRK (2006)	R7 gauge	99[a]	Daily	N/A	6.7	N/A	28	33	40	47	N/A
Value used in current study	*R7 gauge*	*99[a]*	*Instantaneous*	*9.2*	*10*	*37*	*42*	*50*	*63*	*77*	*N/A*

TABLE 6F-4
Summary of Peak Discharge Hydrology (Previous Studies)
Faro Mine Interim Works

Reference	Location	DA (km^2)	Instantaneous, Daily, or Hydrograph	Discharge (m^3/sec)							
				Mean Annual	1-in-2-year	1-in-50-year	1-in-100-year	1-in-200-year	1-in-500-year	1-in-1,000-year	PMF
NHC/BGC (2004)	SFRC[d]	73[a]	Instantaneous	7.3	N/A	29	35	42	53	61	N/A
SRK (2010)	SFRC	73[a]	Instantaneous	N/A	7	N/A	33	39	49	N/A	N/A
SRK (2006)	SFRC	73[a]	Daily	N/A	4.9	N/A	21	25	30	34	N/A
WMC (2006)	SFRC	83.5	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	300
Value used in current study	*SFRC*	*73[a]*	*Instantaneous*	*7.3*	*7*	*29*	*33*	*39*	*49*	*61*	*300*
NHC/BGC (2004)	NFRC at NFRD	118	Instantaneous	11.0	N/A	44	54	65	81	93	N/A
SRK (2010)	NFRC at NFRD	118	Instantaneous	N/A	11	N/A	49	58	72[b]	N/A	N/A
SRK (2006)	NFRC at NFRD	118	Daily	N/A	8	N/A	34	40	48	55	N/A
WMC (2006)	NFRC at NFRD	122.5	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	384
Value used in current study	*NFRC at NFRD*	*118*	*Instantaneous*	*11*	*11*	*44*	*49*	*58*	*72*	*93*	*384*
NHC/BGC (2004)	Rose Creek upstream of Fuse Plug	203	Instantaneous	18	N/A	71	86	103	130	150	N/A
WMC (2006)	Upper End RCD	(217.3)[c]	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	674
NHC/BGC (2004)	X14 gauge	230	Instantaneous	20	N/A	79	96	115	145	167	N/A
SRK (2010)	X14 gauge	229[a]	Instantaneous	N/A	20	N/A	83	98	122[b]	N/A	N/A
SRK (2006)	X14 gauge	229[a]	Daily	N/A	16	N/A	65	77	94	108	N/A
WMC (2006)	Lower end RCD	(217.3)[c]	Hydrograph	N/A	N/A	N/A	N/A	N/A	N/A	N/A	692
Value used in current study	*X14 gauge*	*229[a]*	*Instantaneous*	*20*	*20*	*79*	*83*	*98*	*122*	*167*	*692*
SRK (1990)	Vangorda Creek Diversion	18.8	Instantaneous	4.2	4.1	9.0	10.0	N/A	18.0	N/A	N/A
SRK (2003)	Vangorda Creek Diversion	20.1	Instantaneous	N/A	N/A	N/A	N/A	N/A	31	N/A	180
SRK (2010)	Vangorda Creek Diversion	19.5	Instantaneous	N/A	N/A	N/A	N/A	13	30	N/A	N/A

[a] Drainage area from HEC-HMS model (CH2M HILL, 2013a)

[b] Best fit curve used for 1-in-500-year event instead of envelope curve

[c] Unclear in WMC (2006b) where discharge point is for lower sub-basin

[d] Reported value not in NHC (2004), used plots to extrapolate value

Notes:

DA = daily average
m^3/sec = cubic metres per second
N/A = not applicable
WMC = Water Management Consultants Inc.

Another regional study took place to determine average daily flows for the 1-in-2-, 1-in-100-, 1-in-200-, 1-in-500-, and 1-in-1,000-year floods, as detailed in *Anvil Range Mining Complex 2005 Seepage Investigation at the Emergency Tailings Area* (SRK, 2006). The recurrence interval floods were determined for flow durations ranging from 1 to 365 days. Using plots of peak discharge vs. catchment area, a relatively constant discharge per square kilometre was observed for flow records that represented catchment areas ranging from 13.7 km^2 to 7,250 km^2. This observation led to the conclusion that catchment response to floods could be estimated by using recurrence interval estimates from a single gauge with the most extensive period of record. This conclusion was reached because catchment unit discharge during recurrence interval events appeared to be independent of total catchment area. Table 6F-4 summarizes the daily average peak discharge estimates calculated using the unit discharge estimates for a 1-day-duration flood at the R7 gauge, SFRC sub-basin outlet, NFRD, and X14 gauge locations.

As part of a draft design report for the Vangorda Creek Diversion (SRK, 2010) SRK performed a regional analysis to estimate instantaneous peak discharge for 1-in-2-, 1-in-100-, 1-in-500-, and 1-in-1,000-year floods on Vangorda Creek. The relationships developed between peak instantaneous discharge and catchment area were used to estimate recurrence interval peak discharges at the R7 gauge, SFRC sub-basin outlet, NFRD, and X14 gauge locations. Table 6F-4 summarizes the results of applying the regional analysis curves to the locations on Rose Creek and Vangorda Creek.

Water Management Consultants (2006) conducted a PMF analysis for the Rose Creek watershed. The PMF study applied the 24-hour PMP (Taylor and Hale, 2006) to the Rose Creek catchment. The antecedent conditions assumed saturated soil conditions and a shallow snowpack across the entire Rose Creek catchment. Water Management Consultants used the HEC-HMS software to simulate the rainfall-runoff processes occurring during the PMP event. Outflow hydrographs at the NFRD, SFRC outlet, and lower end of the RCD (assumed to be near gauge X14) indicate the PMF responds to the PMP over approximately 2 to 3 days. For all catchments, peak flows occur between 16 and 17 hours after the PMP event is initiated. The analysis assumed the NFRD would not be in place during the PMF; therefore, no attenuation was modelled through the rock drain. Peak flood discharges in the NFRC and SFRC were estimated to be approximately 384 and 300 m^3/sec, respectively. Peak flood discharge at the lower end of the diversion channel was estimated to be approximately 692 m^3/sec. Table 6F-4 summarizes the PMF peak discharges.

3.3 HEC-HMS Hydrological Modelling

The objective of the CH2M HILL HEC-HMS hydrological modelling was to develop a dynamic hydrological model of the FMC, to provide a better understanding of its hydrological characteristics and support future design and supporting activities.

CH2M HILL (2013a) and Attachment 6F-3 discuss the model calibration methodology and results in more detail.

3.3.1 HEC-HMS Model Application

The surface water model described in CH2M HILL (2013a) and Attachment 6F-3 was used to simulate rainfall-runoff processes at the FMC on a continuous, multiyear simulation basis. It simulated the timing and magnitude of runoff events throughout the year, ranging from low-flow (i.e., base flow) conditions to the peak flows during the spring freshet. The design and investigative studies will use a regional analysis process to establish diversion design flow rates that exceed those produced by the freshet. This will involve transposing flood data from the regional flow gauging stations to the outlets of the respective diversions.

The surface water flow models will need to be refined to support the design of particular surface water diversion structures planned for the FMC, and to support various other design activities. This process will include refining the existing model so it is easier to evaluate potential future hydrological and hydraulic stream diversion behaviour under a variety of flow conditions, up to and including the PMF event. The surface water flow model will be used primarily to develop stream diversion designs, but will also be further integrated with other modelling efforts to support the Faro Mine Remediation Project.

3.3.2 HEC-HMS Model Use and Limitations

The hydrological model detailed in Attachment 6F-3 was developed and calibrated based on available meteorological and flow data collected at the FMC over a number of years, as well as data collected at offsite stations such as the Faro Airport Stations. Modelled hydrographs compare well with those observed at the continuous flow monitoring stations during the analysis. However, continuous flow data were available at a relatively small number of stations, which resulted in the need to lump large catchment areas. The current model catchments are sufficient to define the baseline FMC hydrology for the IW. Refining the model will support diversion and channel design for the Faro Mine Remediation Project.

3.3.3 HEC-HMS Base Flow Modelling

Hydrological modelling enhances the understanding of the FMC hydrology baseline conditions. The following sections summarize the base flow assessment results and compare modelled and monitored flows. Tables 6F-5 and 6F-6 summarize the monitored base flow values for each of the catchments of Rose Creek and the Vangorda Creek watershed.

The continuous flow data sets for R7 and V1 were examined and representative base flow values were then selected from these records to represent average base flow conditions. This is the most appropriate use of this data since the intent of the model was to simulate average conditions.

TABLE 6F-5
Rose Creek Model Monthly Base Flow Estimates
Faro Mine Interim Works

Rose Creek Model Catchments	Area (hectares)	Monthly Base Flow (m^3/sec)
RC1	9,874	Dec-Apr: 0.3 May-Nov: 1.0
RC2	1,589	Dec-Apr: 0.05 May-Nov: 0.16
RC3	992	Dec-Apr: 0.03 May-Nov: 0.1
RC4	7,253	Dec-Apr: 0.22 May-Nov: 0.73
RC5	124	Dec-Apr: 0.003 May-Nov: 0.0125
RC6	1,842	Dec-Apr: 0.06 May-Nov: 0.18
RC7	637	Dec-Apr: 0.02 May-Nov: 0.06
RC8a and RC8b (Siphon)	844	0.4 (monthly)

TABLE 6F-6
Vangorda Creek Model Monthly Base Flow Estimates
Faro Mine Interim Works

Vangorda Creek Model Catchments	Area (hectares)	Monthly Base Flow (m^3/sec)
VC1	2,007	Sept-Apr: 0.30 May-Aug: 0.40
VC2	842	Sept-Apr: 0.11 May-Aug: 0.15
VC3	176	Sept-Apr: 0.04 May-Aug: 0.05
VC4	1,360	Sept-Apr: 0.20 May-Aug: 0.27
VC5	4,430	Sept-Apr: 0.65 May-Aug: 0.87

3.3.4 HEC-HMS Model Calibration Flows

The detailed hydrological model development and calibration discussion provided in Attachment 6F-3 compares the observed and modelled hydrographs at flow monitoring stations R7, X2, and X14 (for the Rose Creek Model) and V1 and V8 (for the Vangorda Creek model). The comparison of the observed and modelled hydrographs spans the years of continuous flow data available for each station

The spot-flow measurements in the *2010 Annual Environmental Monitoring and Activities Report* (DES, 2011) typically did not coincide with significant hydrological events such as a spring freshet or a peak summer storm. Therefore, the general comparison of these data sets to the model results was not always definitive. Results from the *2005 Preliminary Observations Continuous Recording Sites* (Laberge, 2005a) provide data for a more definitive comparison because the spot-flow measurements were taken on May 11 and 12, 2005, which coincides approximately with the peak of the spring freshet (May 17, 2005). Measurements were collected at various locations along the NFRC and the RCD (at R7, X2, X14), and were compared to both the model results and the observed continuous data (Tables 6F-7 and 6F-8, respectively). Note, X14 is the nearest continuous flow monitoring station to Station RCDC4 that includes runoff from both NFRC and SFRC. Although the catchment area tributary to Station X14 is larger than the tributary to Station RCDC4, it is the most representative station for comparison to reported peak flows. Spot flow measurements taken in 2007 (Laberge, 2007) illustrate the potential variability between spot flow measurements and the continuous flow data records that represent the daily average. The HEC-HMS model utilized a daily time step and was calibrated to the continuous flow data.

TABLE 6F-7
Comparison of May 12, 2005, Flow Rates
Faro Mine Interim Works

Flow Monitoring Station	Location	Laberge (2005a)[a] (m^3/sec)	Continuous Flow Data (m^3/sec)	HEC-HMS Model (m^3/sec)
R7	NFRC	4.1	4.6	5.2
X2	NFRC Downstream from Tailings Facility	6.3	N/A	6.3
X14	Rose Creek Downstream from Tailing Facility	13.1	14.3	11.9
RCDC4	Entrance of RCDC	11.1	14.3[b]	11.9[b]

[a] instantaneous (i.e., spot) flow measurement
[b] based on data from continuous station X14

TABLE 6F-8
Comparison of 2007 Spring Freshet Peak Flows
Faro Mine Interim Works

Flow Monitoring Station	Location	Laberge (2007)[a] (m^3/sec)	Continuous Flow Data (m^3/sec)	HEC-HMS Model (m^3/sec)
R7	NFRC	13 (June 6)	6.5 (June 7)	6.3 (May 25)
X14	Rose Creek Downstream from Tailing Facility	30 (June 6)	17.6 (June 6)	14.3 (May 25)
V8	Lower Vangorda Creek at the Footbridge	10 (June 6)	n/a	7.5 (May 25)

[a] instantaneous (i.e., spot) flow measurement

3.3.5 Precipitation

To complete the site-wide HEC-HMS hydrological model, CH2M HILL developed estimated precipitation data sets for the Faro Valley Waste Dump and Grum Overburden Dump. CH2M HILL (2013a) and Attachment 6F-3 describe the development of these data sets in detail. CH2M HILL used the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Station rainfall measurements, precipitation measurements collected by the Environment Canada Faro A and Faro AUT climate stations, and linear regressions developed in 2009 by AECOM to form a complete data set with total daily precipitation record for 2000 to 2011 (except for 2002 and 2003, when there was not enough data to develop an estimate).

3.3.5.1 Rainfall Record

The preferred data source is data collected at the FMC meteorological stations. The data collected at the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations were converted to daily rainfall totals and reviewed for data gaps. The daily rainfall recorded at the Faro Airport Stations was used to augment the rainfall data collected at the FMC by filling identified data gaps with the information collected at the airport. AECOM (2009) developed relationships between the Faro Airport Stations and the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations. These correlations indicate the Faro Valley Waste Dump and Grum Overburden Dump Meteorological Stations receive 6.79 percent and 10.01 percent more rainfall, respectively, than the Faro Airport Stations. These correlations were developed only for the rainfall period between May and September; as such, they were only applied to fill gaps in the FMC rainfall records for that timeframe. If rain fell at the Faro Airport between October and April, the winter correlation was applied. The winter correlation indicated that the FMC stations received approximately 25% (as a water equivalent) more snowfall than the Faro Airport Stations. This was compared with the air temperature record to confirm rainfall was plausible during this period. Figures 6F-10 and 6F-11 show the rainfall records developed for the Faro Valley Waste Dump and Grum Overburden Stations, respectively.

3.3.5.2 Total Precipitation Estimate

The rainfall and snowfall data sets were developed using the described methodology, and were used to compile complete precipitation data sets for each of the two FMC meteorological stations. The precipitation data for the Faro Valley Waste Dump and Grum Overburden Dump Stations are shown on Figures 6F-12 and 6F-13, respectively. When these data sets were reviewed, several outliers were identified, which are shown on these figures.

Outliers were identified by comparing the data with the climate normal reported by Environment Canada for the Faro Airport Station. If an extreme event occurred that was not documented in the available site records, it was determined to be a likely outlier. Where possible, these events were compared with the available continuous flow monitoring data collected at the FMC. If the continuous monitoring data did not reflect a similar increase in surface water flow, the event was corrected using rainfall and snowfall data from one of the nearby stations.

Table 6F-9 compares modelled precipitation estimates, developed as described, for the Faro and Vangorda/Grum Areas of the FMC, with the climate normal for the region, as reported by Environment Canada. This table also presents the percent difference from the Faro Airport Station for each area of the FMC.

TABLE 6F-9
Comparison to Climate Normals
Faro Mine Interim Works

Description	Faro Airport	FMC – Faro Area		FMC – Vangorda/Grum Area	
		Estimate	% Difference	Estimate	% Difference
Average Yearly Rainfall (mm)	214 mm	215 mm	0%	225 mm	5%
Average Yearly Snowfall (cm)	112 cm	162 cm	37%	162 cm	37%
Average Total Precipitation (mm)	316 mm	377 mm	17%	387 mm	20%
Extreme Daily Rainfall (mm)	24.8 mm	28 mm	11%	29 mm	14%
Extreme Daily Snowfall (cm)	12.8 cm	17 cm	27%	17 cm	27%

Notes:

Faro Airport Climate normals are for 1971 to 2000.

Extremes are for period of record.

FMC Area comparison values are for the data available between January 2000 and December 2011 (excluding 2001 and 2002).

cm = centimetre

3.3.6 Air Temperature

CH2M HILL developed a patched temperature record for the Faro Valley Waste Dump and Grum Overburden Dump to complete the surface water modelling task. CH2M HILL (2013a) describes the development of these data sets in detail. Section 2, the Hydrology Modelling section, is provided in Attachment 6F-3. A review of the air temperature records for the Faro Valley Waste Dump and Grum Overburden Dump determined the data to be stable and within climate normals for the region.

Figures 6F-14 and 6F-15 show the complete air temperature records developed by CH2M HILL, indicating the data points from each source respectively.

3.3.6.1 Snowfall Record

As previously discussed, the Faro Valley Waste Dump and Grum Overburden Dump Stations do not record snowfall in water equivalents. AECOM (2009) compared snowpack water content at the Faro Valley Waste Dump and Grum Overburden Dump Stations with accumulated snowfall at the Faro Airport Stations. This analysis indicated the FMC Stations receive about 25 percent more snowfall (as water equivalent) than the Faro Airport. Orographic effects and impacts of blowing snow do influence snow accumulation at the FMC. Therefore, to construct a snow record at the Faro Valley Waste Dump and Grum Overburden Dump Stations, snow depth recorded at the Faro Airport was increased by 25 percent and applied to both stations.

The following assumptions were made while developing the snowfall (as water equivalent) record:

1. To convert the snowfall (reported in cm) recorded at the Faro Airport Station to water equivalents, it is reasonable to assume a snow density of 1 cm equals 1 mm of water equivalent.
2. Where snowfall data are missing for winter months, it is reasonable to patch the data with average-day snowfall from the period of record for the missing dates.
3. It is reasonable to assume that, when snowfall data are missing during summer months (i.e., June to September), no snow fell.

Where gaps exist in the Faro Airport Station records, the average day snowfall was used to patch data gaps. Figure 6F-16 illustrates the snowfall record developed for the FMC for the hydrological modelling.

3.3.6.2 Probable Maximum Flood

Water Management Consultants (2006a) examined the FMC PMF event in 2006. The PMP for this analysis was determined by Taylor and Cadee, also in 2006. The PMP was determined to be a 175-mm-in-24-hours, rain-on-snow event, which is most likely to occur in June. Table 6F-10 summarizes the PMF findings for Rose Creek. CH2M HILL has reviewed Water Management Consultants (2006a) and has found the assumptions and peer-reviewed work to be appropriately conservative.

TABLE 6F-10
Summary of PMF for Rose Creek
Faro Mine Interim Works

Area [a]	PMF (m^3/s) [a]
NFRC	384
Upper end of Rose Creek Diversion	674
Lower end of Rose Creek Diversion	692

[a] Water Management Consultants (2006a)

3.3.6.3 Evaporation and Evapotranspiration Data

The monthly evapotranspiration values for the FMC are shown in Table 6F-11, these are summarized from AECOM (2009). Attachment 6F-2 provides additional evaporation and evapotranspiration data that was used to develop baseline conditions for the FMC.

TABLE 6F-11
Monthly Evapotranspiration Data
Faro Mine Interim Works

Month	Rose Creek Model ET (mm) [a]	Vangorda Creek Model ET (mm)
January	0	0
February	0	0
March	10	10
April	30	32
May	48	47
June	50	56
July	48	57
August	26	30
September	20	20
October	5	4
November	0	0
December	0	0

[a] AECOM (2009)

Note:
ET = evapotranspiration

SECTION 4

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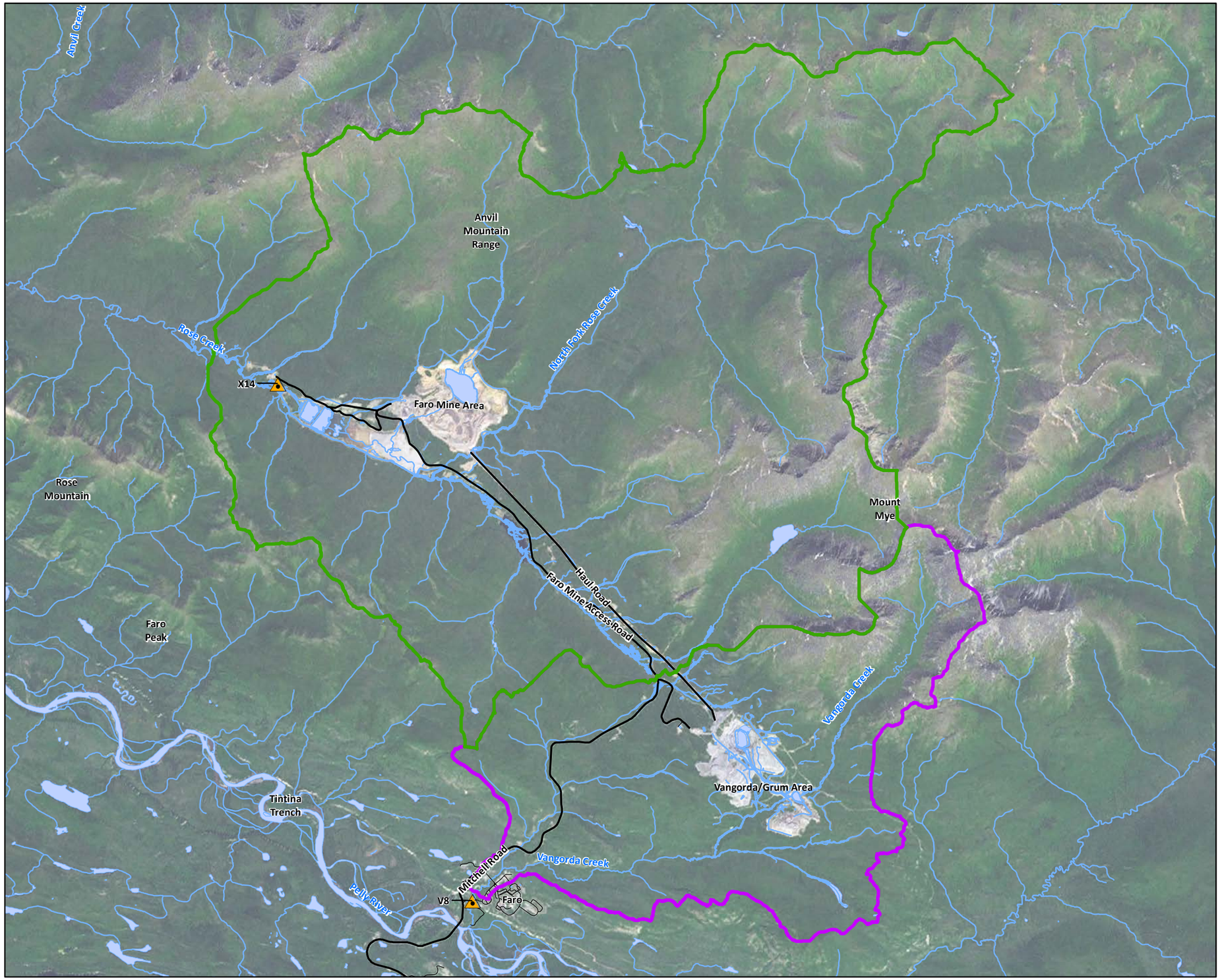
Figures



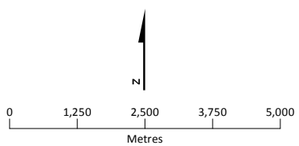


LEGEND

- Flow Monitoring Location
- Rose Creek Regional Catchment
- Vangorda Creek Regional Catchment

Notes:

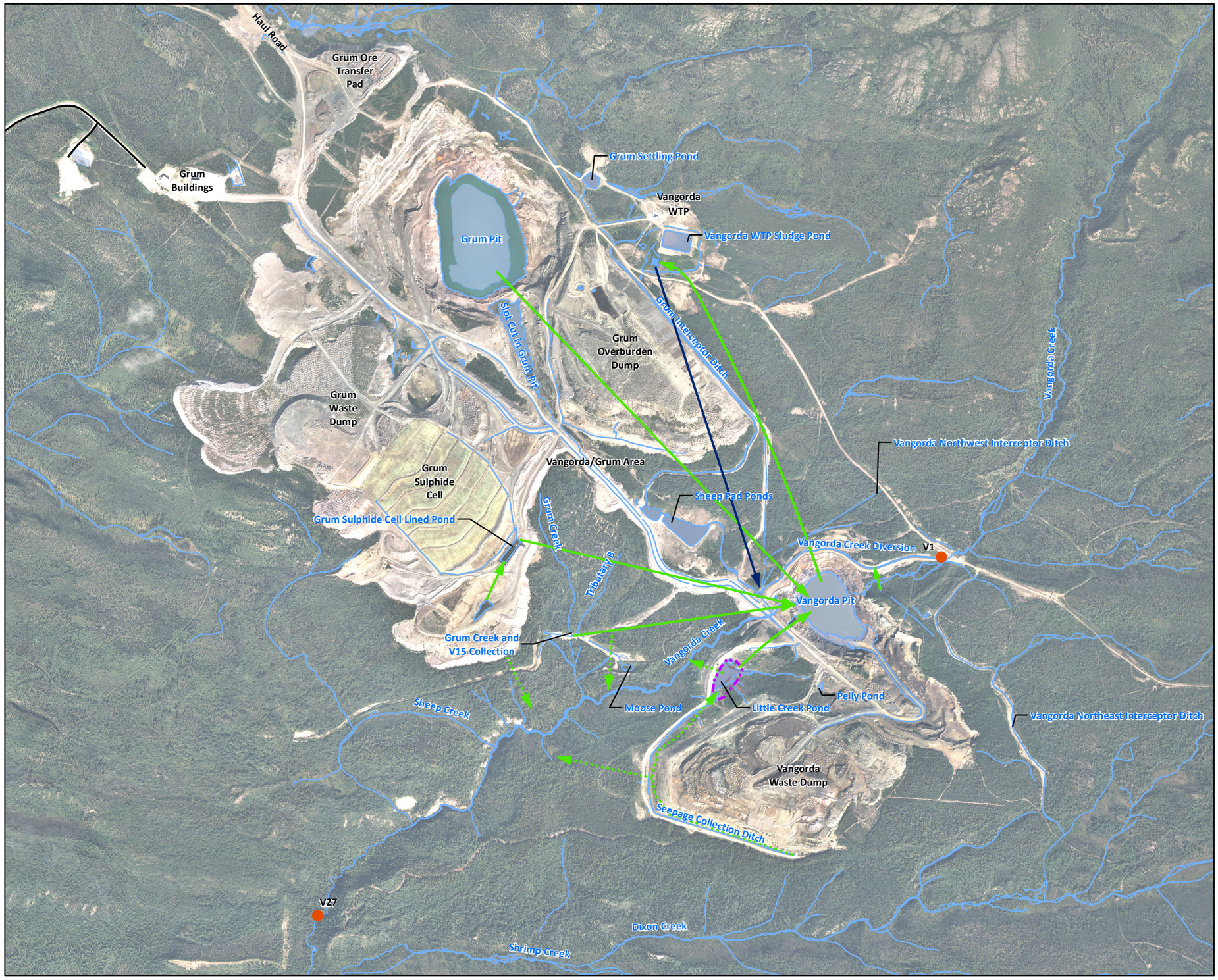
1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro



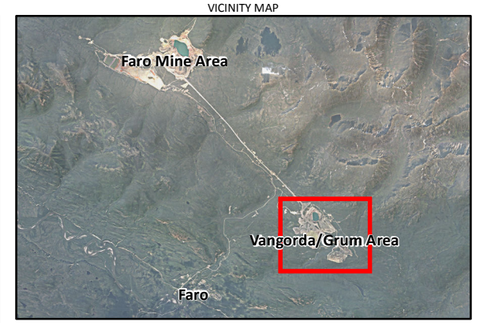
Created by: CRITIGEN

FIGURE 6F-1
Faro Mine Complex Surface Water Catchment Boundary
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

- Streamflow Gauging Station
- Water to Pit or Treatment
- Seepage Bypassing Current Collection
- Treated Water Discharge (via Grum Interceptor Ditch and Sheep Pad Ponds)
- Installed Surface Water Collection
- Water Treatment Plant

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Faro = Town of Faro

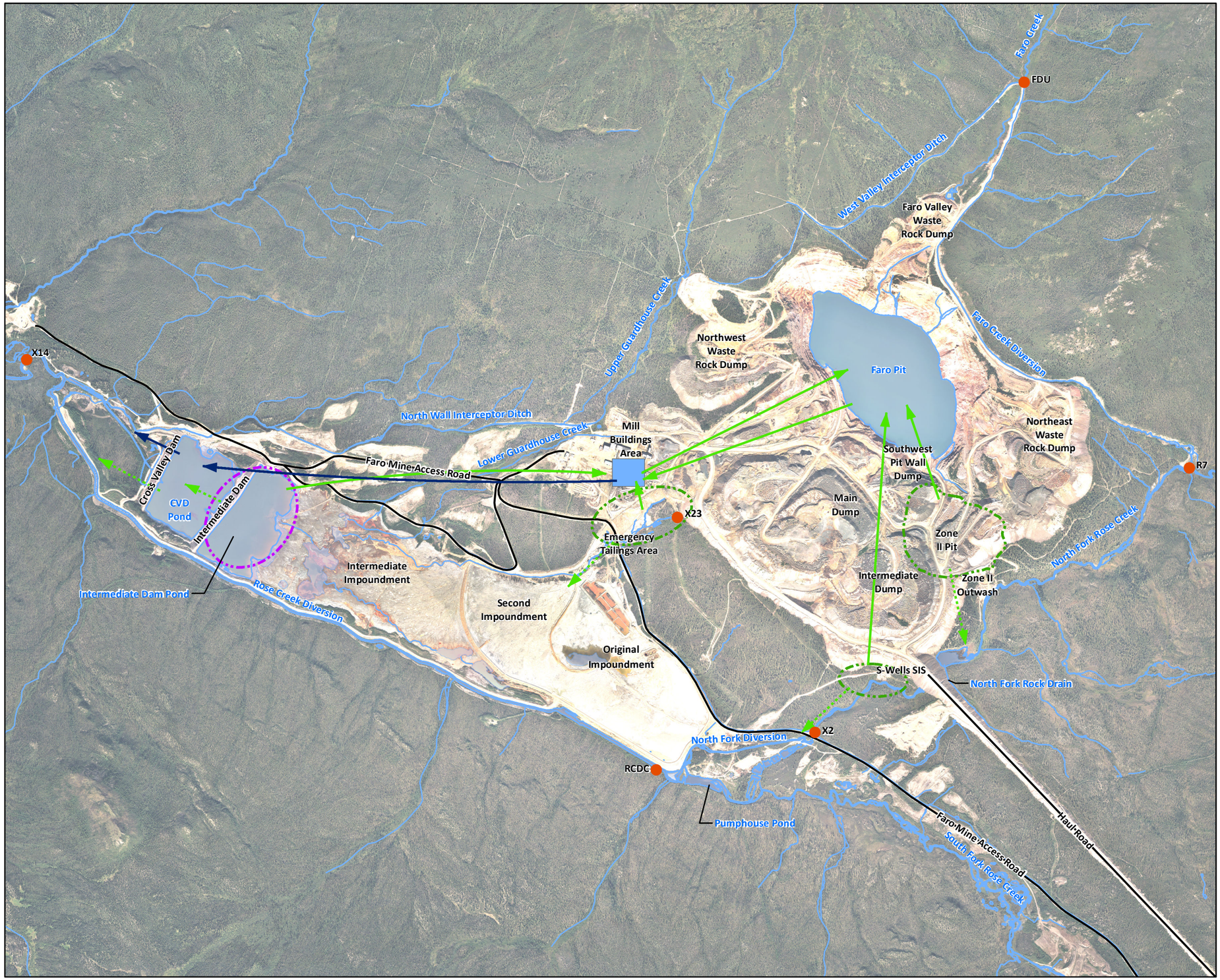
N

0 250 500 750 1,000
Metres

Created by:
CRITIGEN

FIGURE 6F-2
Vangorda/Grum Current Water Collection and Treatment
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

- Surface Water Station
- Water to Pit or Treatment
- Seepage Bypassing Current Collection
- Treated Water Discharge
- Installed Groundwater or Surface Water Collection System
- Installed Surface Water Collection
- Interim Water Treatment System

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. ETA - Emergency Tailings Area
3. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
4. Orthophotography prepared by Critigen Canada Corp.

N

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Metres

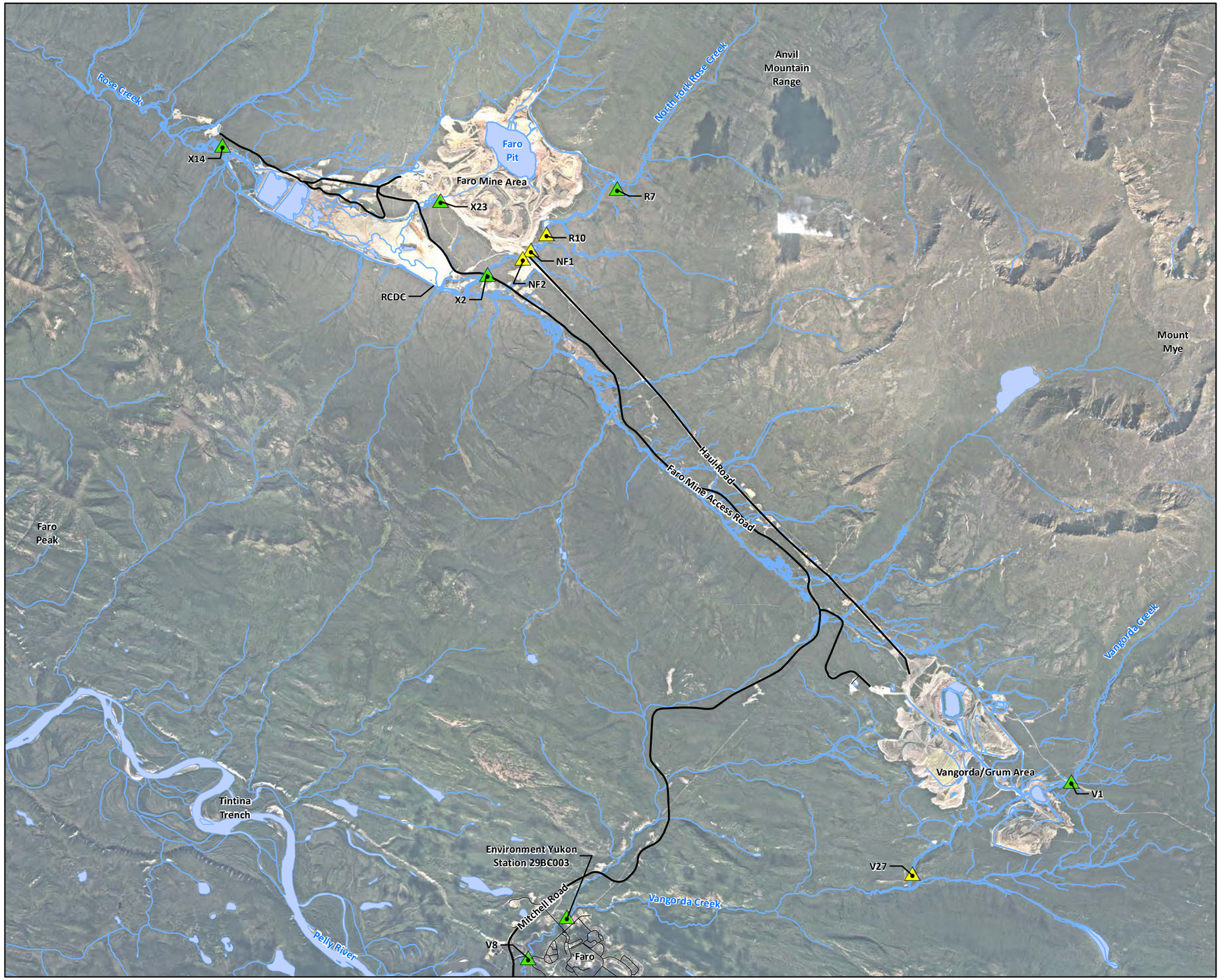
Created by: CRITIGEN

FIGURE 6F-3

Faro Current Water Collection and Treatment

Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

- Continuous Flow Monitoring Location
- Spot Monitoring Location

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Faro = Town of Faro

N

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Metres

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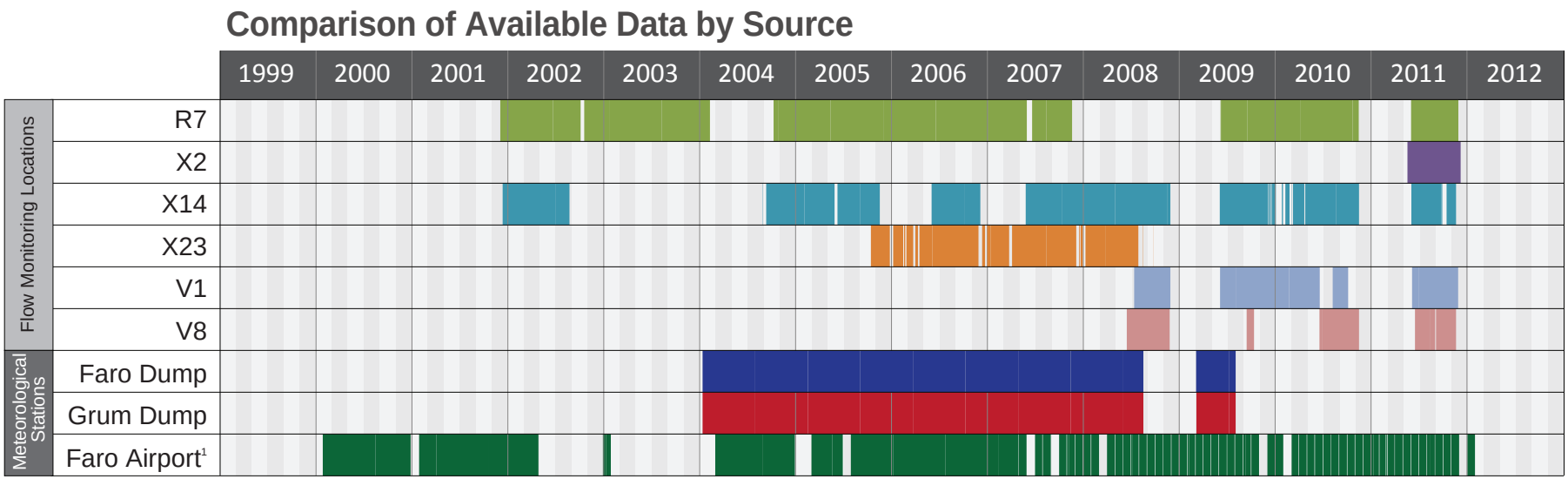
FIGURE 6F-4

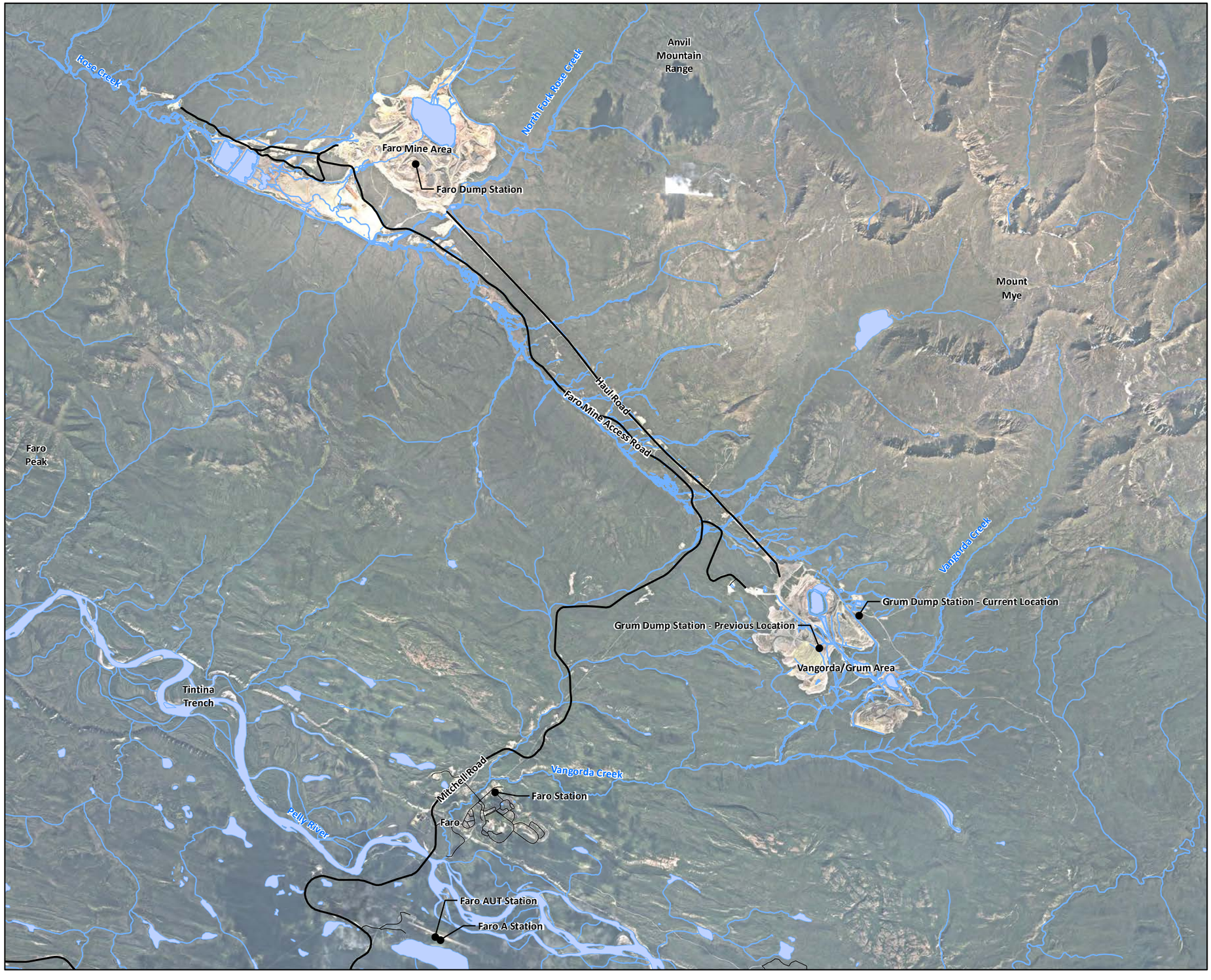
Continuous Flow Monitoring Stations

Faro Mine Interim Works



[1] Environment Canada Climate Station (ID 2100517)

FIGURE 6F-5
Comparison of Available Data by Source
Faro Mine Interim Works



VICINITY MAP

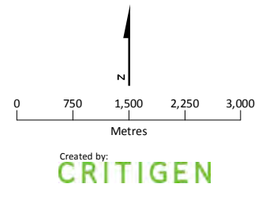


LEGEND

- Meteorological Station

Notes:

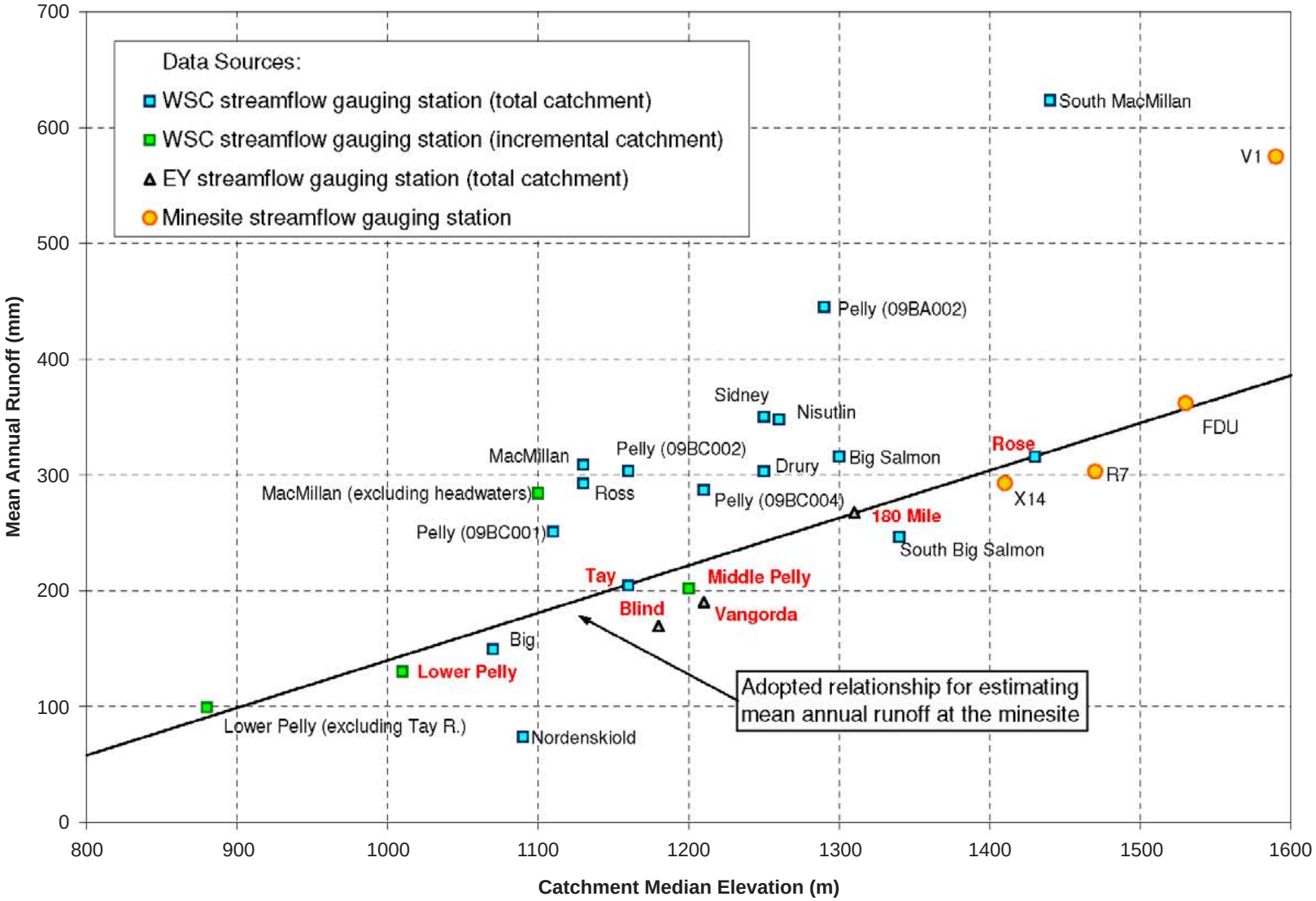
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Faro = Town of Faro



Created by:
CRITIGEN

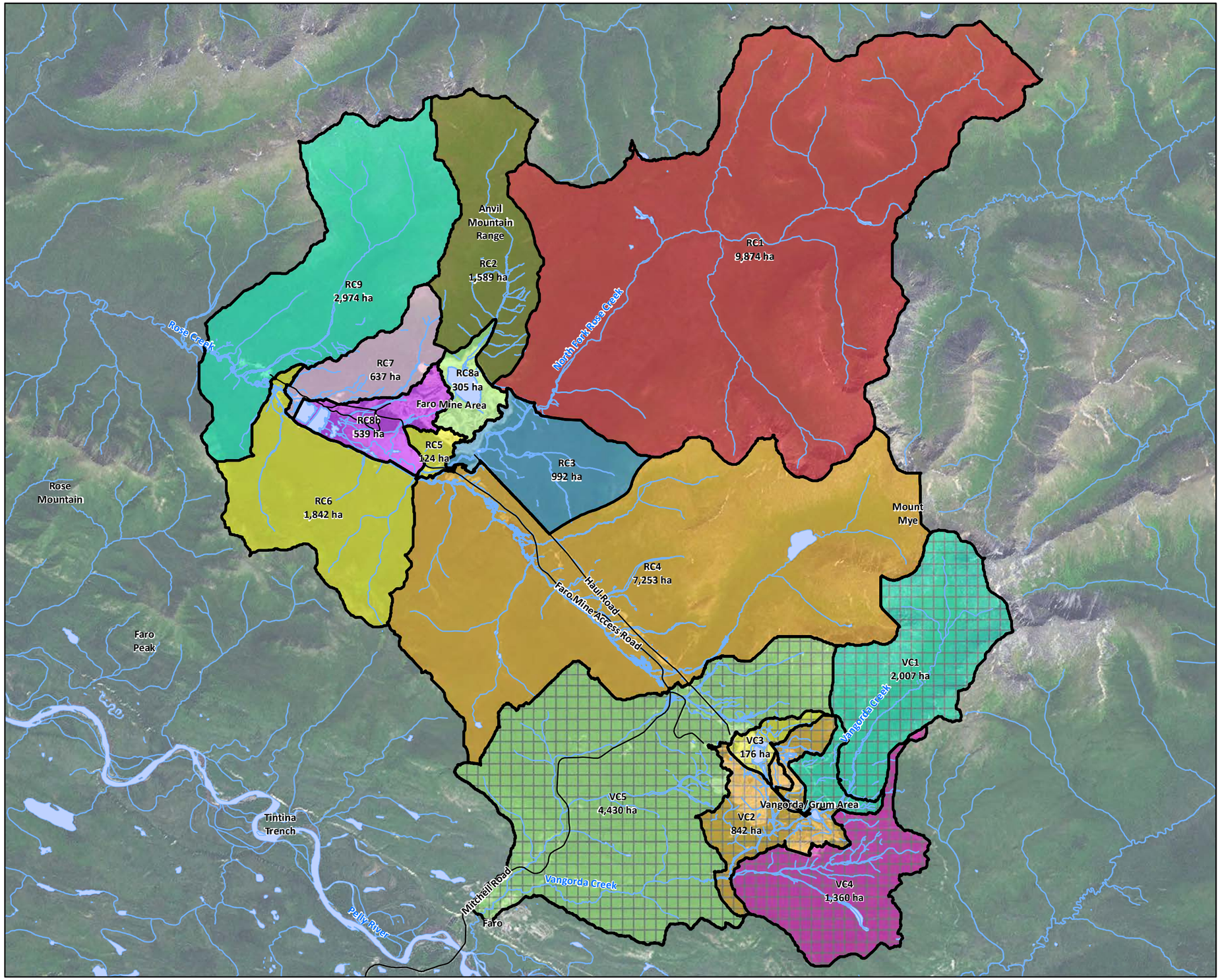
FIGURE 6F-6
Site Area Meteorological Stations
Faro Mine Interim Works

CH2MHILL



Source: AECOM Canada Ltd. (AECOM). 2009. Faro Mine Complex Closure and Reclamation – Project Proposal. Current Environmental Conditions Supporting Document. Prepared for Faro Project Management Team. March 31.

FIGURE 6F-7
Regional Relationship Between Mean Annual Runoff and Catchment Median Elevation
Faro Mine Interim Works





LEGEND

- Catchment Boundary

Catchment Areas Tributary to Rose Creek

- North Fork Rose Creek (Upper) (RC1)
- Faro Creek & Faro Creek Diversion (RC2)
- North Fork Rose Creek (Lower) (RC3)
- South Fork Rose Creek (RC4)
- Rose Creek Diversion (RC5 + RC6)
- Upper Guardhouse Creek/North Wall Interceptor (RC7)
- Faro Pit (RC8a)
- Tailings Area (RC8b)
- Rose Creek (RC9)

Catchment Areas Tributary to Vangorda Creek

- Vangorda Creek & Vangorda Diversion (VC1)
- Vangorda Creek & Shrimp Creek (VC2)
- Grum Pit (VC3)
- Shrimp Creek/Dixon Creek (VC4)
- Vangorda Creek (VC5)

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro
3. ha = hectare

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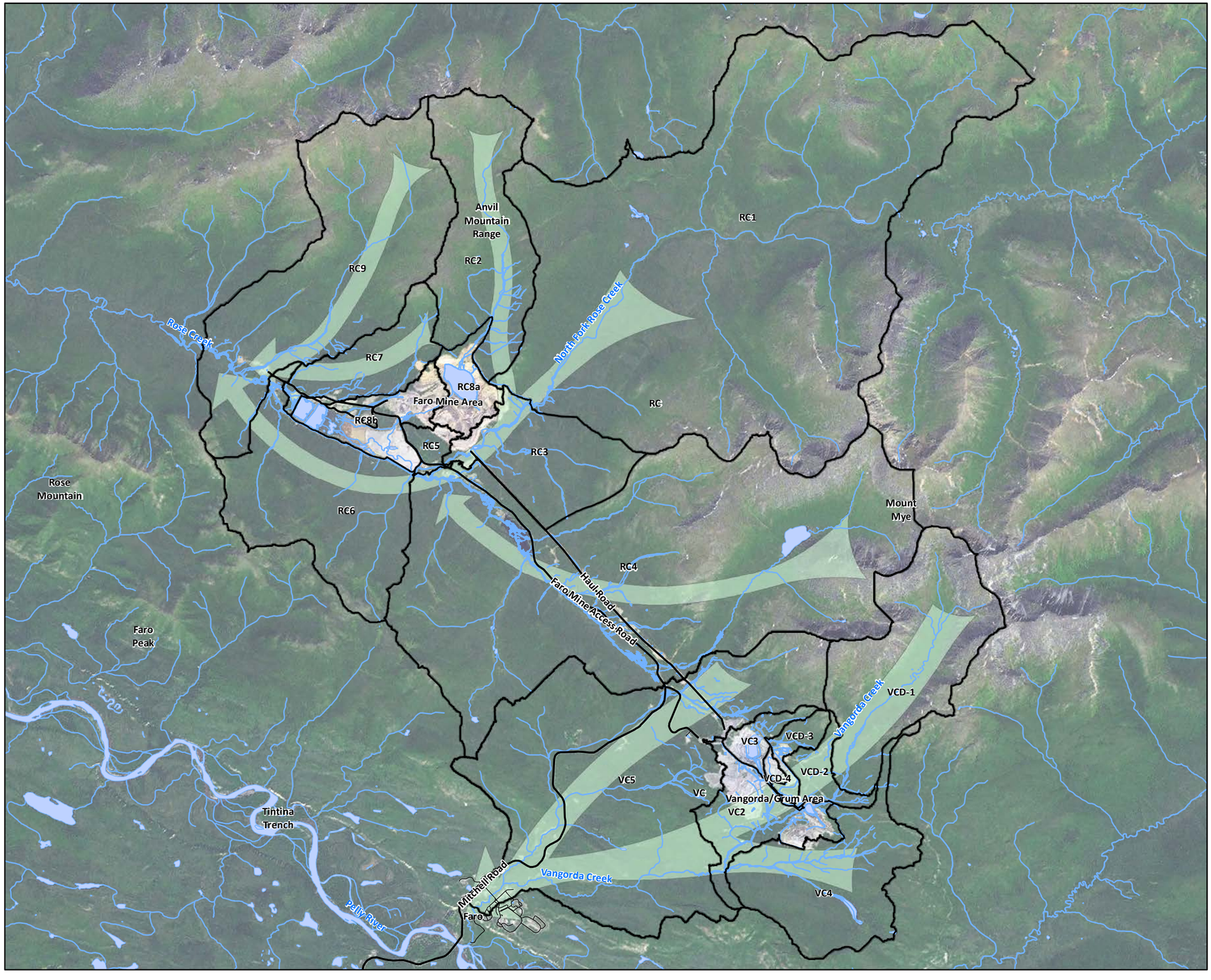
Metres

Created by: CRITIGEN

FIGURE 6F-8

Regional Surface Water Subcatchments

Faro Mine Interim Works





LEGEND

Catchment Boundary

Flow Paths through Catchment

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

N

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Metres

Created by: CRITIGEN

FIGURE 6F-9

Regional Surface Water Subcatchment Flow Paths

Faro Mine Interim Works

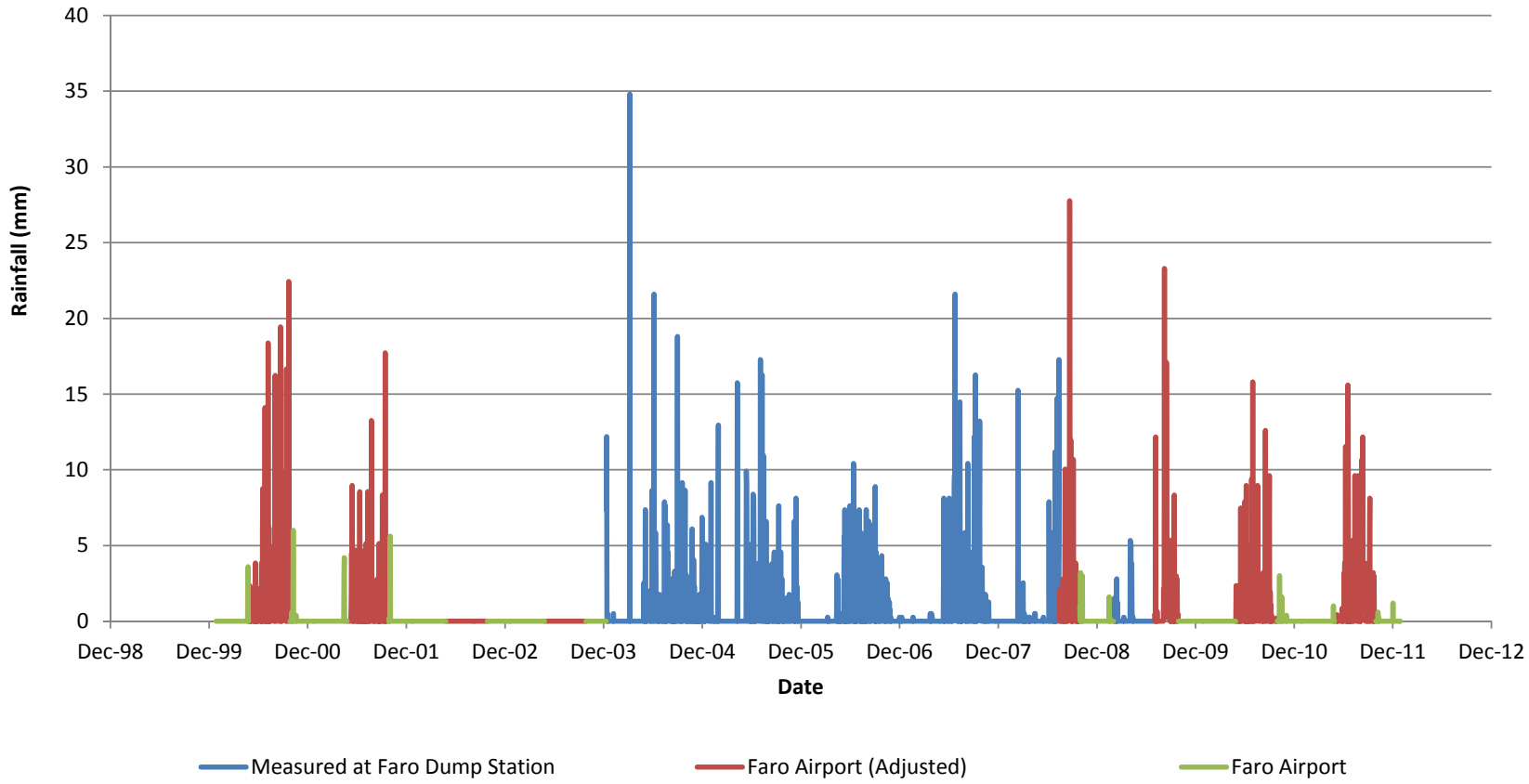


FIGURE 6F-10
Rainfall Record by Data Source – Faro Dump Station
Faro Mine Interim Works

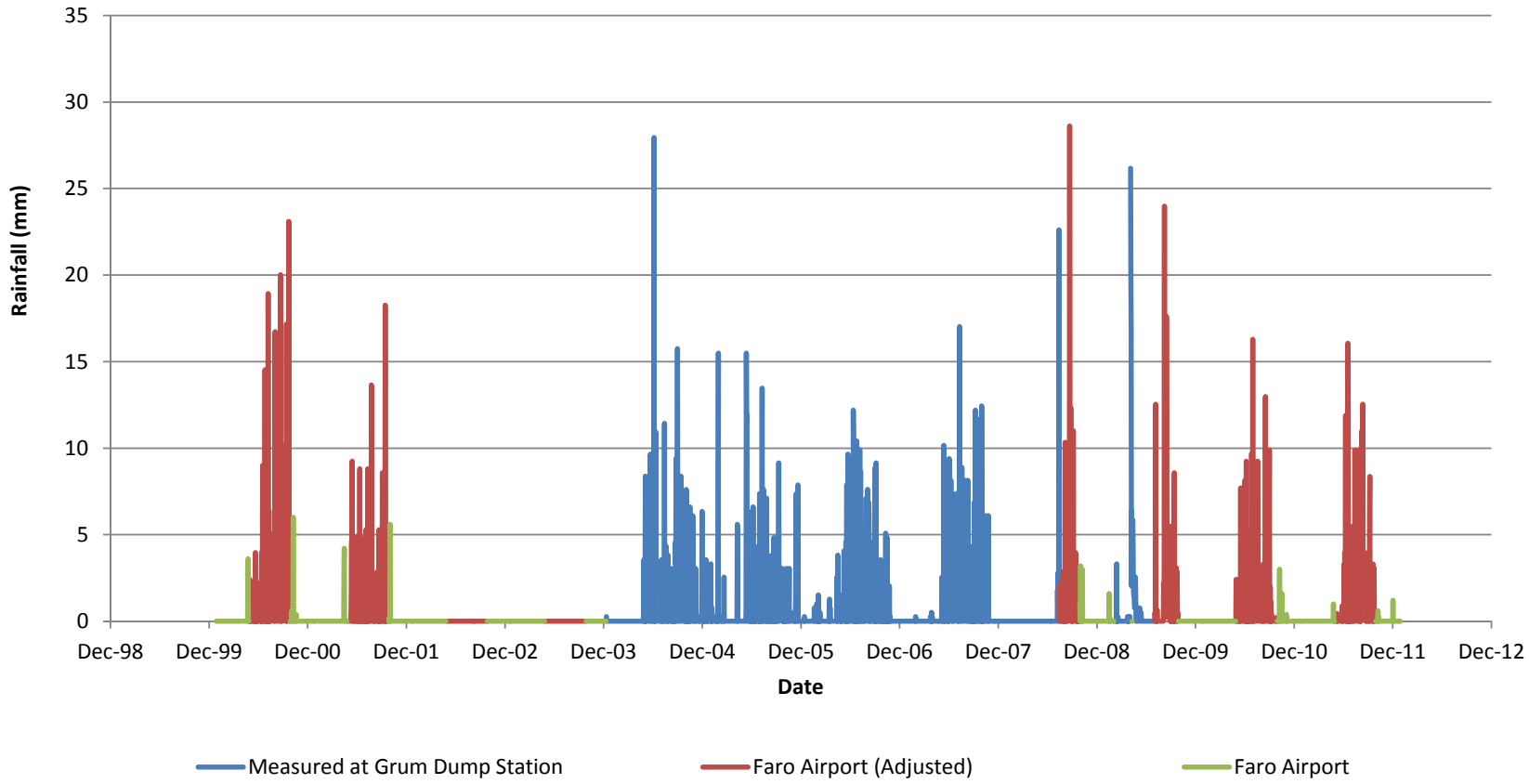


FIGURE 6F-11
Rainfall Record by Data Source – Grum Dump Station
Faro Mine Interim Works

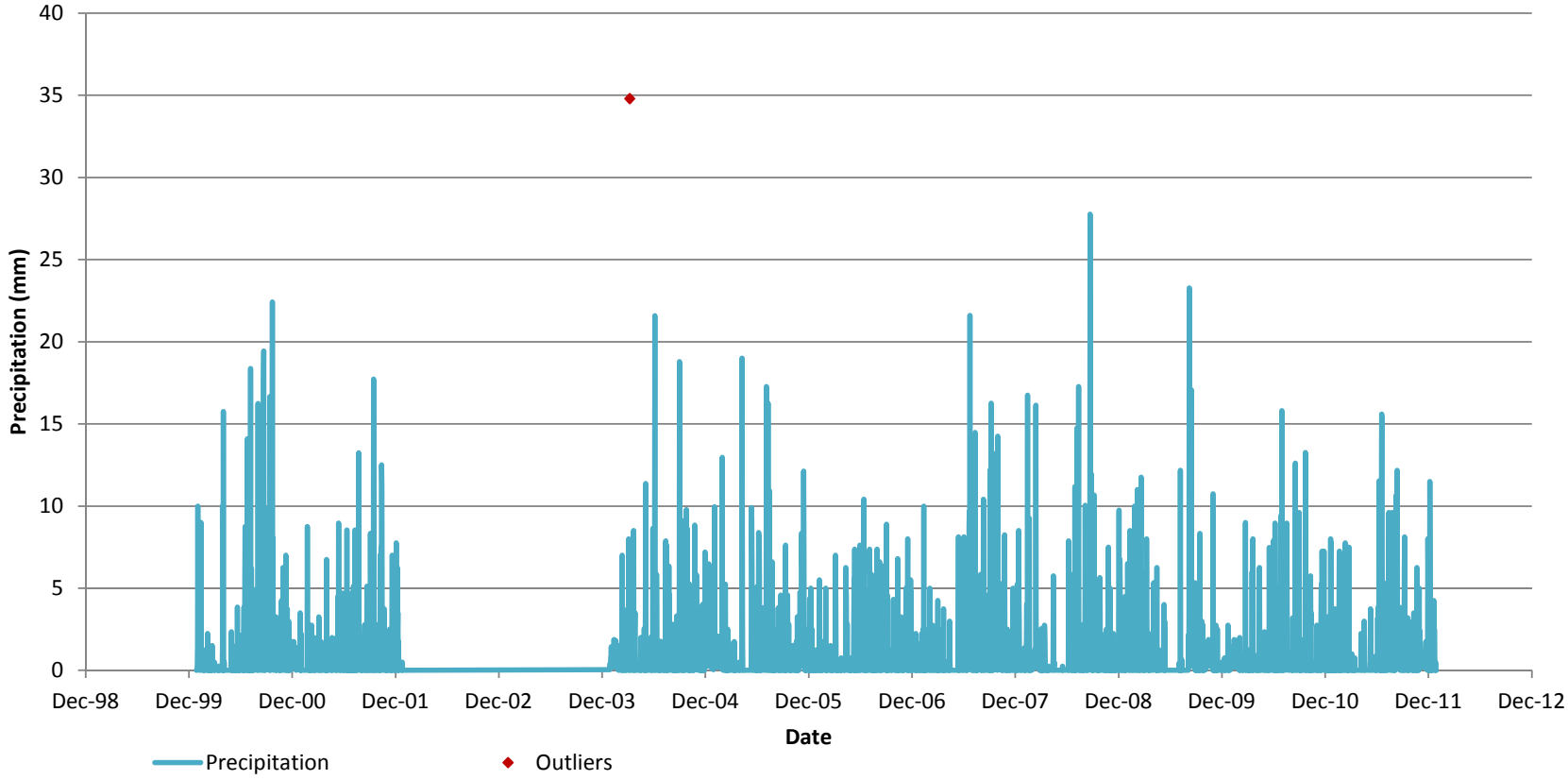


FIGURE 6F-12
Daily Precipitation Estimate – Faro Dump Station Area
Faro Mine Interim Works

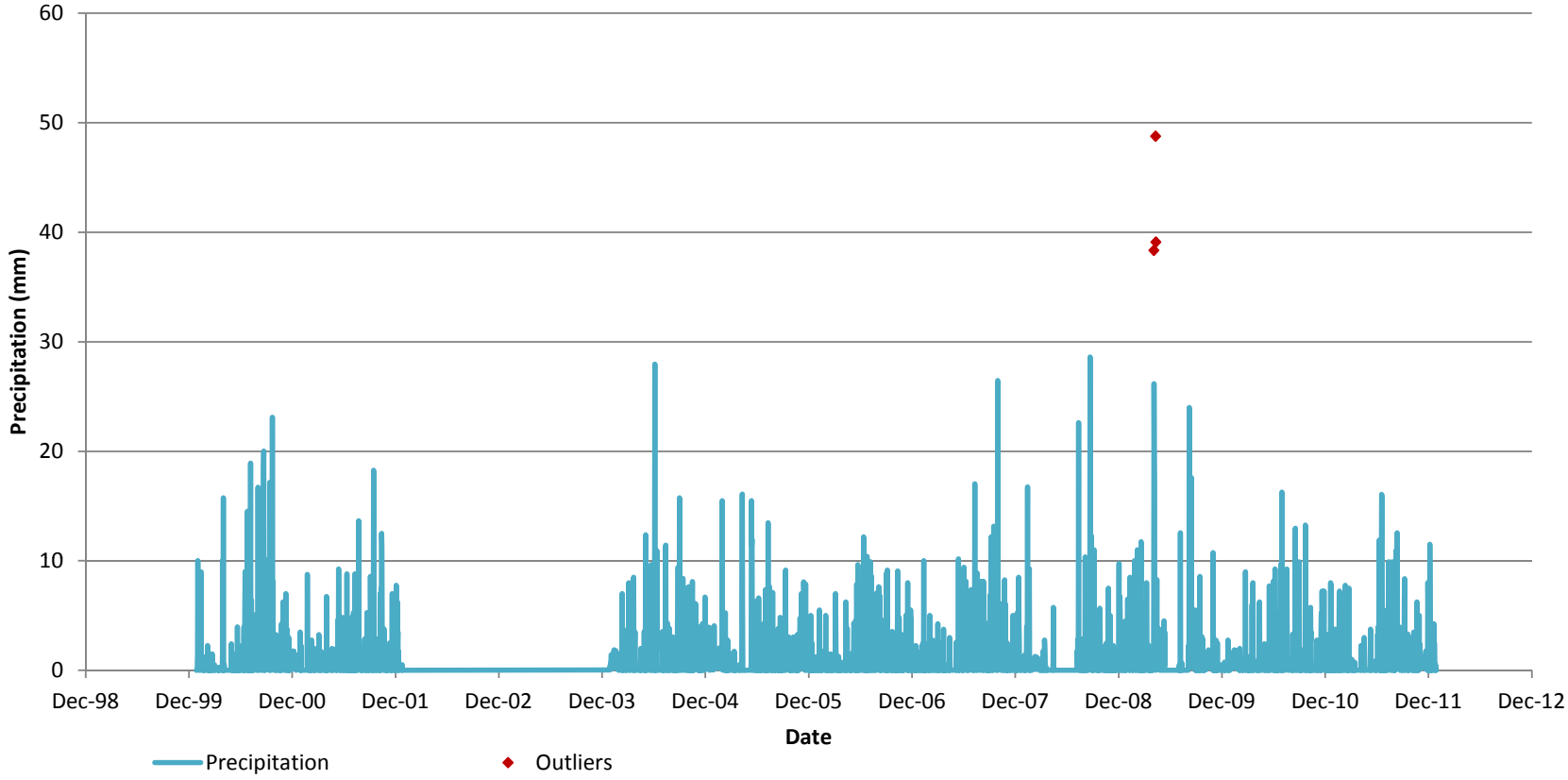


FIGURE 6F-13
Daily Precipitation Estimate – Grum Dump Station Area
Faro Mine Interim Works

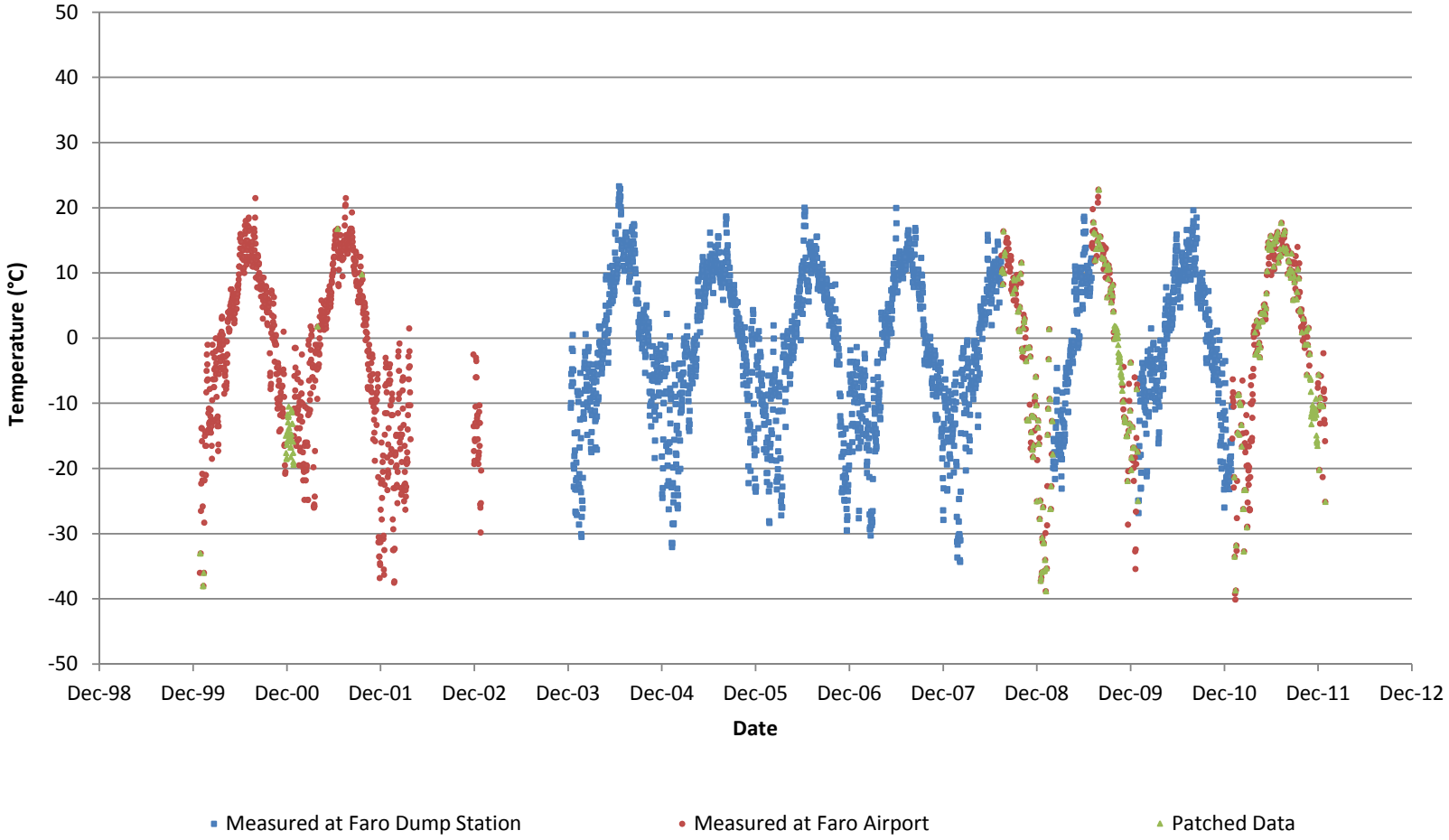


FIGURE 6F-14
Temperature Record by Data Source – Faro Dump Station
Faro Mine Interim Works

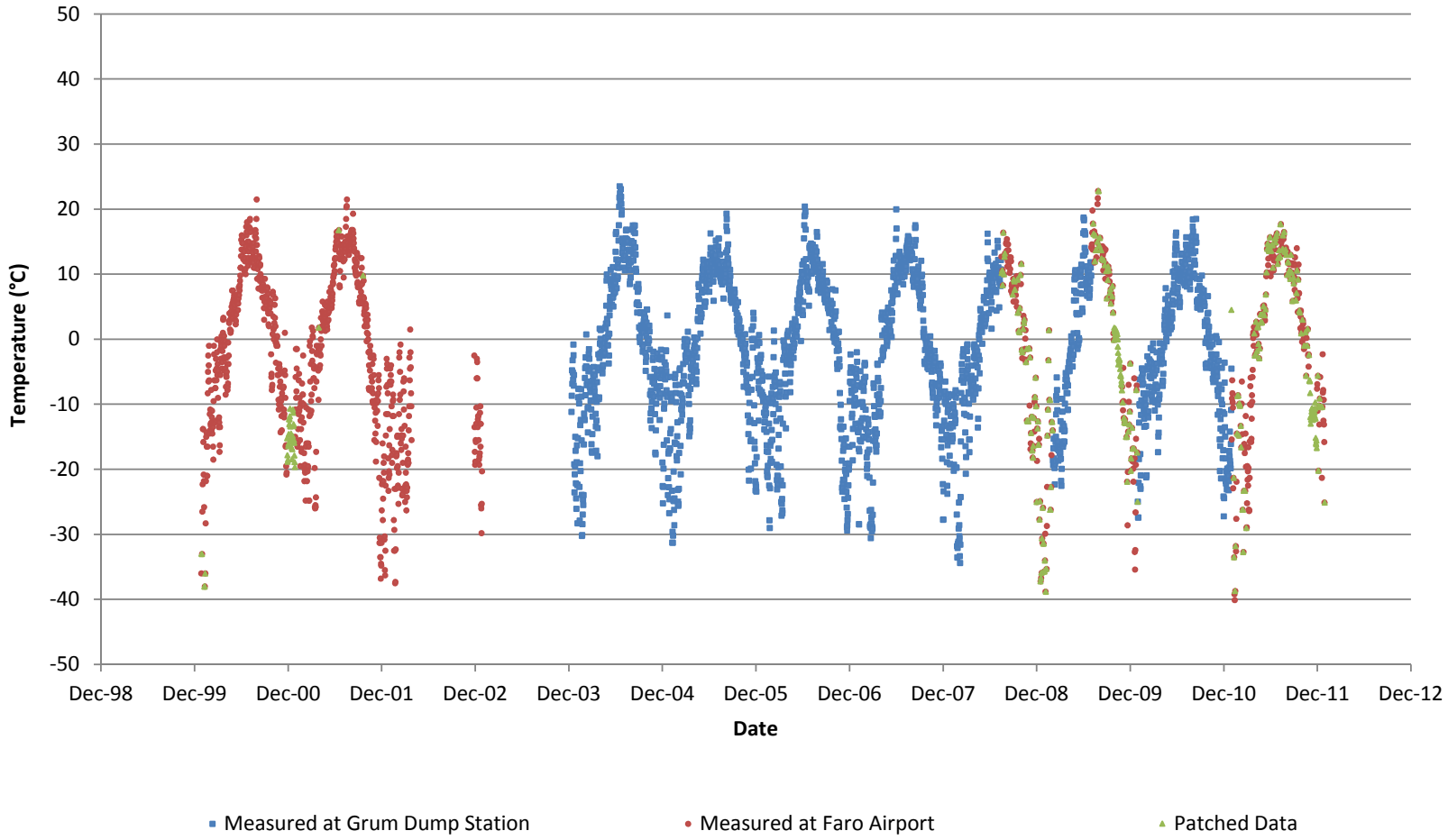


FIGURE 6F-15
Temperature Record by Data Source – Grum Dump Station
Faro Mine Interim Works

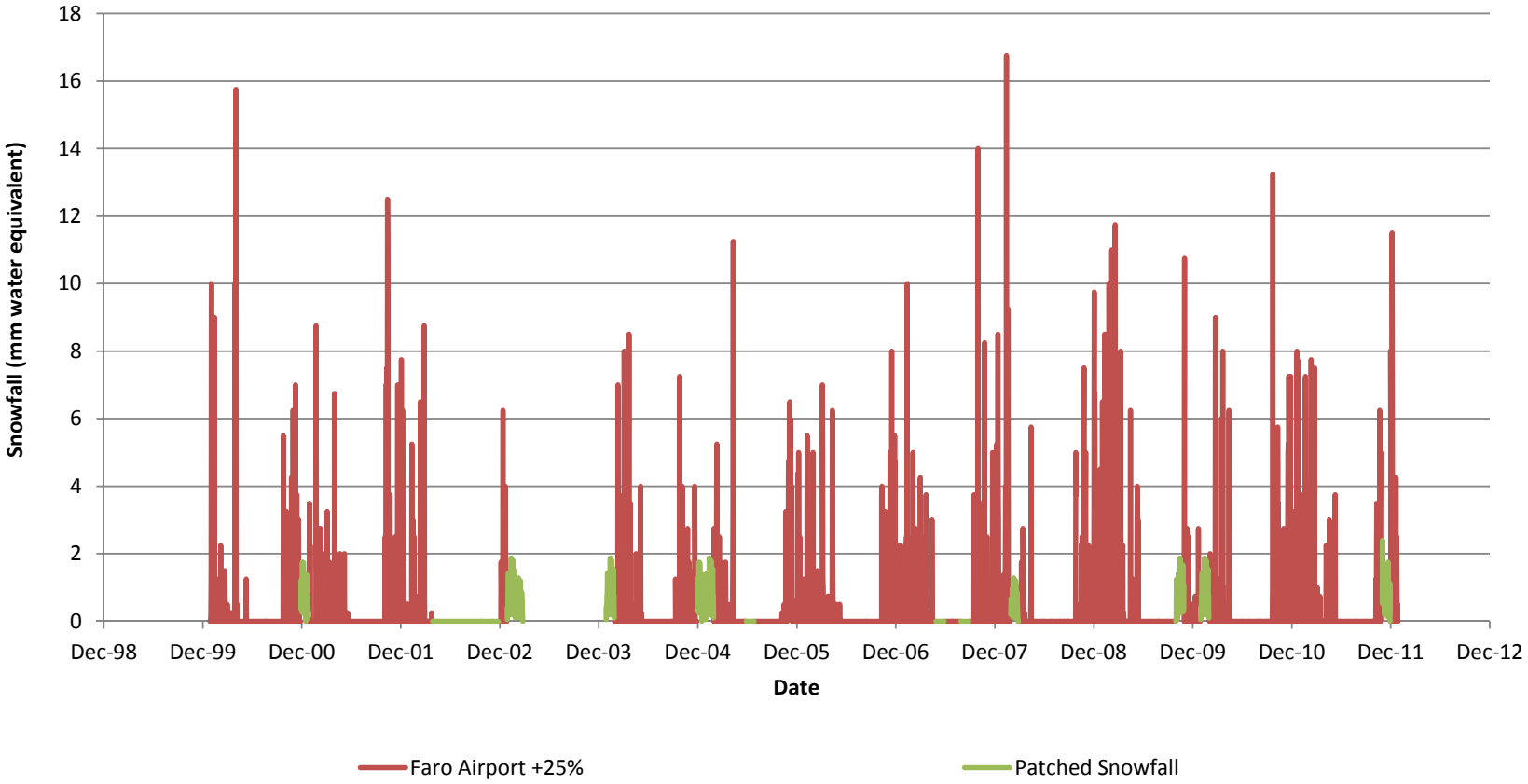


FIGURE 6F-16
Snowfall Estimate – Faro Mine Complex
Faro Mine Interim Works

Attachment 6F-1
Summary of Meteorological Data

TABLE 1
Summary of Meteorological Data Available by Source and Parameter
Faro Mine Interim Works

				Available Data			
Source	**Parameter**	**Units**	**Interval**	**Range**	**% Complete**	**% Complete Years**	**Notable Gaps**
Environment Canada	Data Quality			1977 to 2012	-	-	1977, 2002, 2003
Station: Faro A Lat: 62.21 Long: -133.38 Elevation: 716.6 m	Max Temp	°C	Daily; Hourly	1977 to 2012	84%	32%	
	Max Temp Flag	Flag		1977 to 2012			
	Min Temp	°C		1977 to 2012			
	Min Temp Flag	Flag		1977 to 2012			
	Mean Temp	°C		1977 to 2012		19%	
	Mean Temp Flag	Flag		1977 to 2012			
	Heat Deg Days	°C		1977 to 2012			
	Heat Deg Days Flag	Flag		1977 to 2012			
	Cool Deg Days	°C		1977 to 2012			
	Cool Deg Days Flag	Flag		1977 to 2012			
	Total Rain	mm		1977 to 2012	87%	51%	
	Total Rain Flag	Flag		1977 to 2012			
	Total Snow	cm		1977 to 2012		49%	
	Total Snow Flag	Flag		1977 to 2012			
	Total Precip	mm		1977 to 2012		51%	
	Total Precip Flag	Flag		1977 to 2012			
	Snow on Grnd	cm		1977 to 2012	78%	14%	
	Snow on Grnd Flag	Flag		1977 to 2012			
	Dir of Max Wind Gust)	10s Deg	None	-	0%	0%	
	Spd of Max Wind Gust)	km/h	None	-			

TABLE 1
Summary of Meteorological Data Available by Source and Parameter
Faro Mine Interim Works

Source	Parameter	Units	Interval	Available Data			Notable Gaps
				Range	% Complete	% Complete Years	
Environment Canada	Data Quality			1992 to 2012	-	-	
Faro (AUT) Lat: 62.21 Long: -133.38 Elevation: 716.6 m	Max Temp	°C	Daily; Hourly available by request for 1994	1992 to 2012	88%	29%	1992
	Max Temp Flag	Flag		1992 to 2012			
	Min Temp	°C		1992 to 2012		33%	
	Min Temp Flag	Flag		1992 to 2012			
	Mean Temp	°C		1992 to 2012	87%	29%	
	Mean Temp Flag	Flag		1992 to 2012			
	Heat Deg Days	°C		1992 to 2012			
	Heat Deg Days Flag	Flag		1992 to 2012			
	Cool Deg Days	°C		1992 to 2012			
	Cool Deg Days Flag	Flag		1992 to 2012			
	Total Rain	mm		1992 to 2012	0%	0%	1992 – 2012 (All)
	Total Rain Flag	Flag		1992 to 2012			
	Total Snow	cm		1992 to 2012			
	Total Snow Flag	Flag		1992 to 2012			
	Total Precip	mm		1992 to 2012	37%	0%	1992 – 2012 (All)
	Total Precip Flag	Flag		1992 to 2012			
	Snow on Grnd	cm		1992 to 2012	0%		
	Snow on Grnd Flag	Flag		1992 to 2012			
	Dir of Max Wind Gust)	10s Deg		1992 to 2012	65%	10%	2002 – 2006
	Spd of Max Wind Gust)	km/h		1992 to 2012			

TABLE 1
Summary of Meteorological Data Available by Source and Parameter
Faro Mine Interim Works

				Available Data			
Source	**Parameter**	**Units**	**Interval**	**Range**	**% Complete**	**% Complete Years**	**Notable Gaps**
Faro Mine Site	Air Temperature	°C	Daily to Hourly	2003 to 2008	71%	57%	2003, 2008, 2010
Station: Faro Dump	Relative Humidity	%	At least Hourly	2003 to 2008			2003, 2008, 2009 2010
Elevation: 1,225 m	Wind Velocity	m/s		2003 to 2008			
	Wind Direction	Degrees		2003 to 2008			
	Wind Standard Deviation	Degrees		2003 to 2008			
	Net Radiation	W/m2		2003 to 2008		43%	
	Solar Radiation	kW		2003 to 2008		57%	
	Albedo			2003 to 2008			
	Soil Heat Flux	W/m2		2003 to 2008			
	Soil Temperature 1	°C		2003 to 2008			
	Soil Temperature 2	°C		2003 to 2008			
	Soil Temperature 3	°C		2003 to 2008			
	Soil Moisture	%		2003 to 2008	63%	43%	
	Ave			2003 to 2008			
	Rain	mm		2003 to 2008	71%		
	Snow Water Equivalent	mm		2003 to 2008	6%	0%	
	Snow Depth	m		2003 to 2008	71%	57%	
	Precipitation	mm	Daily to Hourly	2003 to 2008	10%	0%	2003 to 2007

TABLE 1
Summary of Meteorological Data Available by Source and Parameter
Faro Mine Interim Works

				Available Data			
Source	**Parameter**	**Units**	**Interval**	**Range**	**% Complete**	**% Complete Years**	**Notable Gaps**
Faro Mine Site	Air Temperature	°C	Hourly to every 15 minutes	2003 to 2008	72%	50%	2003, 2008, 2010
Station: Grum Dump	Relative Humidity	%		2003 to 2008	71%		2003, 2008, 2009 2010
Elevation: 1,220 m	Wind Velocity	m/s		2003 to 2008			
	Wind Direction	Degrees		2003 to 2008			
	Wind Standard Deviation	Degrees		2003 to 2008			
	Net Radiation	W/m2		2003 to 2008			
	Solar Radiation	kW		2003 to 2008			
	Albedo			2003 to 2008			
	Soil Heat Flux	W/m2		2003 to 2008			
	Soil Temperature 1	°C		2003 to 2008			
	Soil Temperature 2	°C		2003 to 2008			
	Soil Temperature 3	°C		2003 to 2008			
	Soil Moisture	%		2003 to 2008	63%	38%	
	Ave			2003 to 2008			
	Rain	mm		2003 to 2008	71%		
	Snow Water Equivalent	mm		2003 to 2008		0%	
	Snow Depth	m		2003 to 2008		50%	
	Precipitation	mm		2003 to 2008	12%	0%	2003 to 2007

% Complete indicates the number of data points missing over the duration of the data set. % Complete Years indicates the number of years where there is data for each calendar day within a year, this is an indication of the number of years within the data set with data gaps.

Attachment 6F-2
Faro Mine Complex Closure and Reclamation – Project Proposal. Current Environmental Conditions Supporting Document (Hydrology)

3. Water Resources

3.1 Hydrology

3.1.1 Introduction

The Faro Mining Complex is located within the catchments of two right-bank tributaries of the Pelly River: Vangorda Creek and Anvil Creek. The drainage areas of these two tributaries are 91 km^2 and 980 km^2, respectively. The Pelly River controls an area of 22,100 km^2 at a point just downstream of Vangorda Creek. The catchment of this river increases to 23,500 km^2 below the confluence of Anvil Creek and Pelly River. The Vangorda Plateau development is wholly contained within the catchment of Vangorda Creek. The Faro development is located near the geographic centre of the largest tributary of Anvil Creek, namely Rose Creek. A haul road and a mine access road connect the two mine developments, both crossing the drainage divide shared by Vangorda Creek and Rose Creek. Figure 3.1-1 is a small scale map showing the locations of the two mine developments within the catchments of Anvil Creek and Vangorda Creek. Figures 3.1-2 and 3.1-3 are larger scale maps that display the stream network in the immediate vicinity of, respectively, the Faro development and the Vangorda Plateau development.

The objective of this section of the report is to characterize present-day hydrological conditions within the Anvil Creek and Vangorda Creek catchments. As Faro and Vangorda Plateau are existing mines, this characterization must take into account the impact that these two developments have had on surface hydrology. For the most part, this impact is very localized when looked at from a quantity perspective (i.e., in terms of flow rates and volumes). At the mouths of Anvil Creek and Vangorda Creek, the difference in present-day and pre-mining hydrological conditions is practically imperceptible. However, the influence of the mine is significant in the immediate vicinity of the two developments. The mines have impacted the hydrology in a number of different ways. One of these ways is related to the construction of diversion and collection ditches to facilitate the mining of ore and the placement of waste rock and tailings. These ditches had the effect of altering drainage patterns. For example, the development of the Main Pit at Faro required the diversion of the headwaters of Faro Creek. This diversion increased the drainage area of the main tributary of Rose Creek (the North Fork) by some 16 km^2.

The excavation of four open pits at the Faro Mining Complex has also impacted the local hydrology. The pits act as sinks for the groundwater system, locally drawing down water tables and shifting the locations of groundwater divides. Three of the pits contain lakes while the fourth (Zone II Pit) is buried in waste rock. The lakes have locally enhanced evaporation losses.

The tailings deposits and waste dumps have had an important influence on the local hydrology. They contain immense void space that tends to regulate the runoff response from these deposits. In other words, some portion of the runoff that infiltrates into these deposits is temporarily stored within the voids for subsequent release to the receiving streams at a slow rate throughout the year. This is potentially problematic from a water quality perspective because the pattern of releases from the waste rock and tailings is subdued relative to the flow pattern in the receiving streams. This means releases from waste dumps and tailings can be relatively high during periods when the flows in the receiving streams are low, such as winter.

Another influence of the mine developments on surface hydrology is the water management strategy that has been adopted to deal with contaminated drainage at the two mines. This strategy causes an artificial control on the movement and storage of water within the mine developments. For example, contaminated drainage from one of the waste dumps at the Vangorda Plateau development is collected in a small reservoir. This reservoir is normally drawn down once a year, typically during the summer. The collected water is pumped to an open pit, and from there it is delivered to a water treatment plant. Releases from the water treatment plant supplement the flows in Vangorda Creek.

The hydrology of the two mine developments is complex, being influenced by numerous mine elements (e.g., diversion channels, collector ditches, open pits, tailings facilities, and waste dumps) and many individual water management activities (e.g., pumping water to a storage facility, dewatering groundwater systems and operating water treatment plants). To help explain this complexity, flowsheets were prepared to illustrate the generation, movement and storage of water within the mine developments and the associated receiving streams. The flowsheets were made to represent the average conditions in the Vangorda Creek and Anvil Creek catchments during the three-year period from January 2005 to December 2007. Much of the discussion on baseline hydrology is devoted to the development of these flowsheets (see Section 3.1.4). Before these flowsheets could be prepared, it was necessary to characterize key climatic and hydrologic elements, such as evaporation, precipitation and runoff. Section 3.1.3 describes the steps undertaken to characterize these elements. The subsection that follows immediately below lists the data that were available to conduct both the characterization analyses and the reconstruction of the site-wide water balance flowsheets.

3.1.2 Available Data

The hydrology of the Faro Mining Complex was characterized using a mix of regional and site-specific data. Government agencies operate reasonably dense networks of streamflow gauging stations, climate stations and snow courses in the region. The interim receiver and former operators of the Faro Mining Complex have established a network of flow gauging stations within the catchments of Anvil Creek and Vangorda Creek. These stations monitor runoff from catchments ranging in size from 1.8 km^2 to 232 km^2. Most of the stations have been equipped with pressure transducers to provide near-continuous records of water level.

3.1.2.1 Flow Data from Government Agencies

The hydrology of the two mine developments, and their associated receiving streams, was partially characterized using a technique known as Regional Analysis, which entailed developing a set of empirical relationships that could provide flow estimates at ungauged locations. Each empirical relationship relates a flow statistic, such as mean annual runoff, to a catchment physiographic characteristic such as drainage area or catchment elevation. The key input for deriving these relationships was a database of streamflow records representing catchments with a wide range of physiographic characteristics. To locate such data for the analysis, the streamflow monitoring networks of the Water Survey of Canada (WSC) and the Water Resources Branch of Environment Yukon (EY) were searched. This search identified a total of 21 streamflow gauging stations that could provide useful data for the hydrological assessment (18 of which were operated

by the WSC and 3 by EY). Table 3.1-1 provides details of these stations, including their period of record and catchment area. Other information in this table will be discussed below in Section 3.1.3.

The selected WSC and EY stations monitor the runoff from a wide range of drainage areas from 91 km^2 to 49,000 km^2. The periods of record of the stations range from four to 56 years. Over half of the government stations are no longer monitored, most having been closed in the mid-1990's. Their historical streamflow records were, nonetheless, of importance in estimating the site hydrology. Most of the selected stations measure unregulated flows, or flows that have been minimally influenced by human activities.

Two of the government stations listed in Table 3.1-1 were operated on minesite streams. The WSC operated a station on Rose Creek below Faro Creek (Station No. 09BC003) for the period August 1966 to December 1969. This record contained some data gaps. The flows measured at this station were natural up to September 1968 and afterwards were affected by operation of the mine's water supply dam on the South Fork of Rose Creek. EY presently operate a hydrometric station on Vangorda Creek upstream of the Faro Townsite road crossing (Station No. 29BC003). Initially, this station was operated in 1975 and 1976 by a consultant as part of a baseline study for the Vangorda Plateau development. The government then assumed responsibility for this station and operated it from 1977 to present with a three-year break from 1986 to 1988 and a single-year break in 2001. The Vangorda Creek station has only operated during ice-free periods. The locations of Stations 09BC003 and 29BC003 are presented in Figures 3.1-1 and 3.1-2.

3.1.2.2 Flow Data Collected by Site Personnel and Consultants

Over the years since the Faro mine first began operations in the late 1960's, flow data have been collected at over 50 locations within the Anvil Creek and Vangorda Creek catchments. The monitoring effort at these various locations has varied from a few spot measurements to nearly two decades of near-continuous stage measurement. Of all the data collected by site personnel and consultants, the data from a total of 12 stations were of particular importance in characterizing the present-day water balance of the Faro Mining Complex. Table 3.1-2 provides details of these monitoring stations, including period of stage monitoring, drainage area, and number of direct flow measurements made at the site (by bucket and stopwatch, current metering or salt dilution). The first eight stations are located within the Anvil Creek catchment, while the remainder are located within the Vangorda Creek catchment. The locations of the 12 selected monitoring stations are shown on Figures 3.1-1 to 3.1-3. Figures and tables within Sections 3.1.3 and 3.1.4 present the data collected at the 12 stations. In cases where the construction of the present-day water balance only required a subset of the full available record at a station, only the relevant portion of the station's record may be presented in this report.

Data from many of the other locations monitored at the mining complex, and not listed in Table 3.1-2, have played an indirect role in the reconstruction of the Faro Mining Complex historical water balance. For example, many groundwater investigations have been performed over the years and these have provided valuable input to the development of the minesite water balance. Many of these investigations relied on spot flow measurements in local streams, particularly during baseflow conditions, to help characterize groundwater flow rates. Thus, flows collected at sites other than listed in Table 3.1-2 have influenced the understanding that has been developed of the Faro Mining Complex hydrology.

In addition to the flow measurements, the reconstruction of the Faro Mining Complex water balance required information on changes in storage within the various reservoirs at the mine (i.e., the four open pits, Little Creek Dam, and the ponds formed behind the Intermediate Dam and the Cross Valley Dam). At all these reservoirs, site personnel maintain detailed records of water level, often measuring water level at weekly intervals but sometimes as frequently as daily during periods of large water level fluctuation. Since the elevation-capacity relationships for these reservoirs are known to high accuracy, the water level records could be converted into equivalent storage volumes at the end of each calendar month. By taking the difference in storage between successive months, it was possible to estimate net monthly inflows to the reservoirs. This is discussed further in Section 3.1.4.

3.1.2.3 Climate Data

In addition to streamflow data, reliance was also placed on climate data collected by government agencies to help characterize the minesite hydrology. The records from a total of nine climate stations and one snow course were utilized in this hydrology study. These stations are operated by either the Meteorological Service of Canada (MSC) or the Water Resources Branch of Environment Yukon. Table 3.1-3 provides details of all the selected stations, including a listing of the climatic elements that each station provided for the study. Five of the stations are located within or just outside the Anvil Creek and Vangorda Creek catchments (Anvil, Faro Airport, Faro Dump, Grum Dump and Rose Creek). The locations of these five stations are shown on Figures 3.1-1 to 3.1-3.

The Faro Dump and Grum Dump stations provided the most valuable climatic information for the hydrological assessment. The former station is located on the top of the Faro Main Dump at an elevation of approximately 1,225 m. The latter station is located near the eastern edge of the Vangorda Plateau's Grum Dump at an elevation of approximately 1,220 m. The two stations, established in December 2003, are identical in terms of instrumentation and include the following sensors: air temperature, relative humidity, wind speed, wind direction, net radiation, solar radiation, soil temperature (3 levels), soil moisture, rainfall, and snow depth. In February 2008, a weighing precipitation gauge was added to each station, so that precipitation during the winter could be directly measured.

3.1.3 Methods for Estimating Flows at Ungauged Locations

The reconstruction of a minesite water balance requires the evaluation of flow rate at numerous locations. Although the flow monitoring network at the Faro Mining Complex is extensive, it was not practical to measure flow at all the points of interest. Accordingly, techniques had to be developed to estimate flows at the ungauged locations. The two methods adopted for this study, namely climatic water balance and Regional Analysis, are presented below under separate headings. Before the Regional Analysis could be completed, it was necessary to "patch" gaps of missing data in some of the local streamflow records. The methods of making estimates for these missing data are also presented below.

3.1.3.1 Climatic Water Balance

A climatic water balance can provide an indirect estimate of mean annual runoff, as follows:
MAR = MAP – MAET

where: MAR = mean annual runoff;
MAP = mean annual precipitation; and,
MAET = mean annual evapotranspiration (actual, not potential).

All three variables are expressed as depths, usually in units of millimetres. The above equation applies to conditions on a land surface. For a lake, MAET is replaced by the variable MAE, or mean annual lake evaporation.

The methods used to estimate MAP, MAET and MAE are presented below. The application of the climatic water balance to specific points within the Faro Mining Complex is presented in Section 3.1.4.

Precipitation

The distribution of precipitation within a mountainous region tends to vary according to elevation. This observation was exploited to provide a basis for estimating MAP at key locations within the Faro and Vangorda Plateau developments. Figure 3.1-4 presents the analysis undertaken to explore the dependence of MAP on elevation. The data from five local stations, including the two weather stations located on the Faro and Grum waste dumps, were used to develop the relationship.

For the three climate stations not located on waste dumps, the MAP values were simply read from the climate normals published by the MSC (Environment Canada, 2008a). For the two stations on the waste dumps, the data collected at these stations had to undergo initial processing before estimates of MAP could be made. Until recently, the weather stations were not equipped with an instrument that could measure precipitation on a year-round basis. Instead, reliance was placed on two instruments. A tipping bucket rain gauge (equipped with a windshield) was used to measure precipitation during summer, while an acoustic distance sensor was used to measure snow depth. In February 2008, the stations were equipped with a weighing precipitation gauge that should provide reasonably accurate precipitation measurements throughout the year. The records collected at these new instruments were not of sufficient length to be useful at the time this hydrological assessment was prepared.

The tipping bucket rain gauges provided direct measurements of monthly precipitation for the period May to August. For the rest of the year, correlations between the weather station data at the waste dumps and the precipitation record at the Faro Airport were required to estimate monthly precipitation amounts. The analyses essentially involved determining the effects of topography on precipitation during periods of rainfall and snowfall. Figure 3.1-5 examines the orographic effects on rainfall. The top plot on this figure shows the correlation between summer precipitation (mostly rainfall) at the Grum Dump and the coincidental precipitation at the Faro Airport. The middle plot on Figure 3.1-5 shows the same analysis for the Grum Dump weather station. These correlations indicate that the waste dumps tend to receive 7% to 10% more rainfall than does the Faro Airport in the valley bottom.

The top plots on Figures 3.1-6 and 3.1-7 show the observed snow depths at the Faro Dump and Grum Dump weather stations, respectively, for the period December 2003 to July 2008. The water content of the snowpack at the dumps was inferred using data from the closest regional snow course (Rose Creek) and from periodic snow surveys conducted on the mine dumps (see bottom plots of Figures 3.1-6 and 3.1-7). The water contents at late winter were used to estimate orographic effects during snowfall. Table 3.1-4 shows the mechanics of comparing the snowpack contents at the waste dumps with the accumulative winter precipitation at the Faro Airport. The analysis indicates that the dumps receive about 25% more snowfall (as a water equivalent) than does the Faro Airport. This suggests that orographic effects tend to be greater during periods of colder weather.

Table 3.1-5 illustrates how the orographic factors estimated above were used to patch the winter precipitation records (October to April) for the two waste dump stations. When rainfall occurred at the Faro Airport, the Faro Dump was estimated to receive 7% more precipitation than measured at the Faro Airport. The Grum Dump, on the hand, was estimated to receive 10% more rainfall. During periods of snowfall at the Faro Airport, both waste dumps were assumed to receive 25% more snowfall than measured at the airport. The patched winter precipitation values were added to the measured summer precipitation values to arrive at estimates of MAP at the two dump weather stations.

Once the MAP values for all stations were assessed, the next step in the analysis was to develop an empirical relationship between MAP and elevation. The data provided by the five local climate stations were plotted on a graph of MAP versus elevation (see Figure 3.1-4). The data exhibited the expected trend of increasing MAP with elevation but also exhibited significant scatter at the low end of the relationship. A linear regression was fitted to all the data points to provide a means of generating estimates of MAP at ungauged locations. The slope of the regression suggests that MAP increases by an average of 15 mm per 100 m of ascent, at least in the elevational range of 700 m to 1,300 m.

Evaporation

Two rates of evaporation were of interest, namely lake evaporation and actual evapotranspiration. The former refers to evaporation from a free-water surface, while the latter refers to evaporation from a land surface, including transpiration from vegetation. Both rates were estimated using the computer model WREVAP, which was developed by Environment Canada's National Hydrology Research Institute (NHRI, 1985). WREVAP is a semi-empirical, semi-physical model that estimates evaporation from meteorological data (humidity, air temperature and sunshine duration or solar radiation). The model uses different routines to estimate lake evaporation and land evapotranspiration. The lake evaporation routine has been tested against the results of detailed water-budget estimates of 11 lakes in North America and Africa. The evapotranspiration routine has been tested against the long-term water-budget estimates of 143 experimental river watersheds in North America, Ireland, Australia and New Zealand (Morton, 1983).

As indicated in Section 3.2.3, the two dump weather stations monitor the necessary input data for the evaporation model. Accordingly, the WREVAP model was applied to the data sets provided by these two stations. To help detect potential spatial and elevational changes in evaporation rates, the model was also applied to three other climate stations in the Yukon. The results of applying the model to the five stations are presented on Figure 3.1-8. The top plot shows the estimates of average monthly evapotranspiration while the

bottom plot presents estimates of average monthly lake evaporation. The computed mean annual evapotranspiration (MAET) rates for the Faro Dump and Grum Dump weather stations are 229 mm and 246 mm, respectively. These rates are somewhat higher than estimated for the three regional stations, which are all located at lower elevations than the waste dump stations. Three potential reasons are hypothesized for this difference. Firstly, the evapotranspiration rates at the lower stations may be partially limited by availability of moisture, as these stations have lower MAP values than do the dump weather stations. Secondly, the waste dumps may serve to enhance evaporation losses because of the heat generated by the oxidation processes going on within the dumps. Thirdly, the humidity data collected at the waste dump stations may be influenced by evaporation from the nearby pit lakes and, accordingly, the model results may be providing a biased (high) estimate of evaporation from the dump surface.

The computed mean annual lake evaporation (MAE) rates for the Faro Dump and Grum Dump are 472 mm and 484 mm, respectively, or roughly double the corresponding MAET rates. The computed MAE values for the two dump weather stations are similar to the value computed for Mayo Airport and slightly less than the values computed for the two other regional stations.

As partial validation of the lake evaporation values, the bottom plot also shows estimates of lake evaporation for the two closest MSC stations that monitor Class A pan evaporation, namely Whitehorse Airport and Pelly Ranch. The adjusted pan data for these two stations correspond reasonably well with the estimates of lake evaporation provided by the WREVAP model.

3.1.3.2 Patch Missing Streamflow Data

As mentioned in Section 3.1.1, the main method selected for documenting the hydrology of the Faro Mining Complex, and its associated receiving streams, was the development of a historical water balance representing conditions over the recent past (January 2005 to December 2007). To characterize seasonal variations in flow, the historical water balance was constructed on a monthly time step. This necessitated that the flow record for each component of the historical water balance be continuous over the period January 2005 to December 2007. In other words, the average flow for each month in the 36-month study period had to be quantified. Each component of the water balance could be represented solely by measured data, solely by estimated data, or a combination of measured and estimated data. An effort was made to use measured data as much as possible in characterizing the various water balance components. However, few of the records were complete over the 36-month study period and methods were required to patch the gaps of missing data. This section describes how estimates were made for the gaps in the site-specific streamflow records. Development of the Regional Analysis also required the use of patched streamflow records.

The reconstruction of the Faro Mining Complex historical water balance relied heavily on the flow data collected at the following three streamflow gauging stations:

1. R7 – North Fork of Rose Creek above Outlet of Faro Creek Diversion;
2. X14 – Rose Creek below Cross Valley Dam and Rose Creek Diversion Channel; and
3. 29BC003 – Vangorda Creek at Faro Townsite Road.

Stations X14 and 29BC003 were only operated during the open water season over the period January 2005 to December 2007. Although Station R7 was operated year round during this same three-year period, some of the water level data for this station had to be rejected because of backwater effects caused by ice conditions at the gauging site. To provide continuous records of flow over the full three-year study period, the missing data in the records were patched using correlations with a neighbouring WSC station. The independent data used in the correlations for all three minesite stations was provided by the WSC station located on Ross River (09BA001).

Figures 3.1-9, 3.1-11 and 3.1-13 show the correlations used to patch the streamflow records of, respectively, R7, X14 and 29BC003. Figures 3.1-10, 3.1-12 and 3.1-14 present the complete daily flow records for these three stations. Measured data are denoted by blue lines, while patched data are represented by green lines. Tables 3.1-6 and 3.1-7 provide the monthly average flows at R7 and X14, respectively. These tables only present monthly averages for those months with no or very few missing days of measured data.

The streamflow records of Stations X14 and 29BC003 were each patched with a single correlation. These correlations were based only on data collected during the open water season. The tacit assumption was made that these summer correlations were also representative of conditions during the winter. The estimated winter flows for 29BC003 were checked against some direct measurements of flow at Station V8 during winter baseflow conditions in 1992 (see Table 3.1-8). The difference in drainage areas controlled by Stations V8 and 29BC003 is small and, accordingly, the flows at the two stations should be comparable. Examination of the data in Table 3.1-8 suggests that the correlation shown in Figure 3.1-13 may underestimate the true winter baseflows in lower Vangorda Creek. Despite this observation, no adjustment was made to the estimated winter flows at 29BC003 because the accuracy and methodology of the early direct flow measurements at V8 are unknown. Furthermore, two recent spot measurements of flow at V8 in January and February of 2009 suggest that some of the earlier flow measurements at V8 may be overestimating the true baseflow condition (particularly considering that baseflows in 2009 were likely higher than average, given the wet conditions that preceded the 2008/2009 winter).

Numerous direct flow measurements have been made during the winter at Station X14, however most of these were made during periods when the mine was operating and are, therefore, not representative of present-day conditions. The patched winter flows for X14 can be partially validated using the direct flow measurements that were made at X14 just prior to the start of spring freshet in each of the Years 2005, 2006 and 2007 (see bottom plot of Figure 3.1-12). These direct measurements suggest that the patched winter flows for X14 are reasonably accurate. The streamflow record for X14 is not representative of a stationary series because mine operations have had varying degrees of influence on the Rose Creek hydrology over the years. For example, for the period prior to 1993, discharge from the mine's milling facilities represented a large component of the winter baseflows at X14. Up to 2004, the flows at X14 were influenced by the operation of the old water supply reservoir that was located upstream on the South Fork of Rose Creek. Owing to the non-stationarity of the streamflow record, only the 3-year period from 2005 to 2007 was patched. The patched flows for the months February and March 2005 had to be modified to account for controlled releases of water from the Faro Creek Tailings Facility during those months.

The streamflow record of Station R7 was patched using two correlations, one representing open water conditions, and the other representing winter baseflow. The correlation on the bottom plot of Figure 3.1-9

suggests that the winter baseflows at R7 are relatively strong, at least in comparison to the winter flows observed on the large river used as the independent variable in the correlation (Ross River). If the unit baseflows (i.e., discharge per square kilometre) for the two streams were similar, then the slope of the correlation should be similar to the ratio of catchment areas of the two streams (95 km^2/7250 km^2 = 0.0131). However, the actual slope is much higher at 0.0243 which suggests the unit baseflows of the North Fork of Rose Creek are almost double those experienced in the Ross River. The existence of high winter baseflows in the North Fork is advantageous because of the contaminant load this stream receives from the waste dumps that border its lower reach.

3.1.3.3 Regional Analysis

As described in Section 3.1.2.1, Regional Analysis provides a method for estimating flows on streams at locations where no, or minimal, flow measurements have been collected. It involves preparing empirical relationships that relate a hydrological statistic to one or more catchment characteristics. These empirical relationships can be developed to predict any number of hydrological statistics from the 10-year annual minimum 7-day flow to the 200-year peak instantaneous discharge. Two types of hydrological statistics were of prime interest for the baseline hydrology study, namely: mean annual runoff and low flows. The procedures undertaken to derive the Regional Analyses for the two types of hydrological statistics were different, and are therefore described separately.

Mean Annual Runoff

Runoff is defined herein as the portion of precipitation falling on a catchment that is not subsequently evaporated. This excess precipitation is shed from the catchment via three different pathways: overland flow, interflow and groundwater. Runoff values presented in this section do not differentiate between these three pathways, but represent the total of the three components.

Based on the behaviour of precipitation examined in Section 3.1.3.1, mean annual runoff (MAR) would be expected to exhibit a dependence on elevation. The streamflow records collected by government agencies and by site personnel were employed to examine the trend between MAR and elevation. The Regional Analysis presented in this section was originally developed in 1996, as part of the preparatory work leading to the development of the first comprehensive closure plan for the Faro Mining Complex, known as the ICAP (Robertson GeoConsultants Inc., 1996). This section describes the earlier work and then presents site-specific data that were selected to check the accuracy of the original analysis.

Figure 3.1-15 is a reproduction, with a few modifications, of the graph that was used in the ICAP to examine the relationship between MAR and elevation. The vertical axis of this figure displays MAR expressed as an equivalent depth of water (i.e., the average annual runoff volume divided by the contributing catchment area). This is a convenient means of comparing runoff from catchments with vastly different drainage areas. The horizontal axis shows the variable adopted to represent the elevational characteristics of catchments, namely catchment median elevation. Median elevation is defined as the contour that divides a catchment into halves. The following sources of data were assembled to derive a relationship between the two variables on this figure:

- nineteen pairs of MAR and median elevation data provided by regional WSC and EY streamflow gauging stations (as listed in the top two sections of Table 3.1-1); and
- four pairs of MAR and median elevation values provided by four incremental catchments monitored by the WSC (as explained below and identified in the bottom section of Table 3.1-1).

The second source of data is essentially a subset of the first. Where more than one streamflow gauge was located on a river, it was possible to provide a set of MAR and median elevation values for the intervening catchment area between the gauges. For example, the runoff generated by the lower Pelly River catchment was quantified by subtracting the flows measured at Stations 09BB002 and 09BC004 from the coincidental flows at Station 09BC001. The median elevation of this incremental catchment was measured by examining only the area which lies between these three gauging stations.

Once the assembled data were plotted on Figure 3.1-15, a line was drawn through the data that was believed to represent conditions within the Anvil Creek and Vangorda Creek catchments. Positioning of this line turned out to be a reasonably straightforward task because the stations in closest proximity to the Faro Mining Complex all fell within a narrow band on Figure 3.1-15. The labels for the most representative government data are printed in red lettering.

The ICAP recommended using the following four-step algorithm to estimate the long-term average flows of the minesite streams:

- identify a point of interest on a topographic map and then draw the boundary of the catchment controlled by that point;
- measure the drainage area and median elevation of the catchment;
- enter the graph on Figure 3.1-15 at the appropriate value of median elevation and read the corresponding MAR value from the graph's vertical axis; and
- compute the product of MAR and drainage area to estimate the long-term average annual flow for the point of interest. For example, a 50 km^2 catchment with a median elevation of 1,400 m would have an estimated average annual flow of 0.48 m^3/s (i.e., Q = 304 mm/y x 50 km^2 x m/1,000 mm x 10^6 m^2/ km^2 x y/365.25 d x d/24 h x h/3600 s = 0.48 m^3/s).

The accuracy of the empirical relationship between MAR and median elevation was partially tested using streamflow data that has been collected at the Faro Mining Complex since the publication of the ICAP. The test made use of data from four streamflow gauging stations that were not employed in the development of the original relationship. Two of the stations were already introduced in the section above on data patching (X14 and R7). The other two stations are designated FDU and V1 and monitor headwater streams. The former station was established in 2007 just inside the entrance of the Faro Creek Diversion channel and monitors a 14.3 km^2 catchment with a median elevation of 1,530 m. The latter station was established in 2008 above the inlet of the Vangorda Creek Diversion and controls a catchment with drainage area of 18.7 km^2 and median elevation of 1590 m. Figures 3.1-16 and 3.1-17 present the flow data collected at FDU and V1, respectively, since 2008. To obtain estimates of MAR for these two stations, their respective daily flow records were correlated with the coincidental daily flow measurements made at Station R7 on the North Fork of Rose Creek. Given the short periods of overlap, the resulting regression equations could only provide approximate estimates of MAR for FDU and V1.

The pairs of MAR and median elevation data provided by X14, R7, FDU and V1 were superimposed on Figure 3.1-15 (see orange circles). Three of the data points lie fairly close to the original 1996 relationship. The data point provided by V1 lies well above the original MAR-elevation relationship, but this may, at least partially, be the consequence of basing the MAR value on a short period of record. Flow measurements on Vangorda Creek at a location downstream of V1 provide some evidence that the estimated MAR for V1 may be overestimated. Further details on this second set of flow data are provided in Section 3.1.4. The estimated MAR for V1 will improve as more data are collected at this new monitoring station. Taken together, the data provided by the four sets of validation data (X14, R7, FDU and V1) indicate that the original relationship between MAR and median elevation provides a reasonably accurate portrayal of hydrological conditions at the Faro Mining Complex.

As described earlier, reconstruction of the historical water balance for the Faro Mining Complex required the estimation of flows at key locations around the Faro and Vangorda Plateau mine developments for the 36-month period from January 2005 to December 2007. For an ungauged point on a receiving stream, flows were estimated by transposing the measured flow record of a monitoring station, such as R7, to the point of interest. The transposition was accomplished by scaling the measured flow record according to the ratio of estimated mean annual discharges at the ungauged and gauged locations. The estimates of mean annual discharge required for preparing the scaling ratio were derived from the four-step estimation procedure extracted from the ICAP and outlined above.

Low Flow Hydrology

Contaminant concentrations in the receiving streams at and below the Faro Mining Complex tend to be highest during periods of low flow, particularly during the winter months. This is largely due to the mismatch in flow patterns of the sources of contamination (i.e., waste dumps and tailings deposits) and the sources of ambient water (i.e., receiving streams). The flow patterns of runoff from the waste dumps and tailings deposits tend to be subdued relative to the flow patterns of the receiving streams. Because the low flow periods coincide with the highest contaminant concentrations, it was important to develop an understanding of the low flow hydrology of the Anvil Creek and Vangorda Creek catchments. This understanding was largely obtained from the preparation of a Regional Analysis of low flows. This Regional Analysis was similar to the one outlined above for estimating MAR, but had important differences. The main difference involved the use of statistical frequency analysis. The low flow study required frequency analysis whereas the MAR study did not.

A number of different statistics are commonly used to characterize the low flow regime of a stream. To get an overall picture of the range of low flows that can be expected in the local streams, empirical equations are developed in this section to estimate the following six low flow statistics:

- 2-year annual minimum 7-day flow (7Q2);
- 10-year annual minimum 7-day flow (7Q10);
- 50-year annual minimum 7-day flow (7Q50);
- 2-year low annual flow (365Q2);
- 10-year low annual flow (365Q10); and
- 50-year low annual flow (365Q50).

The first three statistics represent the average flow during the lowest part of the annual hydrograph, or more specifically the lowest seven consecutive days. The lowest flows will typically occur in the winter after a prolonged period of freezing. All of the statistics represent thresholds. For the first statistic, it can be expected that there is a 50/50 chance that the 7-day low flow for the upcoming year will drop to or below the flow represented by 7Q2. The second statistic is indicative of moderate drought conditions; the sustained flow of the stream over a 7-day period will only drop to or below this threshold once every ten years, on average. The third statistic is indicative of a severe drought; the flow in a stream is only expected to drop below the 7Q50 level once in every 50 years.

The last three statistics represent the average flow over the entire year. As was done for the 7-day low flows, it was of interest to estimate low annual flows at various degrees of severity (i.e., return periods of twio, ten and 50 years).

Preparation of the Regional Analysis of low flows entailed the following steps:

1) search Water Survey of Canada (WSC) database for streamflow gauging stations that are in reasonably close proximity to the Faro Mining Complex and that have long periods of record;
2) extract annual series of low flow events from the streamflow record of each selected WSC station for durations of seven and 365 consecutive days;
3) fit theoretical frequency distributions to the two annual series to estimate low flows for return periods of two, ten and 50 years; and,
4) identify correlations between low flow and catchment characteristics that could be used to transpose the low flow estimates at the WSC stations to points of interest on the minesite streams.

Table 3.1-9 lists the eleven stations that were selected to perform the Regional Analysis. The table also summarizes the estimated low flow statistics at each station for durations of 7 and 365 consecutive days, and return periods of two to 50 years. To facilitate comparison, the low flows have been expressed as unit discharges in units of L/s/km^2 (i.e., the absolute discharge value has been divided by the contributing catchment area).

Figure 3.1-18 examines potential correlations that can be used to estimate minimum annual 7-day flow flows at ungauged locations. The figure comprises six plots. The ones on the left side of the figure examine the relationship between 7-day low flow and mean annual runoff (expressed as an equivalent depth). The plots on the right examine the relationship between 7-day low flow and drainage area.

Abbreviations are given in the figures to identify the type of flow statistic represented by each plot. Each abbreviation comprises a number, followed by the letter “q”, followed by a second number. The first number denotes the duration of the low flow event in number of consecutive days. For example, the number 7 indicates the low flow event represents the lowest 7 consecutive days in the annual hydrograph. The lower case “q” indicates that the statistic represents a unit discharge. To obtain an absolute discharge, the value must be multiplied by the contributing catchment area. The second number in the abbreviation represents the return period of the low flow event in years.

Figure 3.1-19 explores the relationship between low annual flows, MAR and drainage area. An examination of Figures 3.1-18 and 3.1-19 reveals that drainage area is a poor predictor of how unit low flow varies amongst the eleven WSC stations. Indeed, unit low flow appears to be virtually independent of drainage area, for durations of both 7 days and 365 days. MAR, on the other hand, does help explain at least some of the variation in unit flows across the region. Wetter catchments tend to have higher unit low flows than do drier catchments. The correlations between low flow and MAR are significantly better for the 365-day duration than the 7-day duration. This is expected since MAR and the 365-day low flow events represent the identical duration. Indeed, MAR and 365q2 would represent identical flows if the series of annual flows observed at the WSC stations exactly followed the normal distribution. In reality, the true distribution of annual flow events is usually positively skewed and, therefore, the 365q2 flow rate can be expected to be slightly less than MAR.

The relationships between low flow and MAR presented in Figures 3.1-18 and 3.1-19 produced equations that estimate the low flow events in normalized units (i.e., L/s/km^2). These equations can be altered to predict absolute flow values by multiplying both sides of the equation by catchment area (A). The resulting equations are:

$7Q2 = 0.034\ A\ MAR^{0.605}$
$7Q10 = 0.030\ A\ MAR^{0.553}$
$7Q50 = 0.032\ A\ MAR^{0.481}$
$365Q2 = 0.026\ A\ MAR^{1.034}$
$365Q10 = 0.0081\ A\ MAR^{1.188}$
$365Q50 = 0.0040\ A\ MAR^{1.277}$

where, catchment area A is in km^2, the MAR is in mm and the resulting low flow is in L/s.

3.1.4 Present-Day Water Balance

The baseline hydrology of the Faro Mining Complex was documented by reconstructing the historical water balances of the Anvil Creek and Vangorda Creek catchments. The reconstruction was limited to the period from January 1, 2005 to December 31, 2007 in order to capture a period representative of present-day conditions, prior to implementation of the proposed closure plan. The hydrology of the Faro Mining Complex was reasonably stationary during this three-year period. Earlier years were excluded from the water balance analysis because several significant construction projects had been carried out at the Faro Mining Complex that impacted the surface hydrology, on at least a local level. Prior to 2005, many of the diversions at the two mine developments were upgraded to increase their efficiency, thereby reducing inflows to the open pits. In 2004, a breach was cut into the water supply reservoir, so that the flows in the South Fork of Rose Creek were no longer regulated by this reservoir.

Further construction projects were carried out in the period 2005 to 2007, however, these had relatively minor influences on surface hydrology. These projects were largely aimed at improving water quality. For example, in 2006, a pipeline was installed to convey flows from the Emergency Tailings Area (ETA) to the pond behind the Intermediate Dam. This measure was implemented to improve capture efficiency of contaminated water from the ETA and the waste dumps draining to the remnant Faro Creek channel. In

2007, a ditch was constructed to direct a small seep from the toe of the Grum Dump to an infiltration pond (Moose Pond). These two projects provided important stopgap measures to improve water quality over the short term before the final closure plan can be implemented, but were of little significance in terms of impact on surface hydrology.

For the assessment of the proposed Faro Mining Complex closure plan, baseline conditions refer to conditions as they exist today, not prior to development of the two mine developments. There are many reasons why baseline conditions would be evaluated for an environmental assessment. In the case of the Faro Mining Complex, the need to characterize baseline hydrology conditions was largely driven by the linkages between water quantity and water quality. To accurately predict the water quality that will be achieved with the proposed closure plan, it was important to first characterize the yield and seasonal distribution of runoff from potential contaminant sources, such as open pits, waste dumps and the tailings impoundment. It was equally important to estimate the yield and seasonal distribution of flows within the receiving streams. To capture information on seasonal variations of runoff, both for contaminant sources and receiving streams, the present-day water balance was constructed on a monthly time step.

No significant transfers of water exist between the Faro and Vangorda Plateau developments under present-day conditions. Accordingly, separate water balances were drawn up for the Anvil Creek and Vangorda Creek catchments. In developing the water balances, an attempt was made to use as much measured data as possible. In this regard, the period 2005 to 2007 had high utility because the program of flow monitoring at the mining complex was more extensive in this period than in the past.

3.1.4.1 Anvil Creek Catchment

Flowsheets were used to summarize the overall water balances for the Anvil Creek and Vangorda Creek catchments. The water balances of the Faro and Vangorda Plateau mine developments are complex, comprising numerous elements and flowlines. To ease interpretation of the data, the flowsheets were designed to capture only the most important features of the mine water balances. The flowsheets represent average annual flows under present-day conditions, or more specifically they represent the average of conditions that existed during the three-year period from January 2005 to December 2007.

Figure 3.1-20 presents the flowsheet developed for the Anvil Creek catchment. The flowsheet was designed to allow the reader to quickly identify sources of water contributing to the total flow at four key receiving points within the catchment, namely: North Fork at X2, Rose Creek at X14, Rose Creek at its mouth and Anvil Creek at its mouth. These locations are represented in Figure 3.1-20 as filled circles.

The basic “building block” for the flowsheets was the subcatchment area. To create a representation of the mine development without excessive detail, the Anvil Creek catchment was subdivided into a total of 10 subcatchments. The boundaries of the subcatchments were dictated by the locations of: i) the four key receiving points listed above; ii) diversion channels; and iii) the main mine elements (open pits, waste dumps and tailings impoundment). The boundaries of the 10 subcatchments are outlined on Figures 3.1-1 and 3.1-2. Table 3.1-10 provides details of these subcatchments, including drainage area, catchment median elevation and a preliminary estimate of MAR. This preliminary runoff estimate was derived from the regional relationship between MAR and median elevation presented in Figure 3.1-15. The subcatchments are

represented on the flowsheet as rectangular boxes (see Figure 3.1-20). The subcatchments are labelled with capital letters (A to J) to aid in the cross referencing of figures and tables in this report.

To complete the flowsheet, it was necessary to account for the linkages of flows amongst the subcatchments and the various receiving points. Flowlines on Figure 3.1-20 represent the flow paths judged to be of most importance because they are either associated with a large flow volume or have the potential to convey a large contaminant loading. The number shown on each flowline denotes the average annual flow in m^3/s over the three-year study period.

The estimated average annual runoff generated by each subcatchment over the three-year study period is presented as a number inside the rectangular boxes and is denoted by the variable "R". For the mine elements associated with large storages (i.e., Main Pit, Zone II Pit and the Rose Creek Tailings Facility), the rectangle boxes also include information on the net change in storage over the three-year study period. These net changes in storage are denoted by the variable "ΔS". Both R and ΔS represent the average conditions over the period January 2005 to December 2007 and are expressed in units of m^3/s. A negative value for ΔS indicates that the storage at the end of 2007 was less than the storage at the beginning of 2005.

Flowlines that represent purely groundwater flows are represented on the flowsheets as dashed lines. Solid lines denote all other types of flowlines, including purely surface flow, combinations of surface and groundwater flow, or flow contained in a pipe.

The water balances for specific elements of the Faro mine development are discussed below.

Zone II Pit

A total of four open pits exist within the Faro Mining Complex. The Zone II Pit is the smallest of them and is buried in waste rock.

This section begins by outlining the general approach used to quantify the water balances of all four open pits. It then focuses on the application of the approach to the Zone II Pit. The emphasis of the analyses for all four open pits was to estimate the seasonal pattern of inflows to the pits. This was achieved by applying the continuity equation, which can be written as:

$$I - O = \Delta S$$

where: I = total inflows to pit, including direct precipitation on pit lake, local runoff from area above pit lake and below diversions, groundwater and ditch leakage from catchments controlled by diversions and flows pumped from elsewhere in minesite;

O = total outflows from pit, including direct evaporation from pit lake, groundwater seepage and withdrawals via pumps; and,

ΔS = change in storage within the pit.

As indicated above, the water balance of an open pit can comprise numerous individual components. For the purpose of the historical water balance, it was not necessary to track all the components separately. Instead, many of the inflow and outflow components related to natural processes could be lumped together and represented as a single variable in the water balance. This variable is referred to herein as "net" inflow. It was assumed to represent the combination of three inflow components (direct precipitation on pit lake, local runoff between lake and diversion ditch, and groundwater originating from the catchment of the diversion ditch) minus two outflow components (direct evaporation from pit lake and groundwater seepage from pit). Other slight modifications to the general form of the continuity equation were required to account for special conditions that existed at some of the pits.

Site personnel kept detailed records of pit water level throughout the three-year period of interest. As a result, the net inflow rates to the open pit could be estimated with good accuracy, particularly during periods devoid of pit dewatering. The pits, in effect, acted as giant bucket and stopwatch measurements. The height-capacity curves for the pits are known and, therefore, the pit water level records could be converted into accurate estimates of equivalent storage. The pit water levels were often measured at the end of the month. In cases where this did not happen, the frequency of measurements was sufficient that linear interpolation could be used to provide a reliable estimate of the end-of-the-month water level. Based on the collected water level records, accurate estimates of monthly change in storage (ΔS) could be estimated for the 36 months adopted for the historical water balance reconstructions.

Figure 3.1-21 illustrates the reconstruction of the Zone II Pit water balance for the period January 2005 to December 2007. Since this open pit is buried in waste rock, fluctuations in storage occur within the voids of the waste rock. As a result, a slight modification was required to the method outlined above for estimating pit storage changes. The estimates generated from the height-capacity curve of the un-buried open pit were multiplied by an assumed constant fraction to estimate true fluctuations in water storage. The value of this fraction is known as the drainable porosity and can be interpreted roughly as the difference between total porosity and field capacity (i.e., the portion of water contained in voids that quickly drains by gravity from saturated waste rock as the groundwater table drops below the waste rock).

The top plot on Figure 3.1-21 presents the observed water level record within the pit, as measured from a well. The middle plot shows the measured amount of water pumped from the pit and discharged to the Main Pit. The record of pit dewatering is believed to be reasonably accurate and is based on a record of pump hours and known pump capacity.

The bottom plot shows the estimated monthly net inflows to the pit, as computed by application of the continuity equation (i.e., change in pit storage + measured pit dewatering). To prevent the calculation of negative inflow rates, a relatively small value of drainable porosity (10%) had to be adopted.

The average annual net inflow to the Zone II Pit is approximately 50,000 m^3. To reduce inflows to the Zone II Pit, an interceptor ditch (now buried) was constructed along a portion of the northern perimeter of the pit. This interceptor ditch defines a portion of the boundary of the catchment controlled by the Zone II Pit. The drainage area of the pit's catchment is approximately 0.33 km^2. Based on this catchment area, the 50,000 m^3 inflow is equivalent to a depth of 151 mm. If seepage losses from the Zone II Pit are negligible and the only source of inflows is precipitation falling on the pit's catchment, then the average annual yield of the waste

dump overlying the pit is about 151 mm. The true yield of the waste dump is less than 151 mm because the pit undoubtedly receives a portion of its inflows from groundwater originating from outside the 0.33 km^2 catchment area. This groundwater probably has two main components: i) leakage from the interceptor ditch; and ii) groundwater from areas northeast of the pit that passes below the interceptor ditch. Seepage from the Main Pit is another potential source of water for the Zone II Pit.

A groundwater study was undertaken in 2005 to estimate seepage from the Zone II Pit to the North Fork of Rose Creek (SRK, 2007a). Two estimates of seepage were made in the SRK report, one using Darcy's Law and the other using a chemical load balance in the portion of the North Fork valley alluvium adjacent to the Zone II Pit. The higher of the two estimates, provided by the former method, was used to represent conditions in the reconstructed water balance (see Figure 3.1-20). The low estimate of seepage is a quarter of the high estimate.

Main Pit

Figure 3.1-22 presents the water balance for the Main Pit for the 3-year study period. Unlike the Zone II Pit, the pit dewatering record could not be accurately estimated from pump records. Despite this, an accurate portrayal of the pit's water balance could still be developed. The main reason for this is that, in the months in which pit dewatering was undertaken, the resulting withdrawals represented the dominant component of the water balance. Thus, the change in pit storage during the month represented a large proportion of the total water pumped from the pit.

The accuracy of the water balance was improved by developing a correlation between pit inflows and the monthly flow at Station R7 on the North Fork of Rose Creek. Only inflow rates for months devoid of pit dewatering were used in the preparation of the correlation (not shown).

Preparation of the Main Pit water balance involved five main steps. Firstly, the observed pit water levels were converted into equivalent storage volumes. Secondly, the net inflows to the open pit during months without dewatering activities were estimated. This was simply done by setting the net monthly inflow for a given month equal to the change in pit storage during that month (i.e., with no outflow, inflows equal change in storage). Thirdly, the correlation mentioned above between pit inflow rate and R7 monthly average flow was derived. Fourthly, the correlation was used to estimate net inflows during periods when the pit was being dewatered (see bottom plot of Figure 3.1-22). Finally, the record of flows pumped to the Faro water treatment system was estimated by application of the continuity equation (i.e., net monthly inflow + pumped inflows from Zone II Pit - monthly change in storage). The middle plot of Figure 3.1-22 presents the estimated pit dewatering record.

The estimated average annual inflow to the Main Pit is 1.44 million m^3, excluding the small contribution from the Zone II Pit dewatering. The inflows to the Main Pit are subdued, with the average flow during the highest month (typically May) being only about three times greater than the average flow during the lowest month (typically February or March).

Faro Waste Dumps

A variety of techniques were used to estimate the amount of runoff emanating from the waste dumps at both the Faro and the Vangorda Plateau mine developments.

The most direct measurement of waste dump runoff was made for the Faro Waste Dumps overlying the old Faro Creek Channel downstream of the Main Pit. A triangular weir was established in the old Faro Creek channel some 600 m downstream of the toe of the Main Waste Dump in the fall of 2005. Owing to its location at the mouth of a small canyon, the flow of groundwater in the alluvium below the weir is probably minimal. If the groundwater bypass is indeed small, then the weir captures a very high proportion of the yield generated by the waste dumps overlying the old Faro Creek Channel. The station, designated FCS-4, was operated for just over a year. The flow record for the station is of high quality because validation data (such as staff gauge readings and bucket and stopwatch measurements) were collected on a frequent basis during the weir's operating period, including winter months. Figure 3.1-23 presents the complete stage and flow records collected at the weir. Several of the flow spikes shown in the record are due to short duration releases from the Faro water treatment system.

The reconstruction of the historical water balance required the preparation of a monthly dump release record that spanned the full period from January 2005 to December 2007. For the period October 2005 to September 2006, this was achieved by computing average monthly discharges from the observed flows at the FCS-4 weir. Before computing the monthly averages, the effect of three short-duration releases from the Faro water treatment system were removed from the record. To estimate missing data in the remainder of the three-year study period, a correlation was developed between monthly average flows at FCS-4 and coincidental monthly average flows at Station R7 on the North Fork (not shown). Figure 3.1-24 presents the resulting patched record of flows attributed to releases from the waste dumps overlying the old Faro Creek channel.

The average flow measured at FCS-4, excluding small contributions related to releases from the Faro water treatment plant, is 5.6 L/s. Using pre-mining topography as a guide for the placement of the station's catchment boundary, the drainage area controlled by FCS-4 was estimated to be 1.8 km^2. If the groundwater flow below the FCS-4 weir is indeed small, then the measured flow suggests that the average annual yield of the waste dumps overlying the old Faro Creek channel is about 98 mm. This measured yield can be compared against a climatic water balance prepared at the weather station operated on the Main Waste Dump. Given an estimated MAP of 357 mm and an estimated MAET of 229 mm, the climatic water balance indicates the average annual yield of the waste dumps should be approximately 128 mm (i.e., the difference between MAP and MAET). Three hypotheses are offered to explain the discrepancy in the two estimates. Firstly, the difference may be due to slight inaccuracies in the estimates of MAP and MAET. Secondly, the difference may be real, which could suggest that the waste dumps are still wetting up and have not yet reached their ultimate water content. Thirdly, a significant amount of groundwater may actually bypass the FCS-4 weir.

Weir FCS-4 captures much of the waste dump drainage that enters Rose Creek between water quality stations X2 and X14. To estimate drainage from waste dumps draining to the North Fork above X2, a two-

component mixing model was utilized. The model is a simultaneous solution of the following two conservation of mass equations:

QB + QD = QR

QB CB + QD CD = QR CR

where: QB = discharge from background source of water;
QD = discharge from waste dumps;
QR = discharge at water quality station in receiving stream;
CB = background concentration of tracer;
QD = concentration of tracer in discharge from waste dumps; and,
CR = concentration of tracer at water quality monitoring station.

The mixing model comprises six variables and two equations. Accordingly, if four of the variables are known (either measured or estimated), then the model can estimate the magnitude of the remaining two variables. For this application, the unknowns were QB and QD.

Dissolved sulphate was used as the tracer in the calculations. Background concentrations were based on sulphate measurements at R7, which samples a very high percentage of the background source of water (i.e., a high percentage of water that flows past X2 that is not related to the waste dumps). Table 3.1-11 documents the steps undertaken to estimate the flow-weighted average sulphate concentration of waste dump drainage.

The flows at the water quality monitoring station (QR) were estimated by transposing the monthly streamflow record for Station R7 downstream to the location of Station X2. This was accomplished by scaling the flows at R7 by the ratio of estimated average annual flows at the two stations. A scaling factor of 1.2 was adopted, based on the estimation procedure set out in Section 1.3.3.1. A check on the magnitude of the scaling factor was made using a series of spot flow measurements that have been made at X2. A correlation between these spot measurements and the coincidental flows at R7 (based on water level readings) suggested that the true scaling factor could be less than the adopted value (see top plot on Figure 3.1-25). An alternative explanation is that the adopted scaling factor is accurate and a significant amount of the North Fork flow is passing below Station X2 in the valley alluvium.

The results of applying the two-component model at X2 are illustrated in Figure 3.1-26. The estimated average annual flow from the waste dumps to the North Fork above X2 is 4.7 L/s, or 120 mm when expressed as an equivalent depth over the year. The estimated yield of the waste dumps bordering the North Fork of Rose Creek is similar to the estimated yield of the waste dumps overlying the remnant Faro Creek channel. As can be seen by referencing Figures 3.1-24 and 26, outflows from the Faro Waste Dumps are significantly attenuated. Releases from the waste dumps remain high during winter months, when flows in the receiving streams are at their lowest.

Tailings Impoundment

The water balance of the Rose Creek Tailings Facility (RCTF) comprises a large number of inflow and outflow components. The magnitude of the outflow components and some of the inflow components are known to reasonably high levels of accuracy. The largest unknown in the water balance is the magnitude and seasonal distribution of groundwater inflows to the RCTF. This analysis was aimed at improving the estimates of groundwater inflows to the tailings impoundment. To facilitate the analysis, the entire RCTF and its underlying valley aquifer were treated together as a single black box. The main outflows from this black box comprise:

- siphoned flows from the Cross Valley Dam (CVD);
- groundwater in the underlying aquifer that discharges to surface between the CVD and X14; and,
- groundwater in the underlying aquifer that remains in the alluvium at Station X14.

The sum of the last two components represents the total flow in the valley aquifer at a point below the CVD (and includes seepage through the CVD). As will be discussed later, studies have shown that the valley aquifer experiences zones of both discharge and recharge in the reach of the Rose Creek valley between the CVD and X14. As a result, the third outflow component listed above represents only a small portion of the total flow in the alluvium below X14.

The main inflow streams to the black box are:

- dewatering of Main Pit (after first being treated in the Faro water treatment facility);
- runoff from the Main Waste Dump and parts of the Intermediate and Northwest Waste Dumps;
- local runoff from incremental catchment of the RCTF, defined as area above the CVD and below the waste dumps, the Rose Creek Diversion Channel (RCDC) and the North Wall Interceptor Ditch (NWID);
- leakage from the RCDC and the NWID;
- groundwater originating on the south valley slope that passes under the RCDC;
- groundwater originating on the north valley slope that passes under the NWID; and,
- groundwater in the valley aquifer just upstream of the tailings facility.

Insufficient data are available to accurately estimate the magnitude of the last four components individually. However, the analysis undertaken here was adequate to provide a reasonably accurate estimate of the sum of the four groundwater components.

The final component of the water balance that had to be considered was storage, or more specifically monthly changes in that storage. The black box contains essentially three storages: the polishing pond behind the CVD, the pond behind the Intermediate Dam and the void spaces within the deposited tailings and the valley aquifer sediments. Site personnel maintained detailed records of water level in the two ponds, so the changes in storage within these ponds could be estimated with a high degree of accuracy. However, insufficient data were available to estimate changes in storage within the voids of tailings and alluvial sediment. The implicit assumption was made that changes in storages within the voids was negligible.

Three sources of information were used to estimate the magnitude of the outflow streams from the RCTF and its underlying aquifer. The first source was detailed records collected by site personnel on the siphon operation. These records included information on operating period, percentage opening of valve, CVD pond level and periodic current meterings of flow in channel just downstream of siphon outlet. Figure 3.1-27 presents the processed flow record for the siphon. Using the information assembled by site personnel, an empirical relationship was developed relating release from the siphon to the available hydraulic head and the percentage opening of the control valve. The hydraulic head was computed as the difference between the pond surface elevation and the elevation of the siphon's outlet. The top plot on Figure 3.1-27 shows the water level record for the pond from January 2005 to December 2007. The middle plot shows the estimated monthly outflows from the siphon based on the empirical relationship developed between discharge, hydraulic head and valve opening.

Two tests were conducted to assess the accuracy of the computed siphon flows. Firstly, a theoretical rating curve was prepared for the siphon for the case of the valve being wide open (based on pipe hydraulics). This suggested that the empirical relationship was probably overestimating the true discharge rates by about 23% when the siphon is operated with a wide-open valve. Secondly, the computed monthly withdrawals were compared with the corresponding drawdowns in the CVD pond, particularly during periods of known low inflow to the pond. This second test also indicated that the empirical relationship probably overestimates the true release rate from the CVD pond. To account for the probable overestimation, the flows generated by the empirical relationship were subsequently multiplied by a factor of 1/1.23 (i.e., they were reduced by 23% to make them consistent with the theoretical rating curve for the siphon). The corrected flows are presented in the bottom plot of Figure 3.1-27.

The second source of information for assessing outflows from the RCTF was a record of flows at a rectangular weir, known as X13, located some 100 m downstream of the toe of the CVD. The main source of water measured at this weir is discharge from the valley aquifer in the area between the CVD and X13. Figure 3.1-28 presents the stage and flow records for Station X13 for the three-year study period.

The final source of information for assessing RCTF outflows was a study entitled "Water and Load Balance Study for Rose Creek Tailings Storage Facility" (Robertson GeoConsultants Inc., 2005). This study interpreted flow and chemistry data collected during a synoptic field survey in October 2004. This synoptic study was conducted during stable low flow conditions. The following key information was extracted from the Robertson GeoConsultants Inc. report as it relates to the RCTF water balance:

- The valley aquifer continues to discharge to surface downstream of Station X13. During the October 2004 field trip, the discharge between X13 and the outlet of the RCDC was approximately 51 L/s.
- Based on interpretation of the October 2004 data, the groundwater flow in the aquifer below the CVD was approximately 107 L/s. Of this amount, approximately 24 L/s was estimated to remain in the valley aquifer at Station X14.

A range of techniques were used to estimate the inflow streams to the RCTF (including its underlying aquifer). The water balance work for the Main Pit was used to estimate the inflows from the combined dewatering of this pit and the Zone II Pit. The analysis of flows at Station FCS-4 was used to quantify inflows from the waste dumps. The flows at FCS-4 were scaled by a factor of 1.2 to account for waste dumps that

drain to the RCTF but are outside the drainage area controlled by Station FCS-4. The factor 1.2 is the estimated ratio of the planimetric area of waste dumps in the RCTF catchment to the drainage area of FCS-4.

The local runoff generated by the incremental catchment of RCTF below the waste dumps is a relatively small component. Its magnitude was estimated to be 2% of the flows measured at Station R7, based on ratio of estimated average annual flows of the RCTF incremental catchment and the R7 catchment. The Regional Analysis described in Section 3.1.3.3 was used to estimate the average annual flows for these two catchments.

The combined groundwater inflow to the RCTF (including its underlying valley aquifer) was estimated by the application of the continuity equation. Figure 3.1-29 illustrates the mechanics of applying the continuity equation. The top plot on this figure shows the combined storage of the ponds behind the CVD and Intermediate Dam. The second plot shows the monthly record of estimated combined outflows from the RCTF. The third plot presents the combined surface inflows to the RCTF, which are largely all measured. The bottom plot shows the estimated total groundwater inflows, as computed by the continuity equation (i.e., total groundwater outflows + total surface outflows + change in storage - total surface inflows). The computed groundwater inflows represent water that either recharges the underlying aquifer or eventually surfaces at the ponds. It should be noted that these estimates of groundwater inflow contain the net error in the estimates of the other components of the water balance. This error includes the storage fluctuations that occurred within the voids of the deposited tailings and the sediment of the underlying aquifer over the three-year study period. As mentioned earlier, the storage within voids was not explicitly accounted for in the water balance analysis.

The estimated average annual groundwater inflow to the RCTF and its underlying aquifer is 148 L/s. The estimated average annual inflow from all other sources (waste dumps, local runoff on incremental catchment of RCTF and dewatering of the two open pits) is 76 L/s, or about half the input from groundwater sources.

Diversions

The Faro mine development contains four main diversions. The Faro Valley Interceptor Ditch (FVID) and the Faro Creek Diversion (FCD) were constructed to facilitate development of the Main Pit. The North Wall Interceptor Ditch (NWID) and the Rose Creek Diversion (RCD) were constructed to allow the construction of the tailings impoundment within the Rose Creek valley.

Leakages from the FVID and FCD represent a significant component of the total inflow to the Main Pit. Leakage, as defined herein, encompasses water that infiltrates the bottom and sides of a ditch, together with groundwater that originates within the ditch's catchment that subsequently flows below the ditch. The combined leakage from the FVID and FCD was estimated indirectly by subtracting local runoff generated by the Main Pit's incremental catchment from the total inflow to the pit (but excluding contribution from the Zone II Pit). The local runoff comprises net precipitation on the pit's lake and runoff generated by the area above the lake and below the two ditches. The magnitude of the local runoff was estimated using the estimation techniques described in Sections 3.1.3.1 and 3.1.3.3. The estimated average annual combined leakage from the two ditches worked out to about 34 L/s, or about 20% of the total runoff generated by the catchments

controlled by the two ditches. Expressed another way, the FVID and FCD have a combined efficiency of 80%.

Insufficient data were available to estimate the efficiencies of the NWID and the RCD. As determined in the previous section, the total average groundwater inflow to the Rose Creek Tailings Facility and its underlying aquifer is substantial at 148 L/s. Owing to the large size of catchments controlled by the NWID and particularly the RCD, leakages from these two diversions must contribute a sizable proportion of the 148 L/s groundwater inflow.

Receiving Streams

The flows in the receiving streams were estimated using the records of two long-term streamflow gauging stations at the Faro mine development, namely R7 and X14. The former station is representative of natural conditions, unaffected by mining operations. The latter is located on Rose Creek downstream of all mine development and, accordingly, has been influenced to some degree by the Faro mine.

These two streamflow records were employed in two different ways to estimate the monthly flow record at ungauged locations for the period from January 2005 to December 2007. The method used in all but one case involved transposing the R7 flow record to the point of interest. The transposition was achieved by scaling the R7 flows according to the ratio of average annual flow at the point of interest to the average annual flow at R7. The estimates of average annual flow were obtained from the regional relationship between MAR and median elevation presented in Figure 3.1-15. This technique was used to characterize the runoff generated by Subcatchments A, B, I and J on Figure 3.1-20. Station R7 controls a large proportion of Subcatchment B.

Subcatchment G represents a substantial proportion of the intervening catchment between Stations R7 and X14. Accordingly, as a first approximation, the difference in flows at the two stations could be used to represent the runoff generated by Subcatchment G. This first approximation was improved by subtracting contributions from the mine development that enter the Rose Creek system between R7 and X14. Two checks were made on the estimated flow record for Subcatchment G. Figure 3.1-30 presents the results of the first check. The red line represents the flow record adopted for the historical water balance. The blue line shows what the flow record would have been if the method adopted for Subcatchments A, B, I and J had been applied (i.e., transposition of the R7 flow record). Except for May 2005, the two techniques provide similar estimates of monthly flow for Subcatchment G.

The second check made use of a series of direct flow measurements made at the inlet of the Rose Creek Diversion Channel (RCDC). This point gauges a substantial proportion of the flow generated by Subcatchment G combined with the flows from the North Fork of Rose Creek. The flow measurements at the diversion inlet were correlated with the coincidental flows at Station R7 (see bottom plot of Figure 3.1-25). This correlation suggests that the flows at the inlet of the RCDC should be approximately 2.19 times greater than the flows measured at R7. The adopted method for estimating Subcatchment G flows result in flows at the entrance to the RCDC that are in reasonably close agreement with the correlation presented in Figure 3.1-25.

As described in Section 3.1.4.1, an interpretation of a synoptic field investigation in October 2004 (Robertson GeoConsultants Inc., 2005) was used to estimate some of the outflow components for the RCTF water balance. This same investigation also provided important information on groundwater conditions at Station X14. Based on observed continued increases in flow in the reach of Rose Creek downstream of Station X14 during the synoptic study, it was determined that the alluvium at X14 was probably conveying a substantial flow. The estimate provided in the Robertson GeoConsultants Inc. report of 230 L/s was used to represent groundwater flow at Station X14 in the 2005 to 2007 historical water balance.

3.1.4.2 Vangorda Creek Catchment

Figure 3.1-31 provides the flowsheet used to represent average conditions in the Vangorda Creek catchment during the period 2005 to 2007. The conventions used in developing the flowsheet for the Anvil Creek catchment were adhered to in developing the flowsheet for the Vangorda Creek catchment. The focus of the flowsheet was to examine sources of flow at two key receiving points within the catchment: Vangorda Creek at V27 and Vangorda Creek at V8.

As with the other flowsheet, the basic building block was the subcatchment area. The Vangorda Creek was subdivided into eight subcatchments, as dictated by the locations of diversions, open pits, waste dumps, and the two key points noted above. The subcatchments are labelled with capital letters (K to R) to aid in the cross referencing of figures and tables. The boundaries of the eight subcatchments are shown on Figures 3.1-1 and 3.1-3. Table 3.1-10 provides details of the subcatchments, including drainage area and median elevation.

The flowlines shown on Figure 3.1-31 were judged to be of importance because they were either associated with a large flow rate or had the potential to convey a large contaminant loading.

Vangorda Pit

The reconstructed water balance for the Vangorda Pit is illustrated on Figure 3.1-32. Like the Main Pit, the volume of water pumped from the Vangorda Pit was not directly measured. However, since the volumes of water withdrawn from the pit represent the dominant component of the water balance, it was still possible to develop an accurate inflow record for the pit. The same method of deriving the Main Pit water balance was followed in reconstructing the Vangorda Pit water balance.

The top plot of Figure 3.1-32 presents the measured water level in the pit. As can be seen, pit dewatering took place only during one summer over the three-year study period. As a result, the water balance for this pit probably has a higher accuracy than was achieved for the Main Pit. The bottom plot on Figure 3.1-32 presents the reconstructed record of pit inflows. The net inflow rate for most months was simply set equal to the change in pit storage during the given month. For the three months where this estimation technique was not applicable, the net inflow rate was estimated using a correlation between pit inflow rate and monthly average discharge at the streamflow gauging station on Vangorda Creek (29BC003). The correlation (not shown) was based only on estimated net inflows for those months that did not experience pit dewatering.

The middle plot presents the estimated pit dewatering record. For the three months of significant pit dewatering, the withdrawal rate was estimated by application of the continuity equation (i.e., net pit inflow + dewatering of Little Creek Dam – change in pit storage). For the one month of minor pit dewatering (May 2005), the estimated dewatering rate was estimated from pump hours and the estimated average withdrawal rate over the succeeding three months.

The estimated average annual inflow volume to the Vangorda Pit is 370,000 m^3, or about 26% of the inflows to the Main Pit. This estimate excludes the flows pumped from the Little Creek Dam to the Vangorda Pit.

Grum Pit

Figure 3.1-33 illustrates the reconstructed water balance of Grum Pit. This was the most straightforward water balance to prepare because the pit was allowed to fill throughout the period January 2005 to December 2007 (see top plot of Figure 3.1-33). Indeed, no withdrawals have yet been made from the pit since the cessation of mining activities in 1998.

Because no pit dewatering occurred, it was only necessary to use a single technique to estimate net inflows for all months of the three-year study period. The net inflow for a given month was set equal to the increase in storage volume for that month.

The estimated average annual inflow to the Grum Pit is 340,000 m^3, a volume very similar to the average annual inflow to the Vangorda Pit.

Vangorda and Grum Waste Dumps

As was done for the Faro mine development, the estimation of waste dump drainage at the Vangorda Plateau required a mix of techniques. To estimate runoff from the Vangorda Waste Dump, a water balance was prepared for the collection pond that receives drainage from this dump, which is known as the Little Creek Dam (LCD). The water balance was constructed in a similar fashion as was done for the four open pits. The volumes of water pumped from the LCD to the Vangorda Pit were inferred from changes in storage within the LCD during months in which the pumping occurred. This technique can be expected to provide reasonably accurate estimates of outflow because the withdrawals were typically made in the summer when inflows to the pond are small. In this case, the change in storage over the month is virtually all attributable to the water pumped from the pond. Figure 3.1-34 presents the storage, outflow and inflow components of the LCD.

The average annual net inflow to the LCD is approximately 48,000 m^3. The LCD controls a total area of 0.72 km^2, including the contributions from the collector ditch that runs along the southern side of the Vangorda Waste Dump. The average annual net inflow volume suggests that the average annual yield of the Vangorda Waste Dump is approximately 67 mm, which is less than the estimated yields of the Faro Waste Dumps. There are several potential reasons that the yield of the Vangorda Waste Dump is lower than that of its counterparts at the Faro mine. Firstly, the collector ditch around the waste dump may be experiencing significant leakage, including groundwater flows that pass below the ditch. Secondly, the water content of the waste dump may not have yet reached a quasi-steady state. Thirdly, the oxidation processes in the waste dump may be particularly vigorous and are generating more heat than at the Faro Waste Dumps, thus causing more evaporation of infiltrated water.

For the purpose of reconstructing the historical water balance, the assumption was made that the true average annual yield of the Vangorda Waste Dump is 100 mm, or a value similar to what was observed for the Faro Waste Dumps. The difference between the assumed total yield and the water that ended up in the LCD pond was assumed to represent leakage, both from the waste dump's collector ditch and the LCD itself. These leakages are represented as dashed lines on Figure 3.1-31.

A two-component mixing model was used to estimate drainage from the Grum Waste Dump. The model was applied to the water quality monitoring station V27, located on Vangorda Creek just upstream of Shrimp Creek. As was done for Faro, dissolved sulphate was selected as the tracer. Gaps in the sulphate record at V27 were patched using a correlation between coincidental V27 and VGMAIN sulphate concentrations. Water quality data at Station V1, located upstream of the entrance to the Vangorda Creek Diversion, was used to characterize background concentrations. Missing data in the V1 record were patched using a correlation between V1 sulphate concentration and coincidental monthly average flow at Station 29BC003. The flow-weighted average concentration for the Grum Dump drainage was estimated from data collected at surface and groundwater monitoring stations located along the toe of this dump. Spot measurements of flow at V27 collected since 1993 were used to transpose the 29BC003 flow record to the V27 site. The results of applying the two-component model at V27 are presented in Figure 3.1-35.

The estimated average annual discharge from the Grum Dump is 6.3 L/s. This corresponds to an average annual yield of about 100 mm, which is comparable to the estimates of yield made for the Faro Waste Dumps.

A partial validation of the inferred Grum Dump flows was made using a record of flows collected at a triangular weir on old Grum Creek below the toe of Grum Dump. The catchment controlled by this weir is estimated to be roughly half of the total footprint of the Grum Dump. Accordingly, the flows at this weir would be expected to be roughly half of the total runoff emanating from the Grum Dump. The station was operated during the open water seasons in the period January 2005 to December 2007. Figure 3.1-36 presents the complete stage and flow records for this station. A visual comparison indicates that the flows measured at the weir are, as expected, roughly half those inferred from the two-component mixing model.

The weather station operated on Grum Dump offered an opportunity to estimate the yield of the Grum Dump based on a climatic water balance. The estimated MAP and MAET at this weather station are 369 mm and 246 mm, respectively. An estimate of the yield of the waste dump can be obtained by subtracting MAET from MAP, which works out to 123 mm. There are at least three potential reasons why the yield estimate provided by the climatic balance is higher than the estimate obtained from the two-component mixing model. Firstly, the estimate of MAP may be too high or the estimate of MAET too low. Secondly, the Grum Dump may still be wetting up and therefore is not discharging as much water as it ultimately will once the dump's field capacity has been reached. Thirdly, the sulphate concentration assigned to the waste dump drainage may be too high in the mixing model calculations, thus resulting in an underestimation of actual dump discharge.

Diversions

Many diversion and interceptor ditches have been constructed at the Vangorda Plateau minesite. Three of these have had significant influence on the water balance of the mine. The Vangorda Creek Diversion (VCD) and the Vangorda Northeast Interceptor Ditch (VNEID) were constructed to facilitate the development of the Vangorda Pit. The Grum Interceptor Ditch (GID) was developed to minimize inflows to the Grum Pit.

The combined leakage from the VCD and the VNEID was estimated by following a similar approach as was used to infer the amount of leakage from the Faro Creek Diversion to the Main Pit. The estimated local runoff from the Vangorda Pit was subtracted from the estimated total inflow to the pit. Of the 370,000 m^3 of water that inflows to the pit each year on average, approximately 225,000 m^3 of this was attributed to leakages from the VCD and the VNEID. This works out to an average annual flow rate of 7.1 L/s.

The procedure outlined above was also applied to the GID for the purpose of estimating its contribution to the total inflows of the Grum Pit. In an average year, some 340,000 m^3 of water accumulates in the pit. Approximately 35% of this total, or 3.9 L/s, can be attributed to ditch leakage from the GID.

Receiving Streams

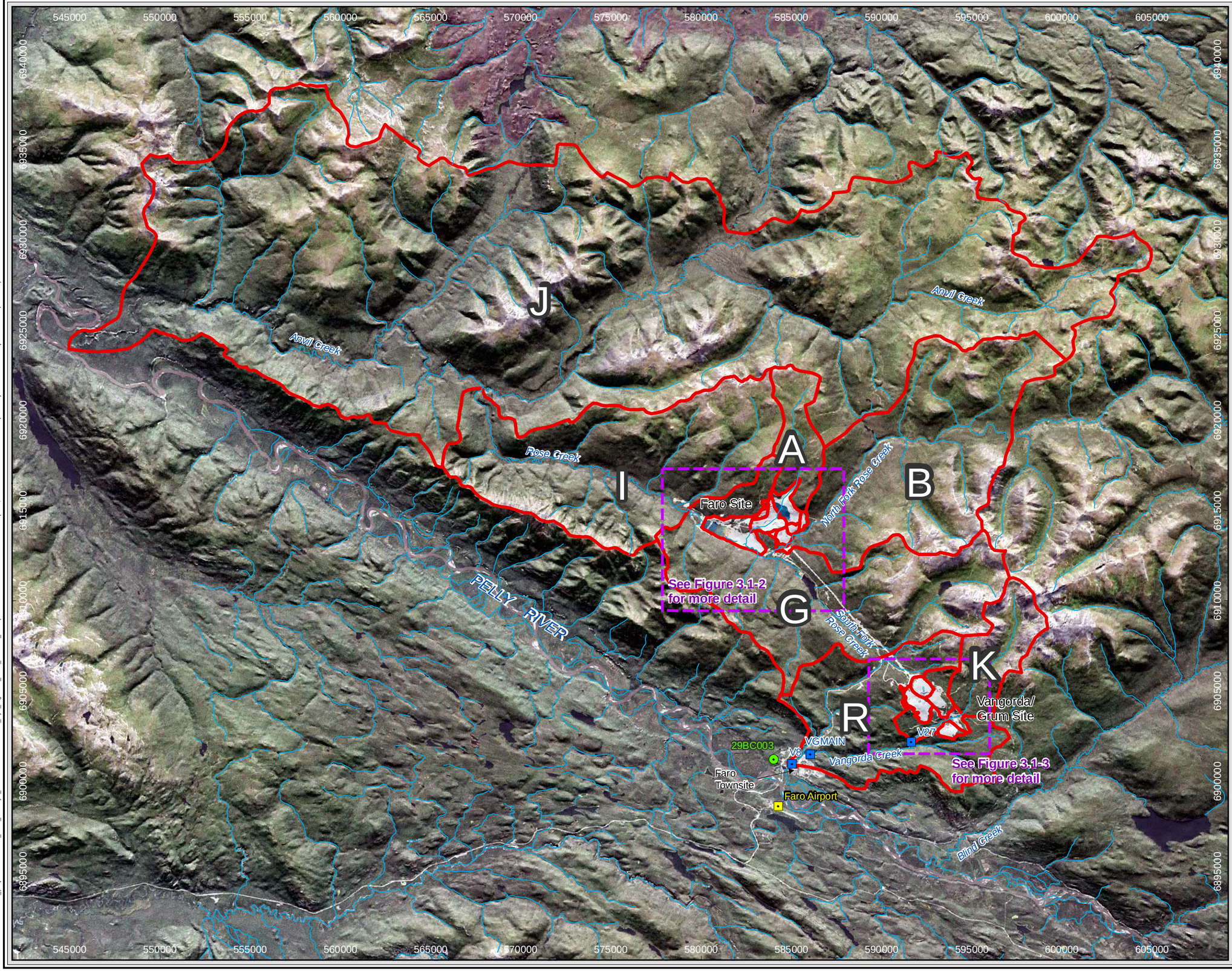
Construction of the historical water balance required records of monthly flows at key locations within the Vangorda Creek catchment spanning the period January 2005 to December 2007. For ungauged locations, this was achieved by transposing a measured record to the point of interest. The transposition was achieved in the same manner as used in the Anvil Creek catchment – the flows from the measured station were scaled by the ratio of average annual flows at the ungauged and gauged locations. Estimates of average annual flows were obtained from the regional relationship between MAR and catchment median elevation described in Section 3.1.3.3. The measured flows were provided by the government-operated gauging station on Vangorda Creek (29BC003).

The technique outlined above was used to estimate the flows generated by Subcatchments K, N, Q and R (see Figure 3.1-31). There are two pieces of evidence to suggest that the technique underestimates flows generated by the headwaters of Vangorda Creek (i.e., Subcatchment K). Firstly, as already presented in Section 3.1.3.3, a new gauging station was established in the headwaters of Vangorda Creek in 2008 (Station V1). A preliminary estimate of MAR for this station was discovered to be significantly greater than would be predicted by the relationship adopted to estimate MAR (see Figure 3.1-15).

The second piece of evidence was related to the record of spot measurements collected at V27. A correlation was performed between V27 flows and coincidental 29BC003 flows as a preparatory step in applying the two-component mixing model to Station V27 (see Section 3.1.4.2). This correlation also indicated that the flows in upper Vangorda Creek may be underestimated. The flowsheet for Vangorda Creek (Figure 3.1-31) shows the mean annual discharge at V27 to be 0.22 m^3/s. The correlation between V27 and 29BC003 flows (not shown) would suggest the flow should be higher at about 0.25 m^3/s.

Despite the evidence presented above, no alterations were made to the estimates of flow in the upper Vangorda Creek, largely because the evidence is based on either a short record (V1) or intermittent data (V27). After one or two more years of data collection at Station V1, changes to the estimated headwater flows may become warranted. If the estimated discharges in the headwaters are increased, then an offsetting decrease must be made in the estimated flows of lower Vangorda Creek. This is required so that the sum of the flows from the headwater and lower regions of Vangorda Creek are consistent with the measured flows at Station 29BC003, near the mouth of this stream.

The average annual flow at Station V8 during the period 2005 to 2007 was approximately 0.50 m^3/s. Over this same period, the measured flow in the Pelly River just below Vangorda Creek (Station 09BC004) was 210 m^3/s. Thus, Vangorda Creek contributed approximately one quarter of 1% of the flow in the Pelly River.



Legend

- Streamflow Gauging Station
- Water Quality Station
- MET Station
- Watercourse
- Subcatchment Boundary
- Additional Figure

Climate stations from Environment Canada, 2009. Catchment polygons digitized by Pat Bryan, 2009. Base data, Yukon Territorial Government and NTDB, 1:50K. Select streamflow stations from Environment Yukon and Water Survey of Canada.

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation

Minesite Subcatchments

April 2009

AECOM

Figure 3.1-1

Project: 107403 (80649-1)
Prepared by: MM
Date Revised: April 6, 2009
File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy7_CatchmentsWH\107403_By7_Fig3-1-1_Mine_Catchm_09dApr03.mxd

Legend

- Snowcourse
- Water Quality Station
- Streamflow Gauging Station
- MET Station
- Watercourse
- Subcatchment Boundary
- Contours (Index 10m)

Imagery from SRK Consulting, flown August 19, 2008.
Climate stations from Environment Canada, 2009. Catchment polygons digitized by Pat Bryan, 2009. Base data, Yukon Territorial Government and NTDB, 1:50K. Select streamflow stations from Environment Yukon and Water Survey of Canada.

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation

Minesite Subcatchments in the Vicinity of Faro Mine Development

April 2009

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Figure 3.1-2

File Location: E:\GIS\GIS_pro\jY2009\107403_Faro_GWBy7_CatchmentsWH\107403_By7_Fig2_MineVicFaro_09dApr03.mxd Date Revised: April 6, 2009 Prepared by: MM Project: 107403 (80649-1)

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Vangorda Haul Road
Grum Pit
Grum Rock Dump
Grum Dump
Vangorda Pit
Till Dump
Vangorda Rock Dump
Grum Creek
Vangorda Creek West Fork
Vangorda Creek
Shrimp Creek
V1
O
N
K
R
P2
P1
Q
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L
R

Legend

- Watercourse
- Streamflow Gauging Station
- MET Station
- Subcatchment Boundary
- Contours (Index 10m)

Imagery from SRK Consulting, flown August 19, 2008.
Climate stations from Environment Canada, 2009. Catchment polygons digitized by Pat Bryan, 2009. Base data, Yukon Territorial Government and NTDB, 1:50K. Select streamflow stations from Environment Yukon and Water Survey of Canada.

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation

Minesite Subcatchments in the Vicinity of Vangorda Plateau Development

April 2009

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Figure 3.1-3

File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy7_CatchmentsWH\107403_By7_Fig3_MineVangorda_09dApr03.mxd
Date Revised: April 6, 2009
Prepared by: MM
Project: 107403 (80649-1)

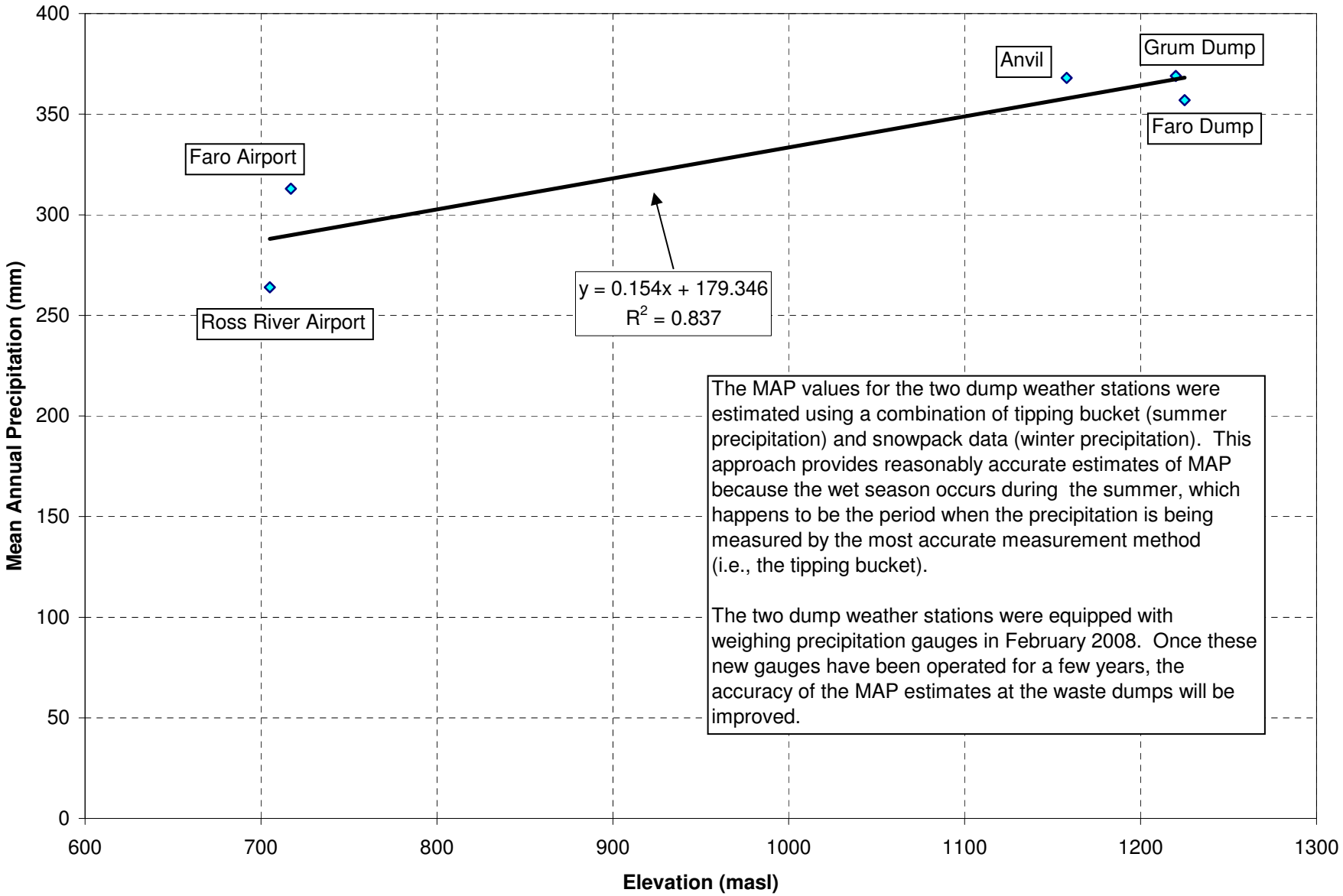


Figure 3.1-4 Relationship Between Mean Annual Precipitation and Elevation

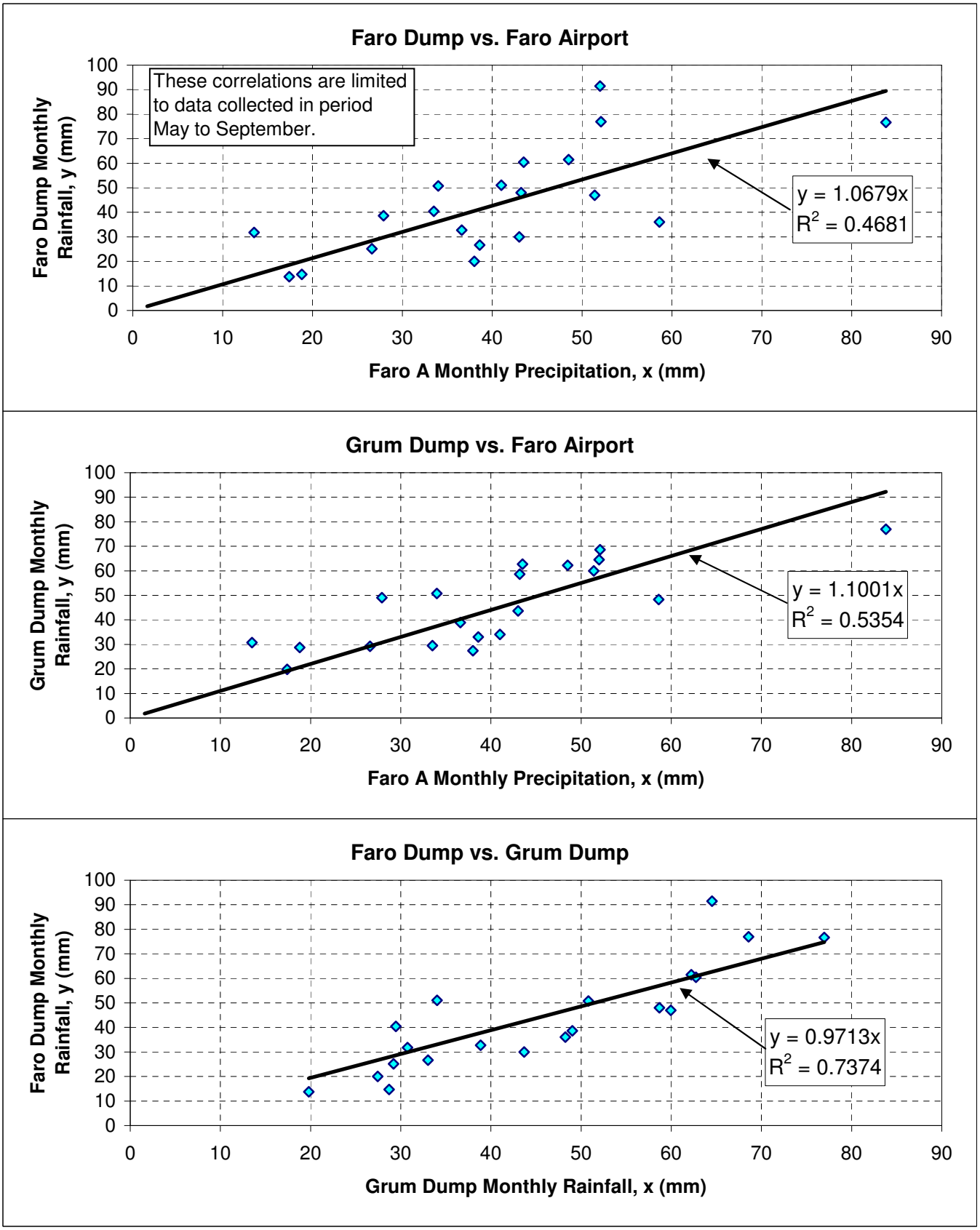


Figure 3.1-5 Examination of Orographic Effects During Rainfall Events

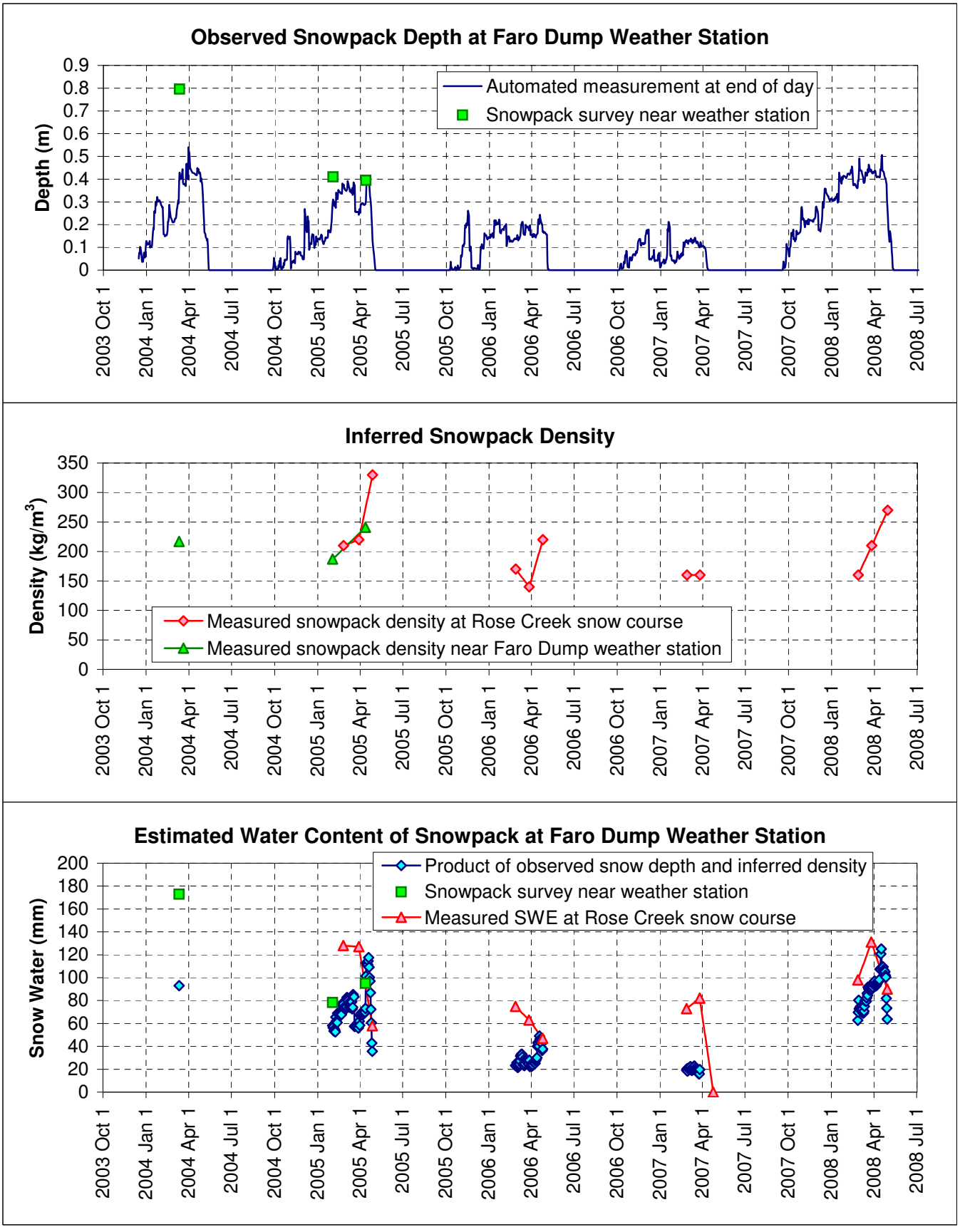


Figure 3.1-6 Snowpack at Faro Dump Weather Station

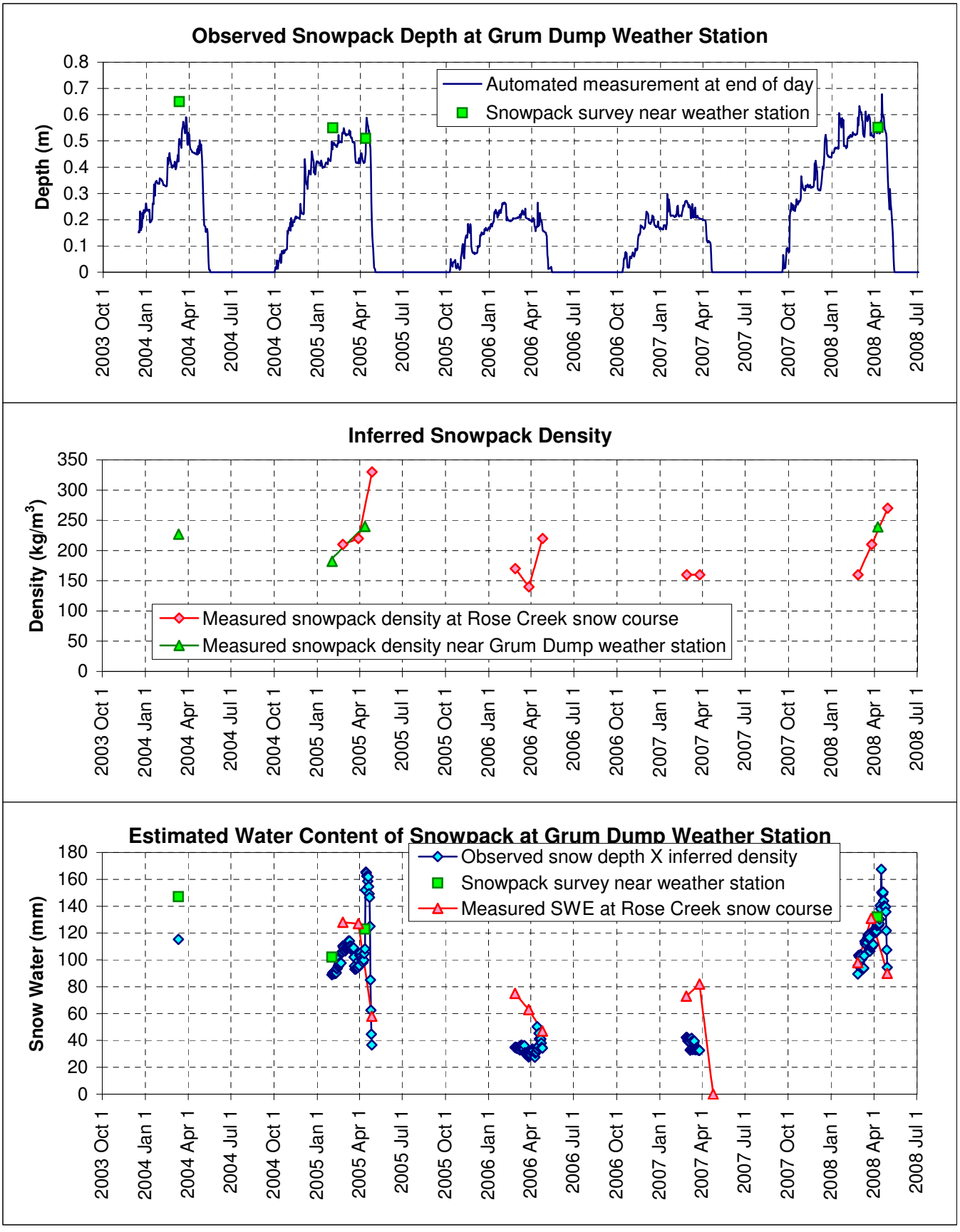


Figure 3.1-7 Snowpack at Grum Dump Weather Station

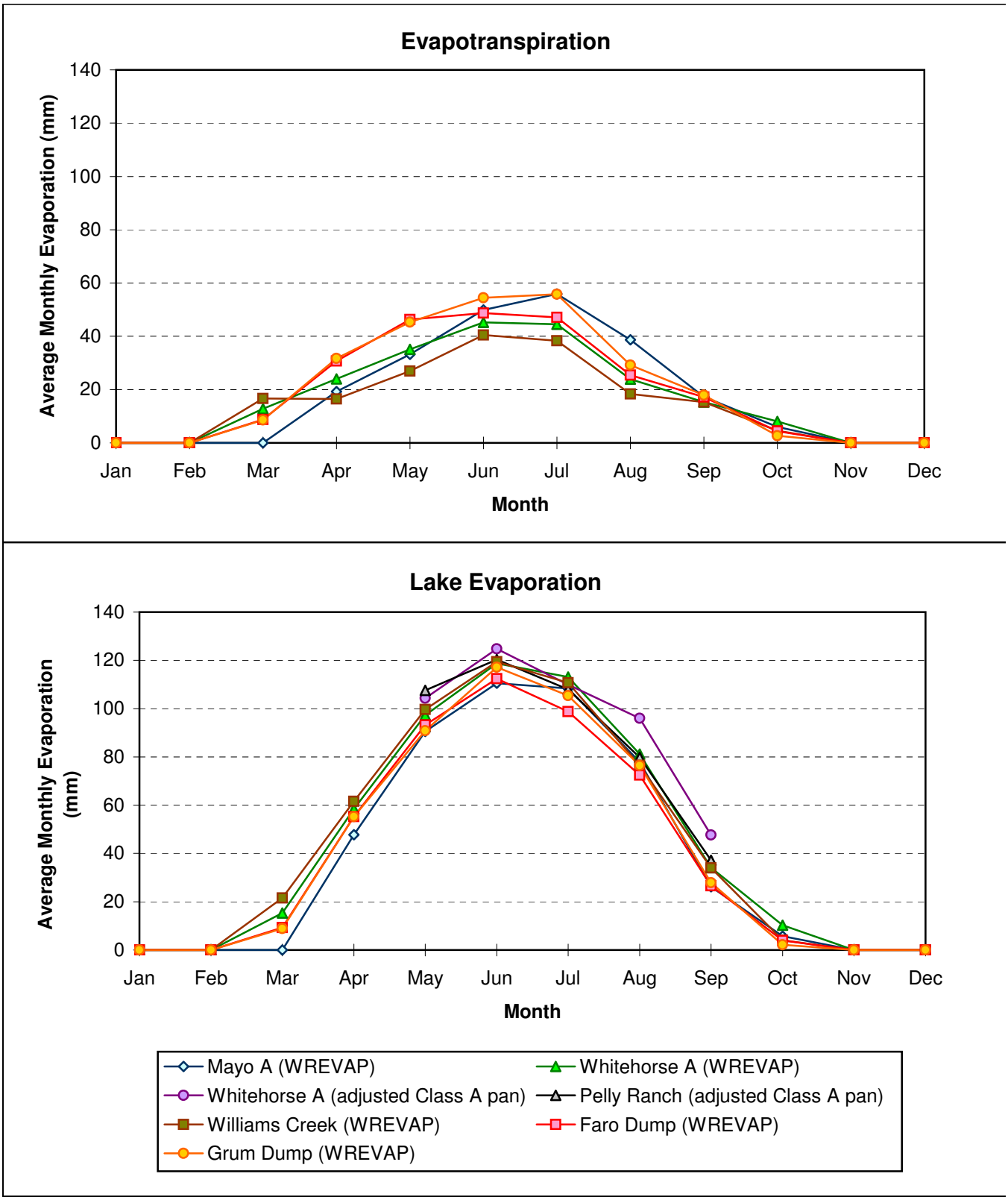


Figure 3.1-8 Estimated Lake Evaporation and Evapotranspiration

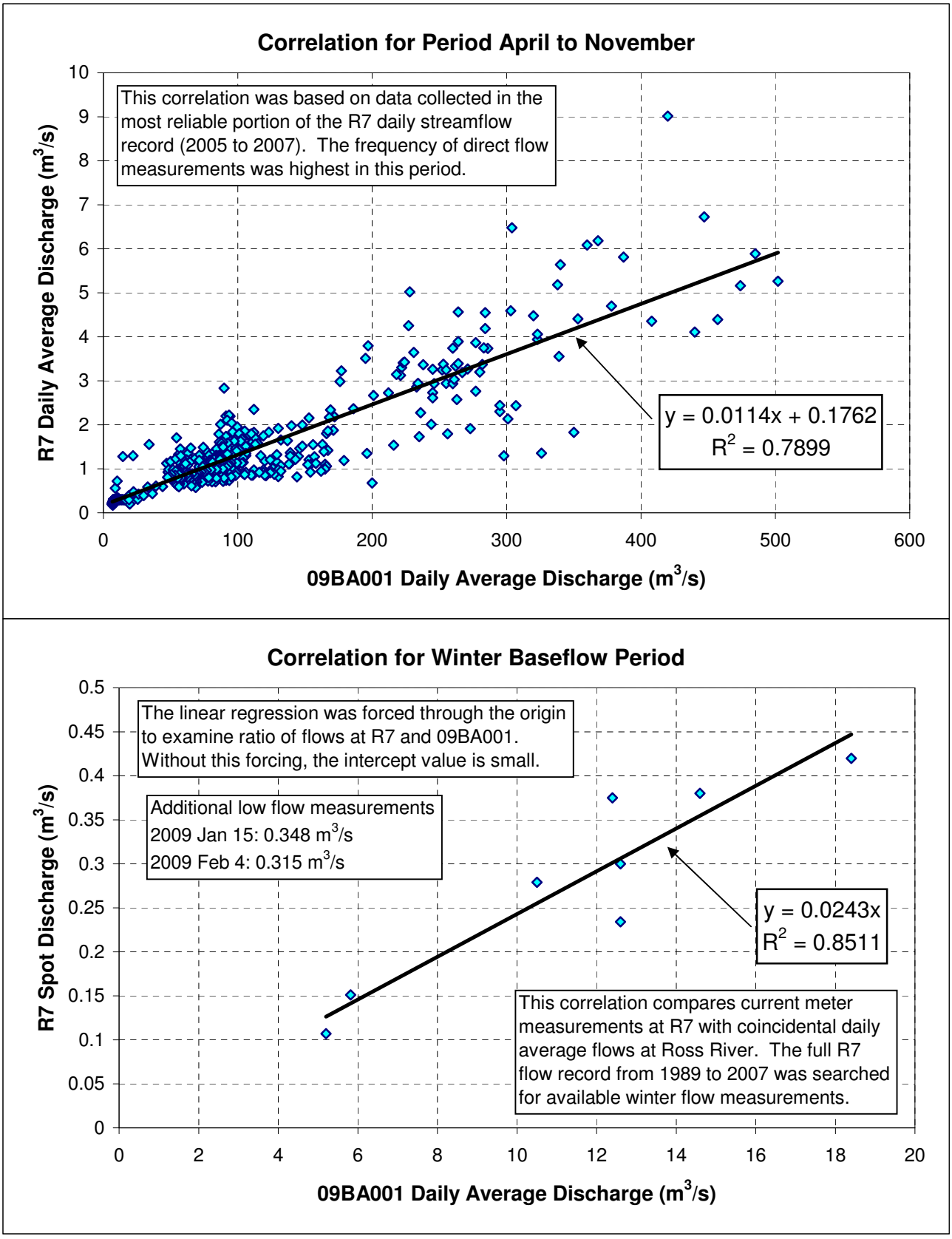


Figure 3.1-9 Correlations Used to Patch R7 Streamflow Record

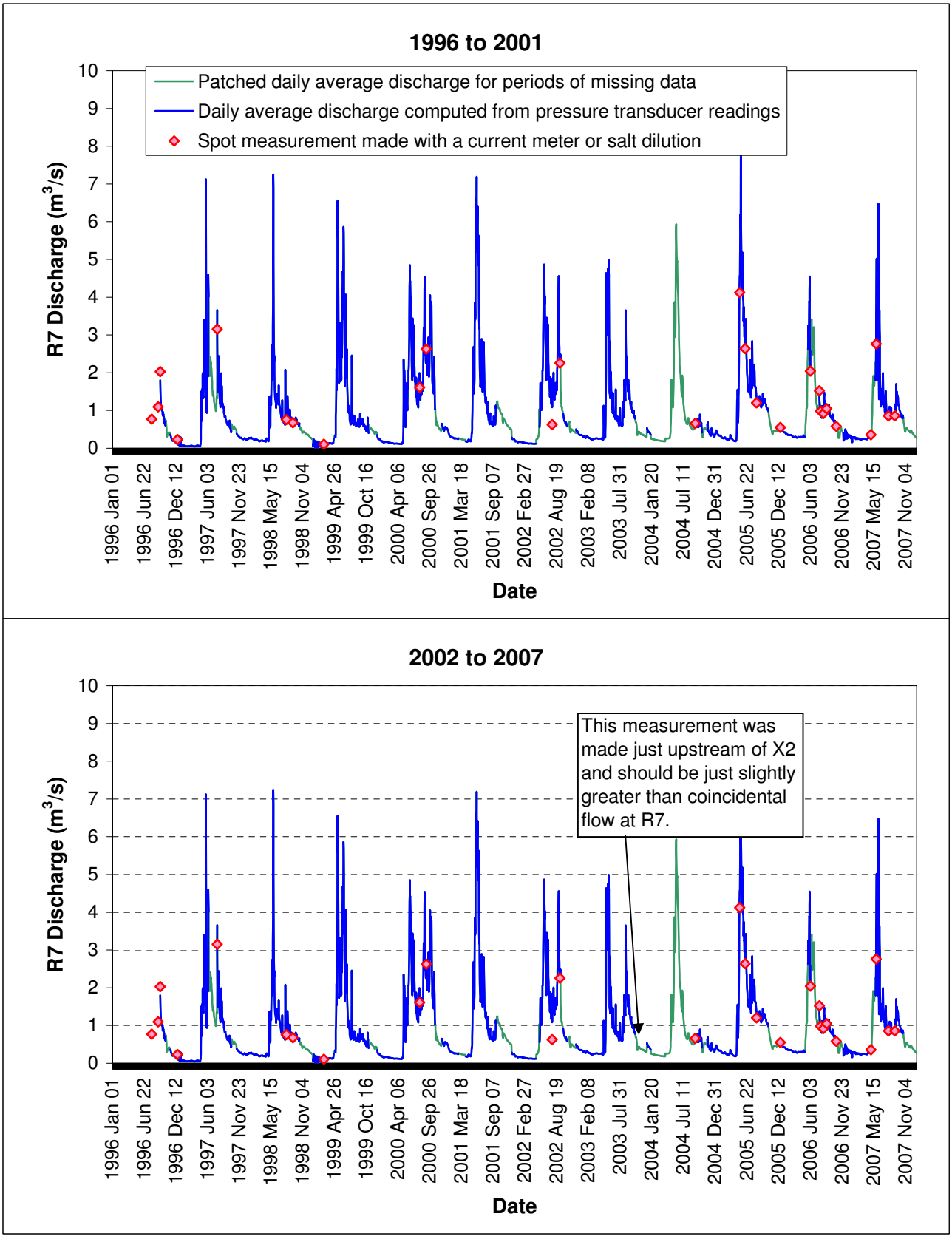


Figure 3.1-10 Daily Flow Record for North Fork of Rose Creek at R7

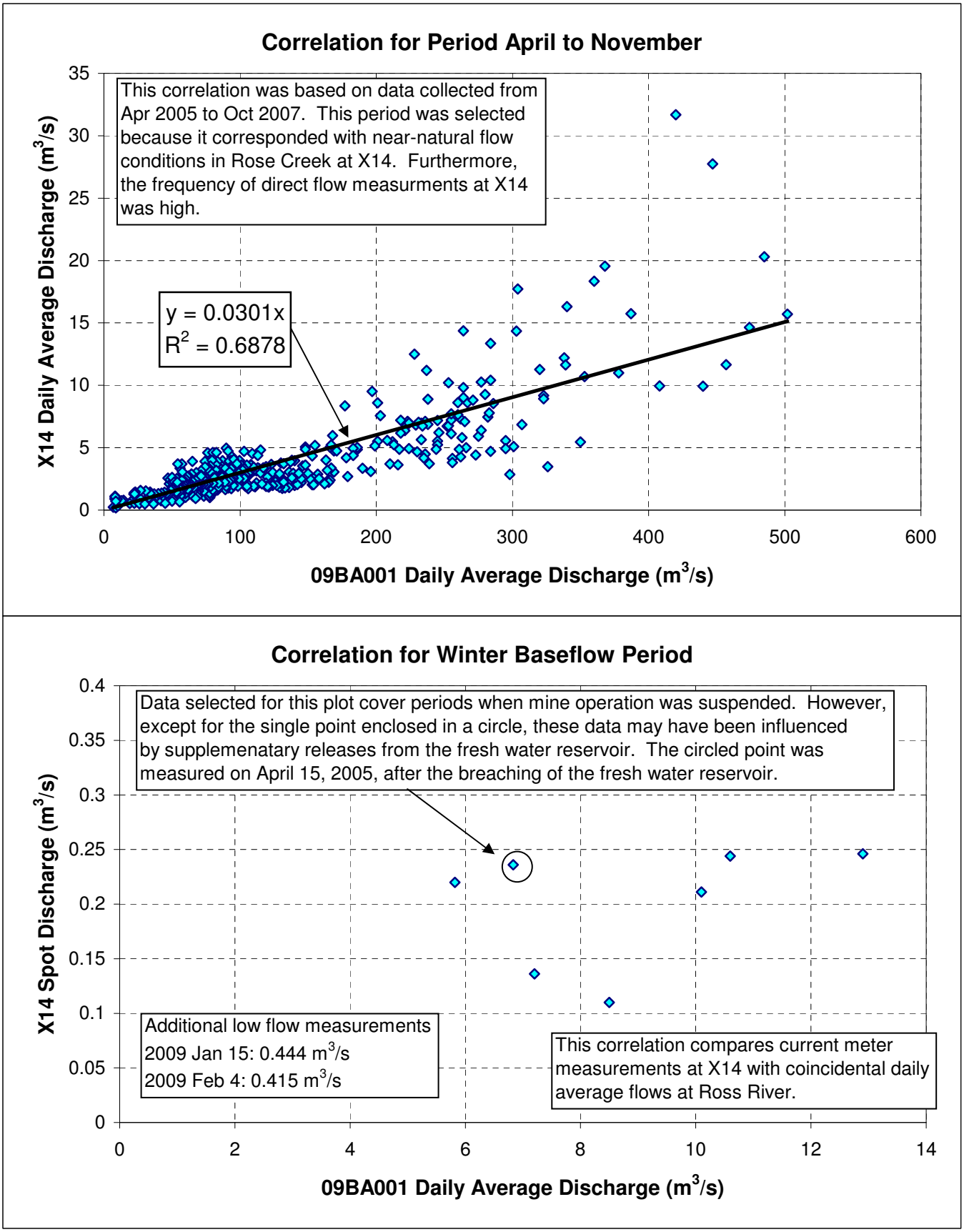


Figure 3.1-11 Correlations Used to Patch X14 Streamflow Record

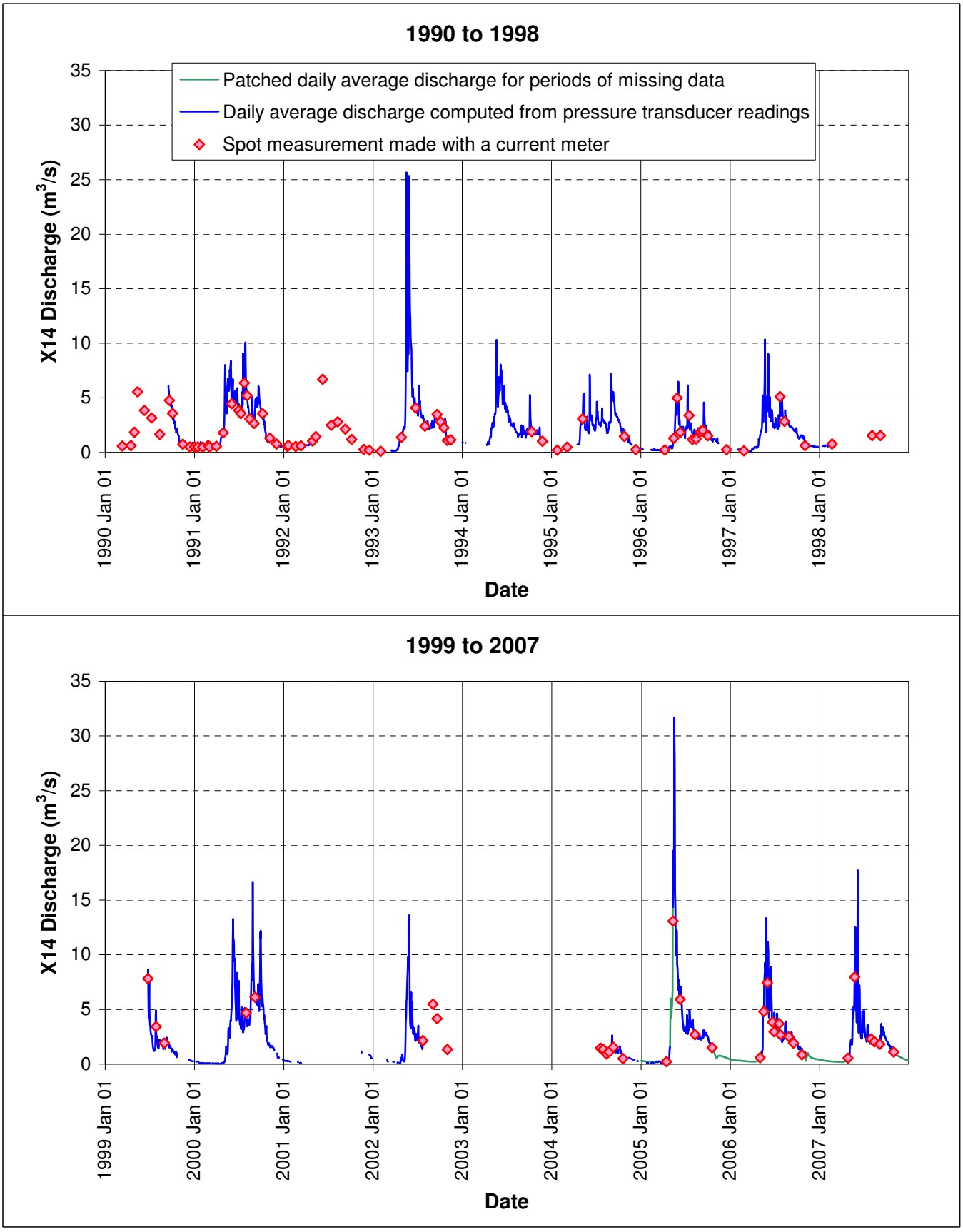


Figure 3.1-12 Daily Flow Record for Rose Creek at X14

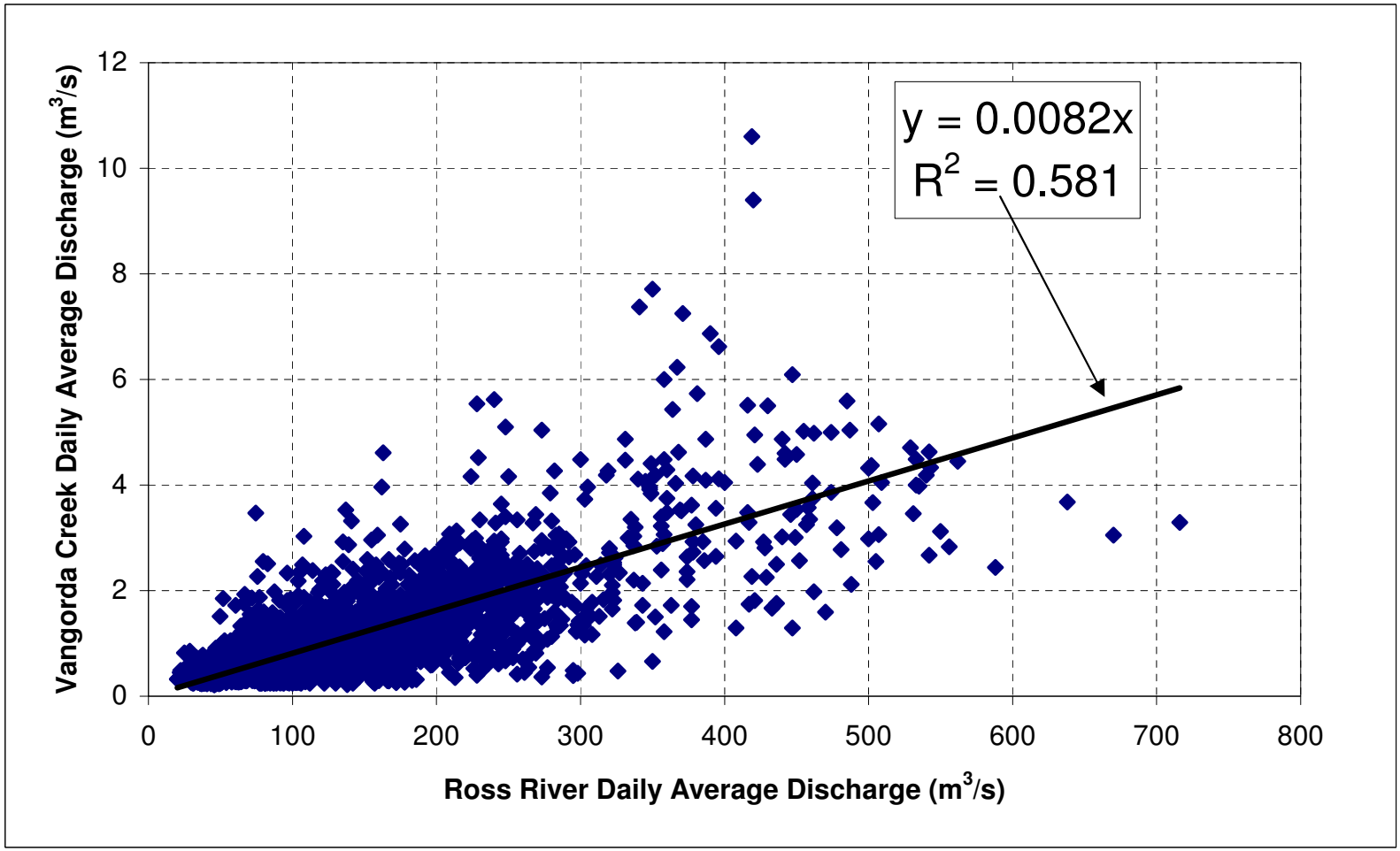


Figure 3.1-13 Correlation Used to Patch 29BC003 Streamflow Record

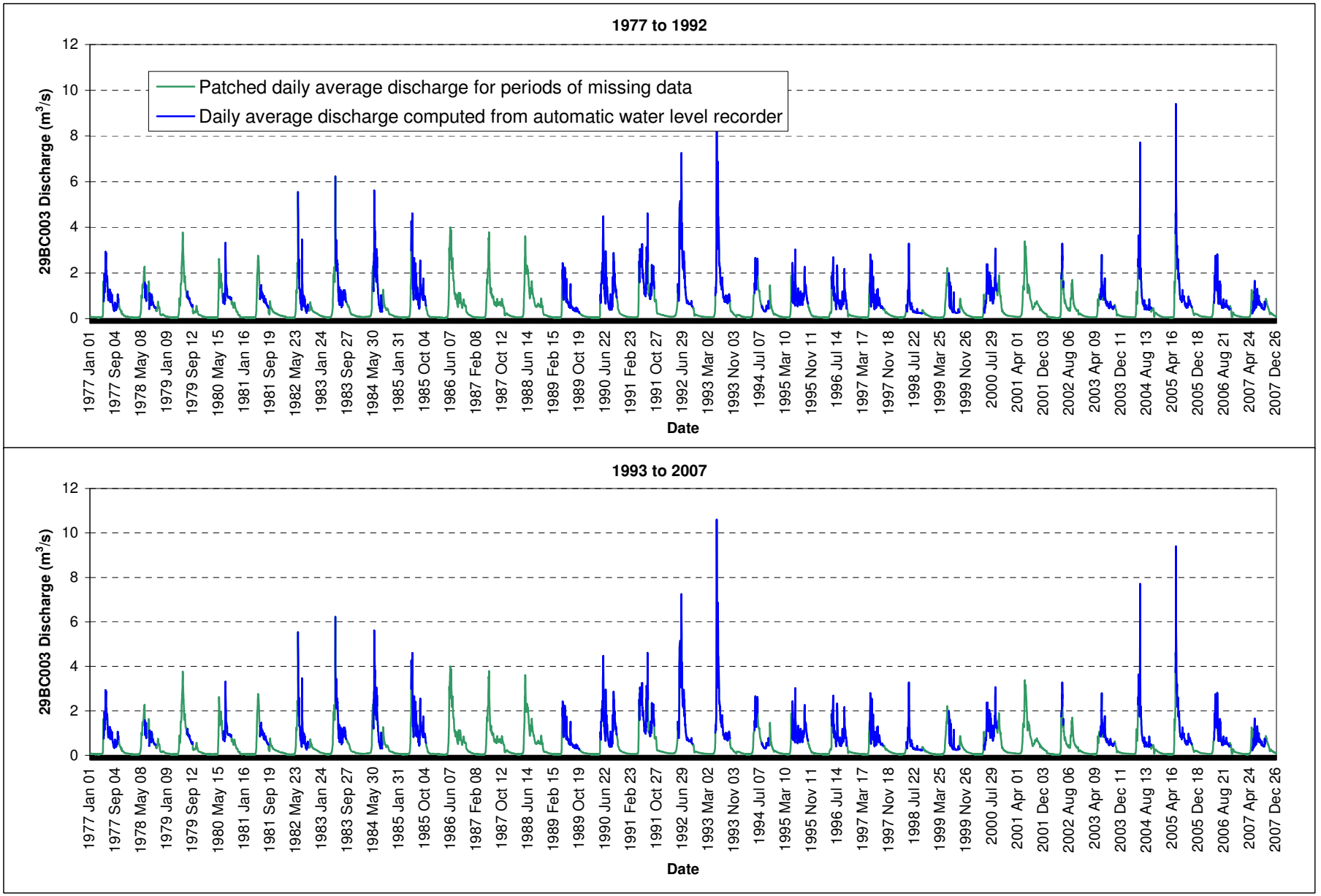


Figure 3.1-14 Patched Daily Flow Record for Vangorda Creek at 29BC003

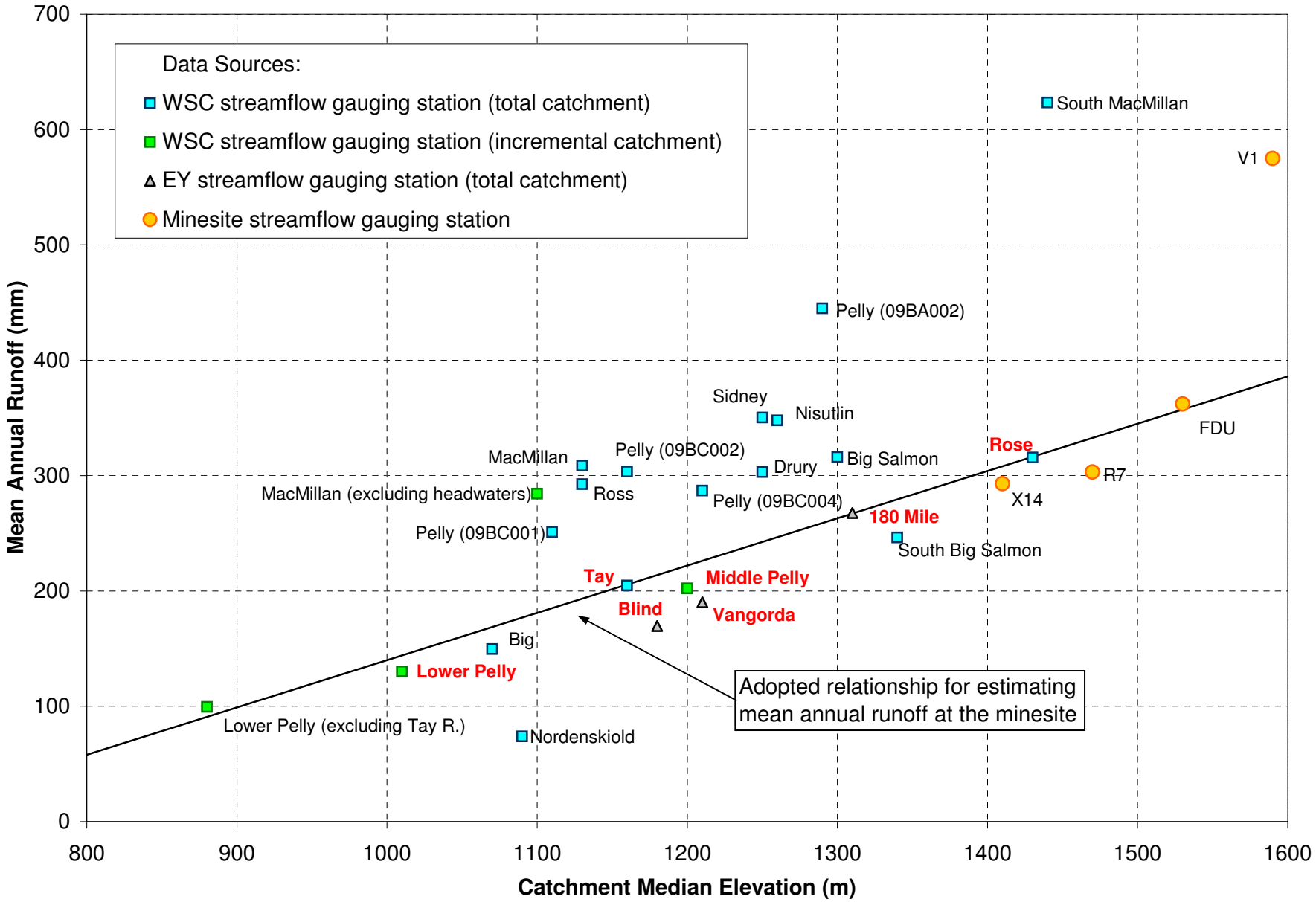


Figure 3.1-15 Regional Relationship Between Mean Annual Runoff and Catchment Median Elevation

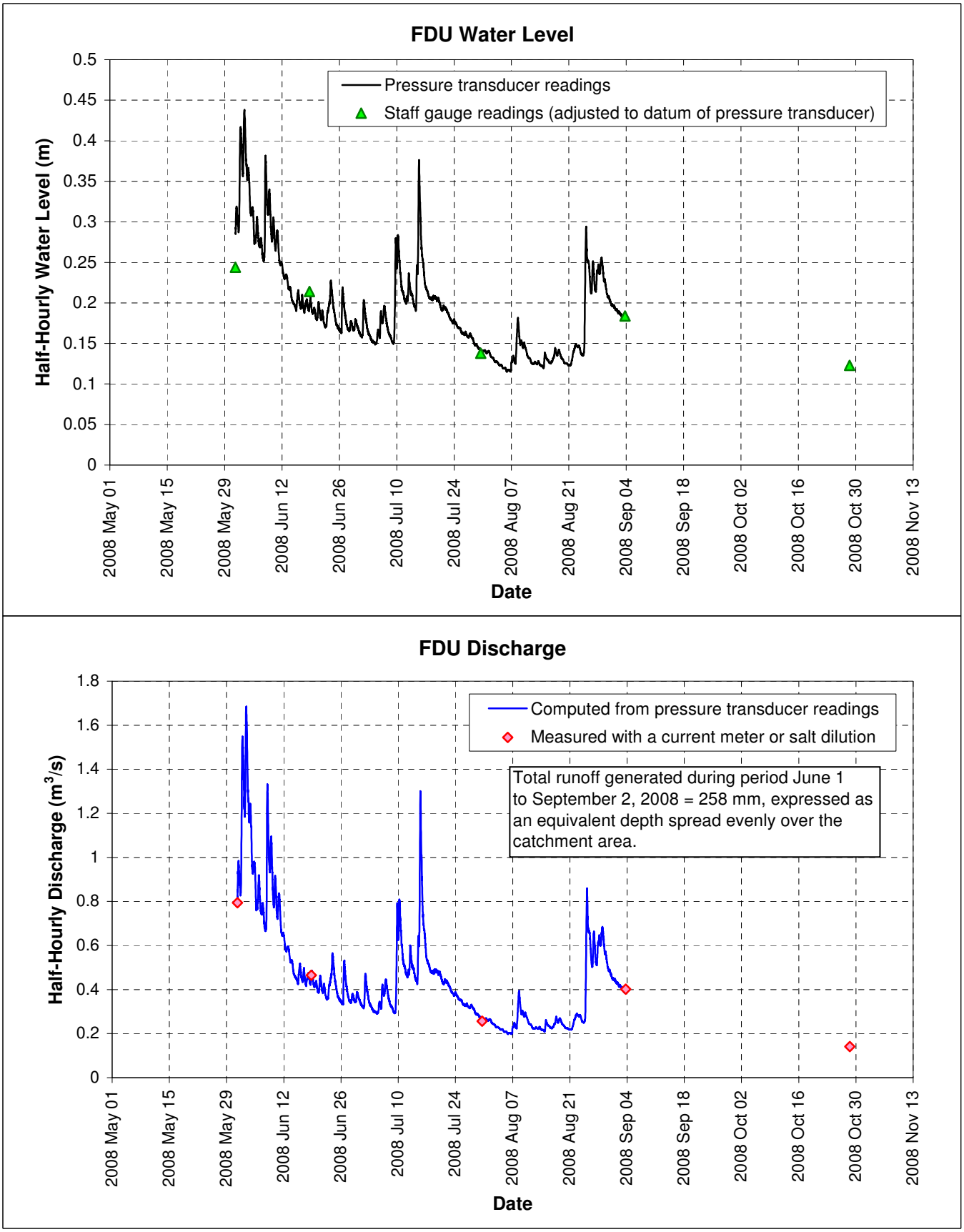


Figure 3.1-16 2008 Stage and Flow Records for Faro Creek at FDU

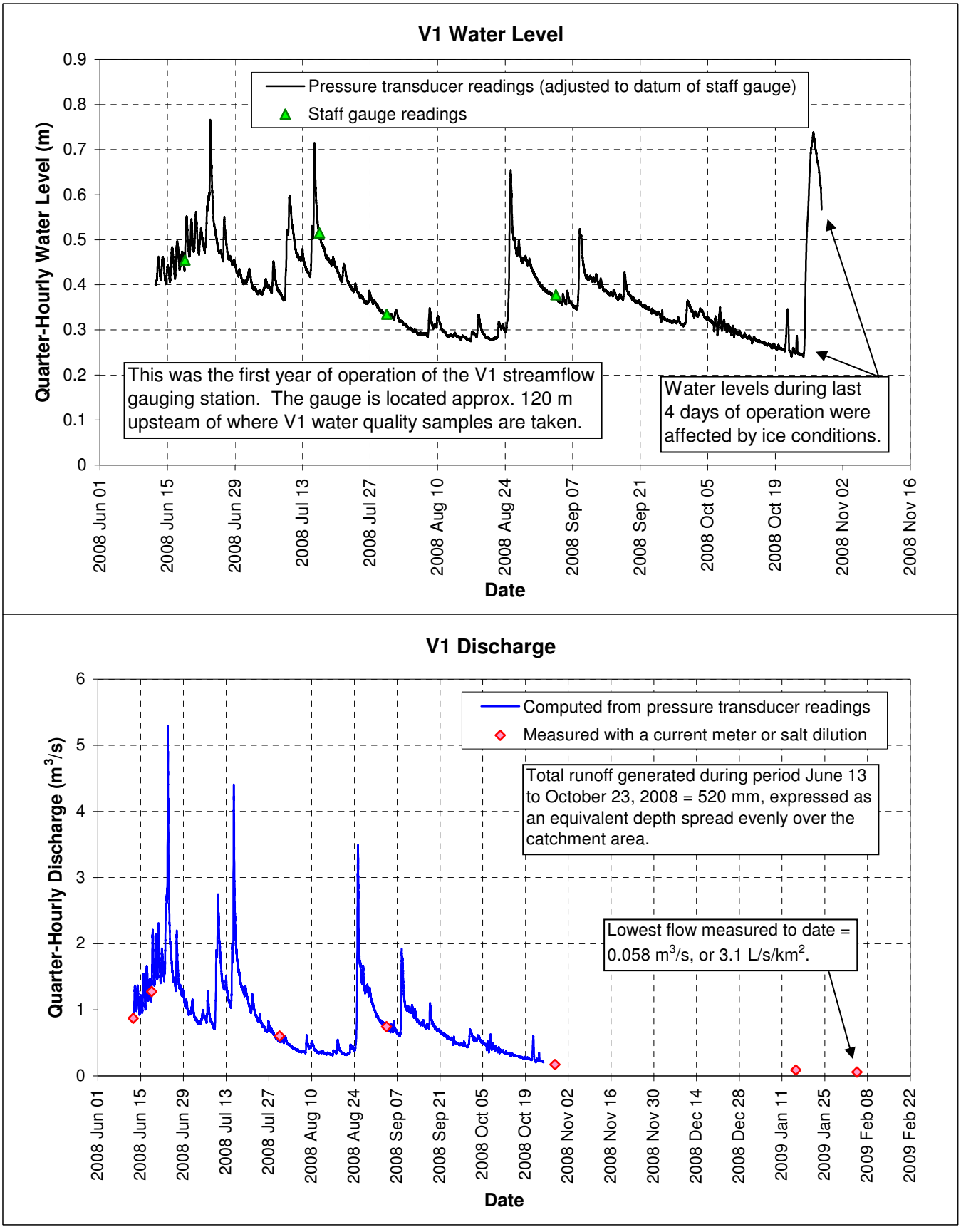


Figure 3.1-17 Stage and Flow Records for Vangorda Creek at V1

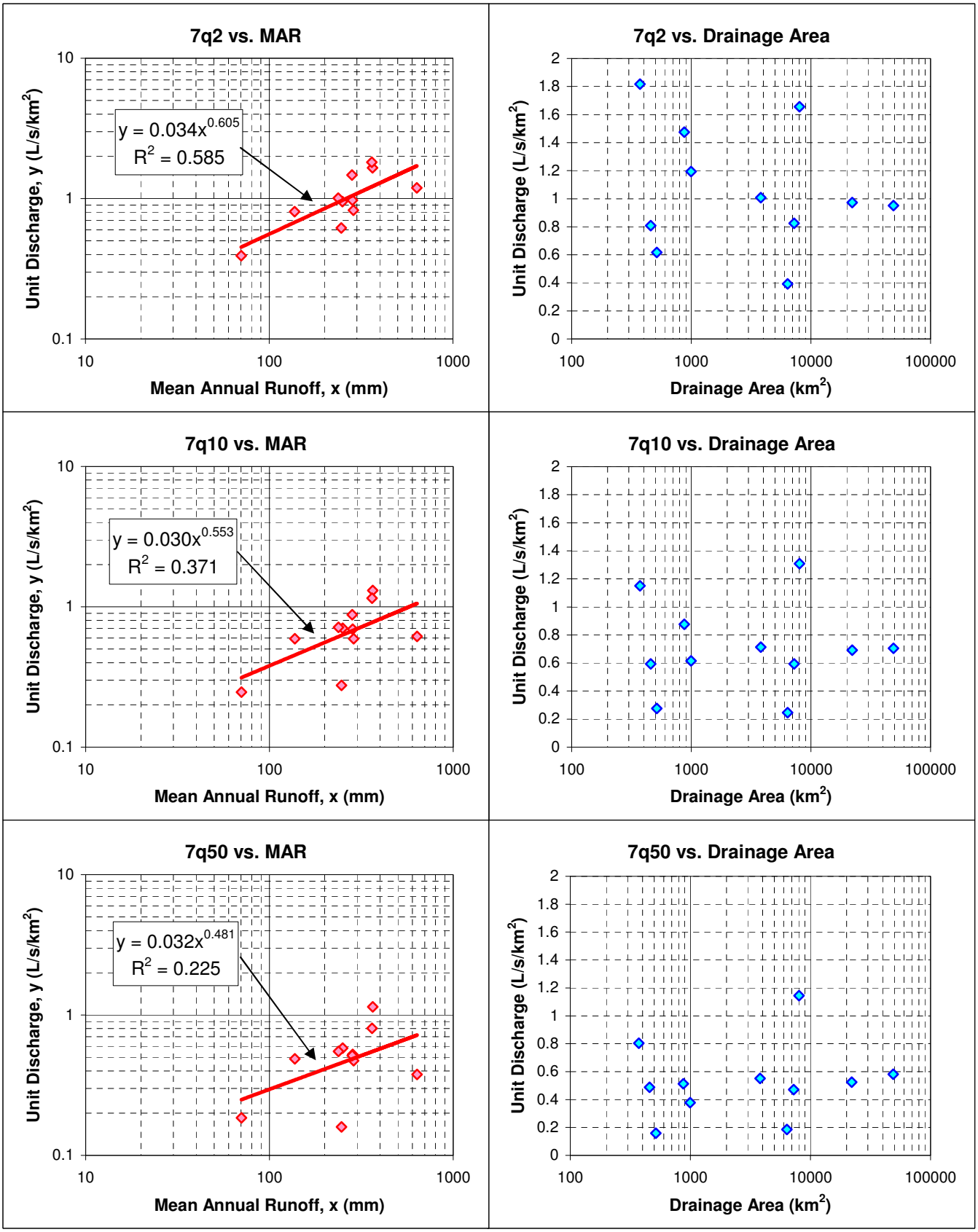


Figure 3.1-18 Annual Minimum 7-Day Low Flow vs. Mean Annual Runoff and Drainage Area

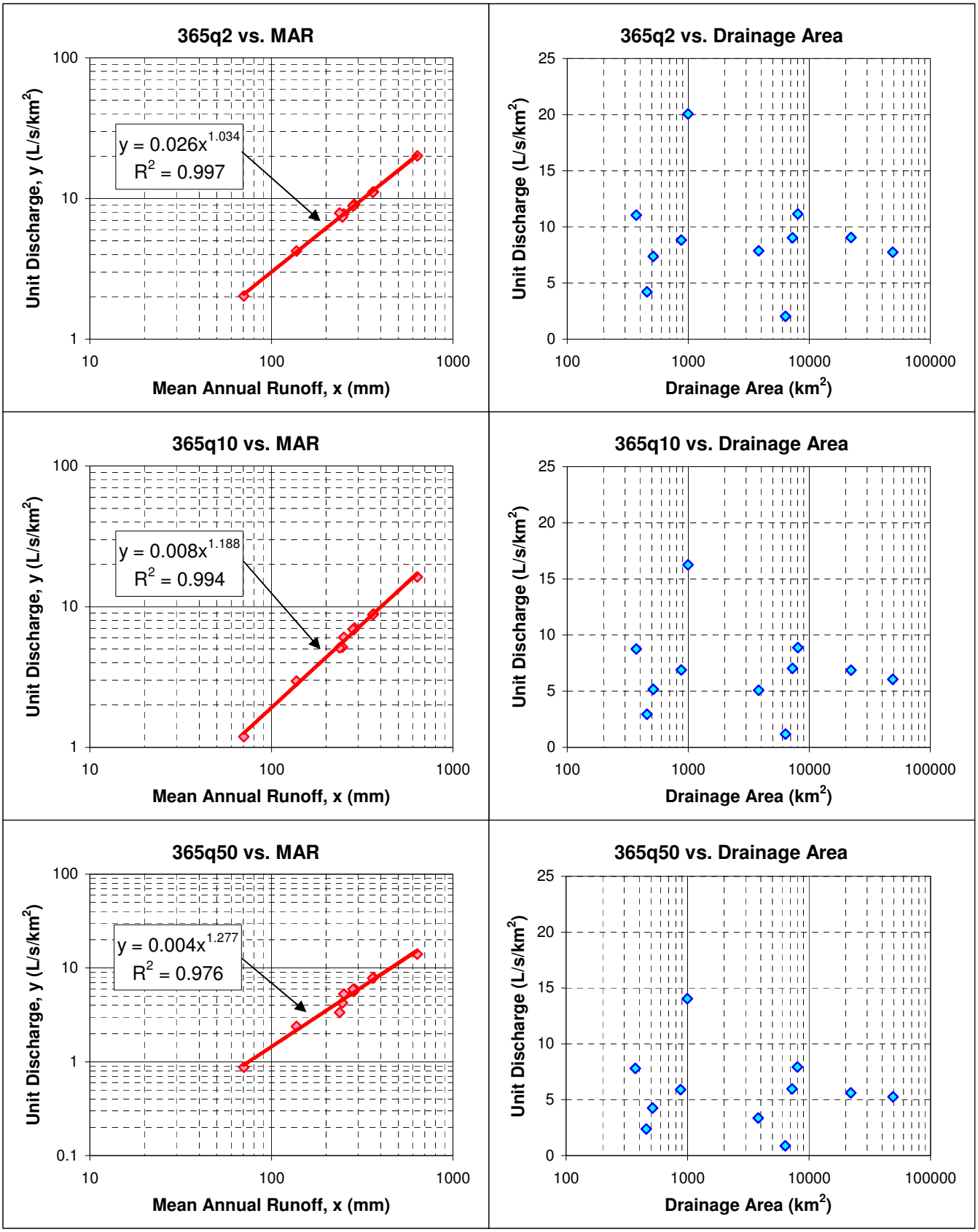


Figure 3.1-19 Annual Minimum 365-Day Low Flow vs. Mean Annual Runoff and Drainage Area

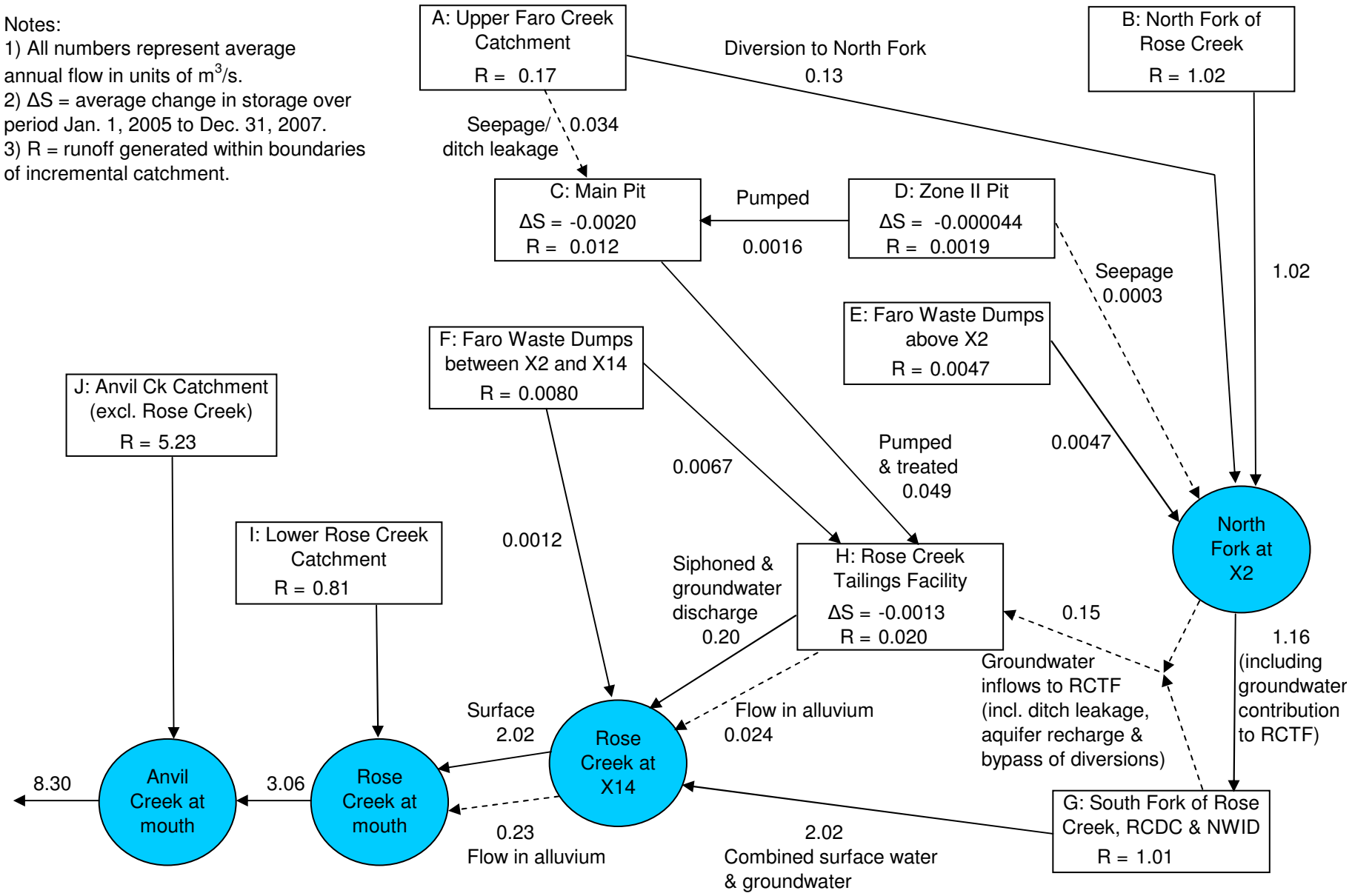


Figure 3.1-20 Average Annual Water Balance for Anvil Creek Catchment (2005 to 2007)

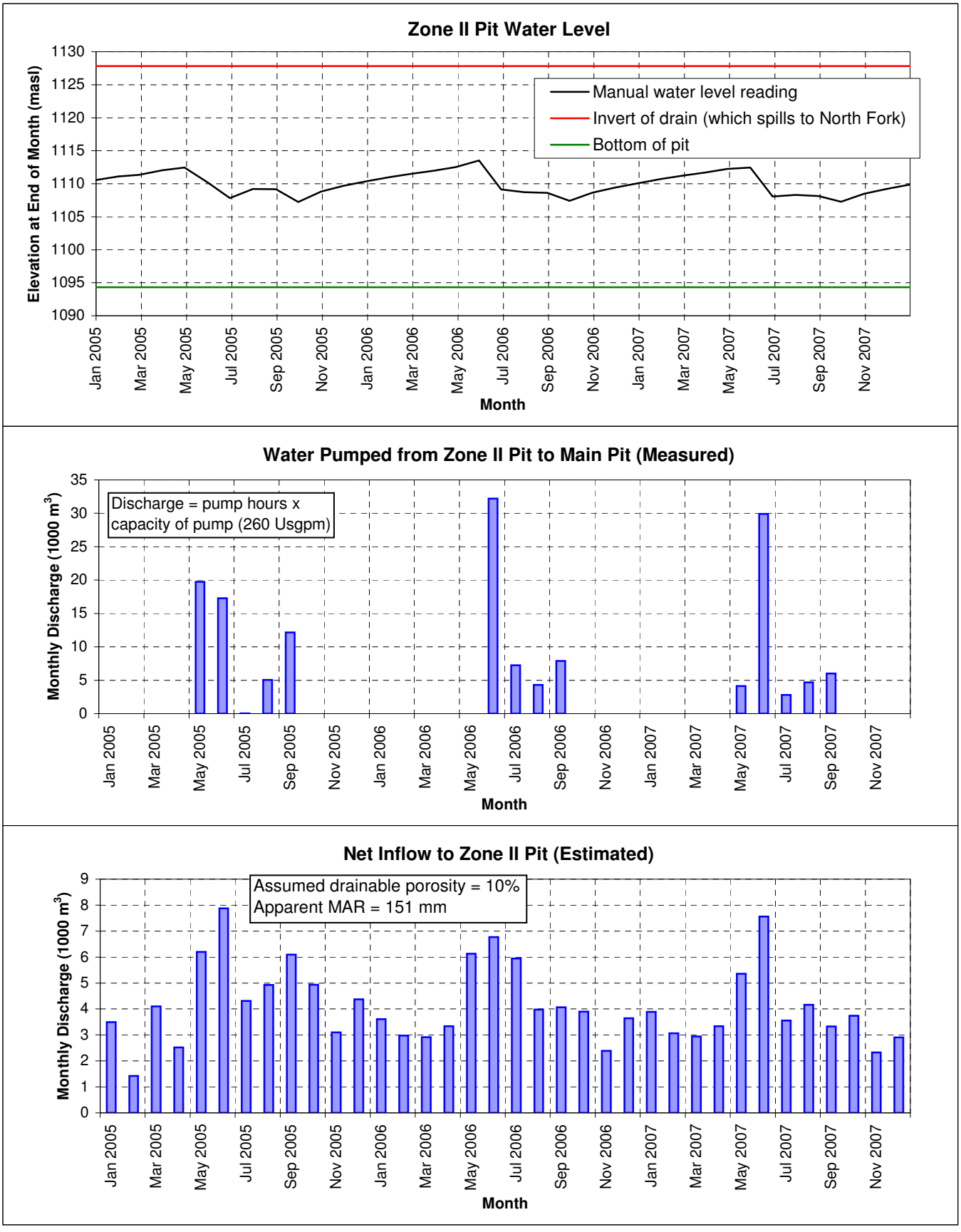


Figure 3.1-21 Water Balance for Zone II Pit (2005 to 2007)

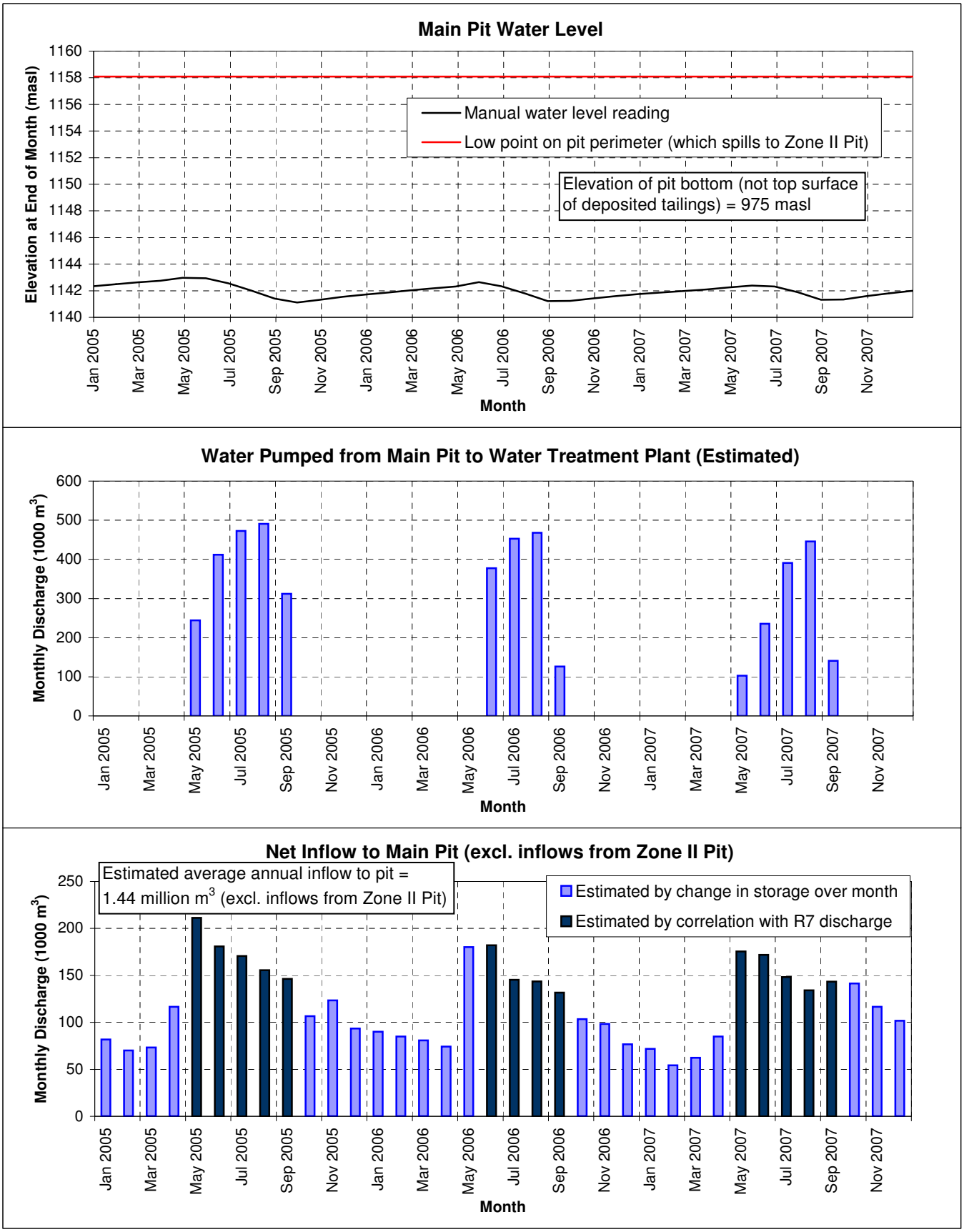


Figure 3.1-22 Water Balance for Main Pit (2005 to 2007)

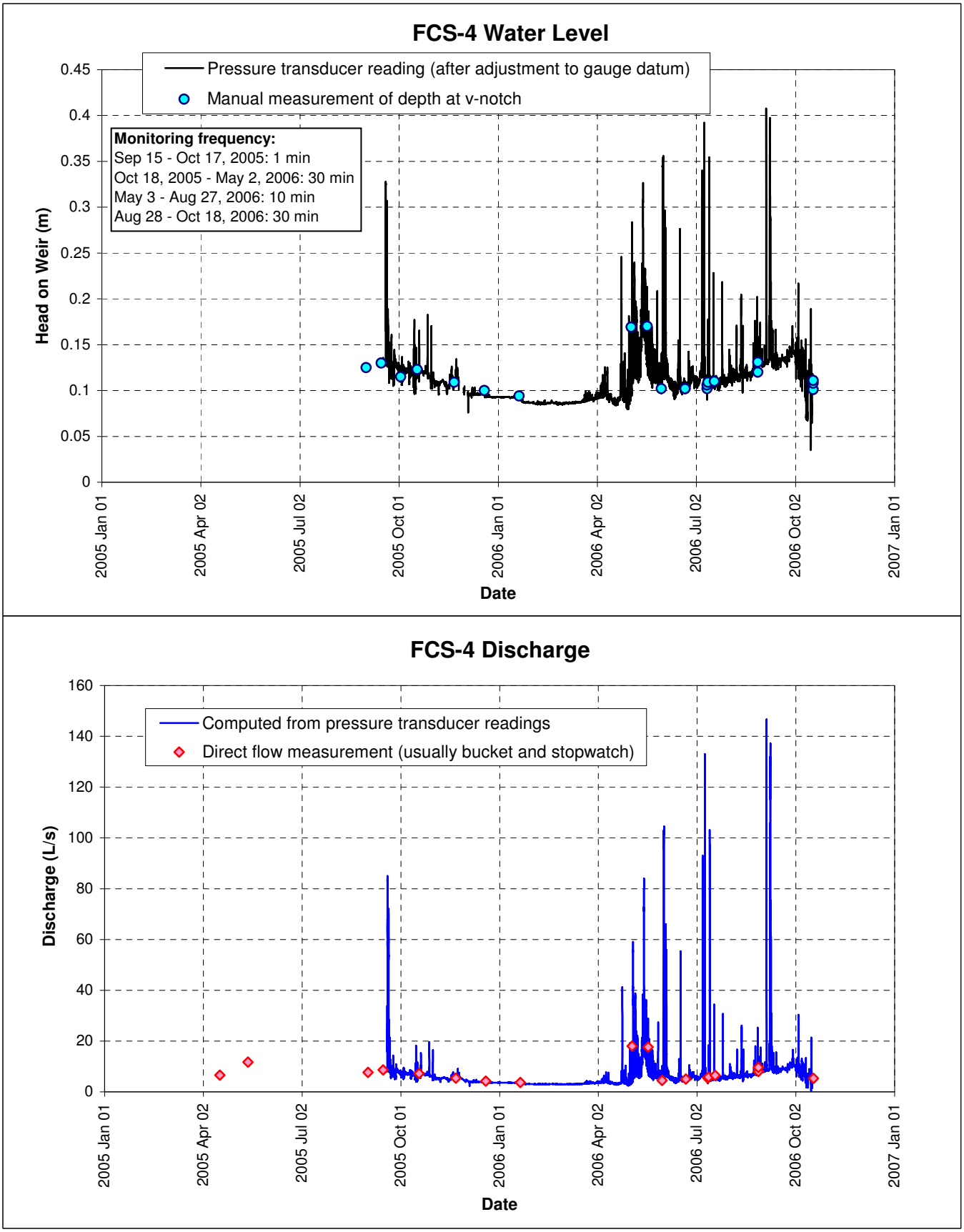


Figure 3.1-23 Stage and Flow Records for Station FCS-4

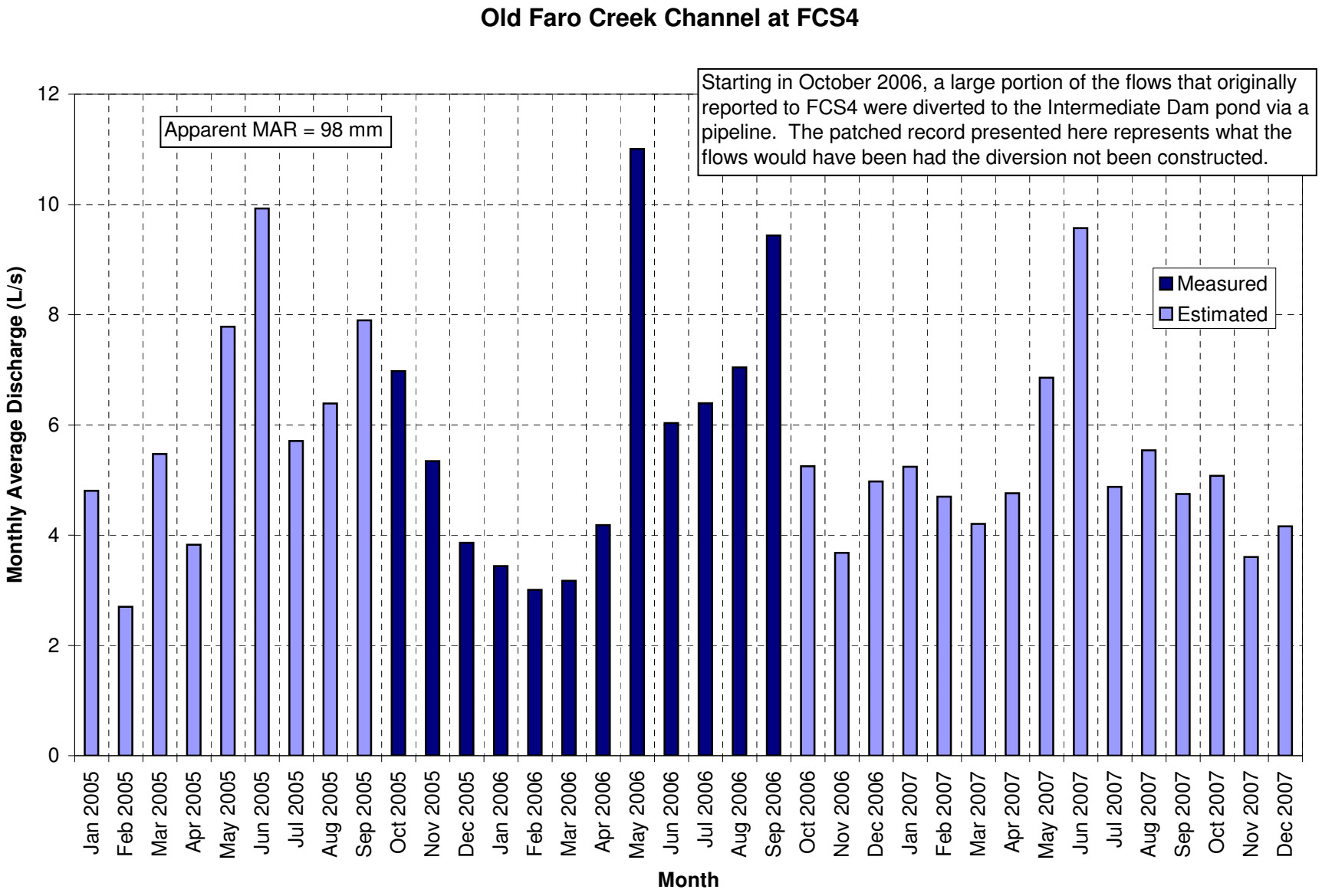


Figure 3.1-24 Patched Monthly Flow Record for Waste Dumps Draining To Old Faro Creek Channel

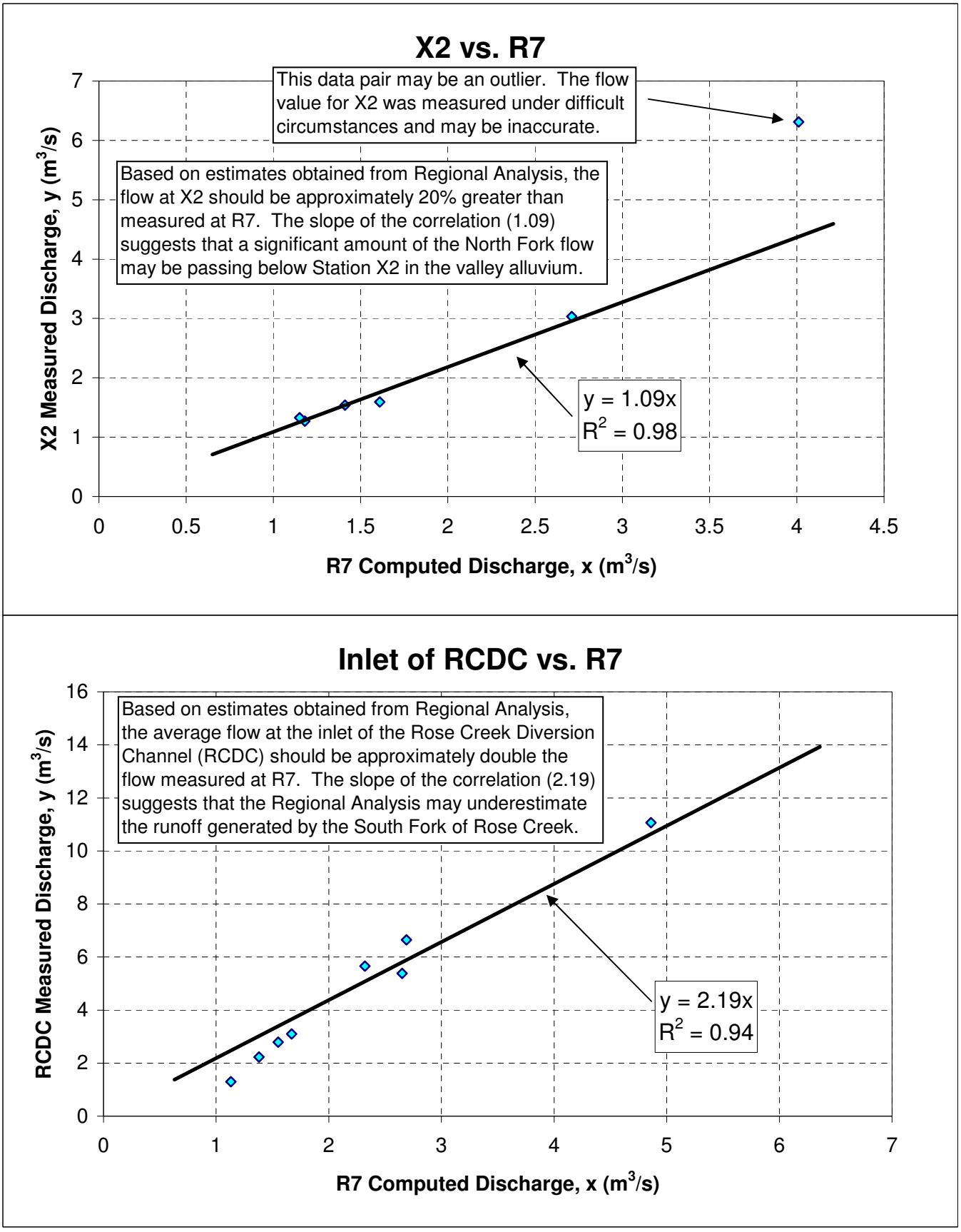


Figure 3.1-25 Comparison of Coincidental Flows at X2, Inlet of RCDC and R7

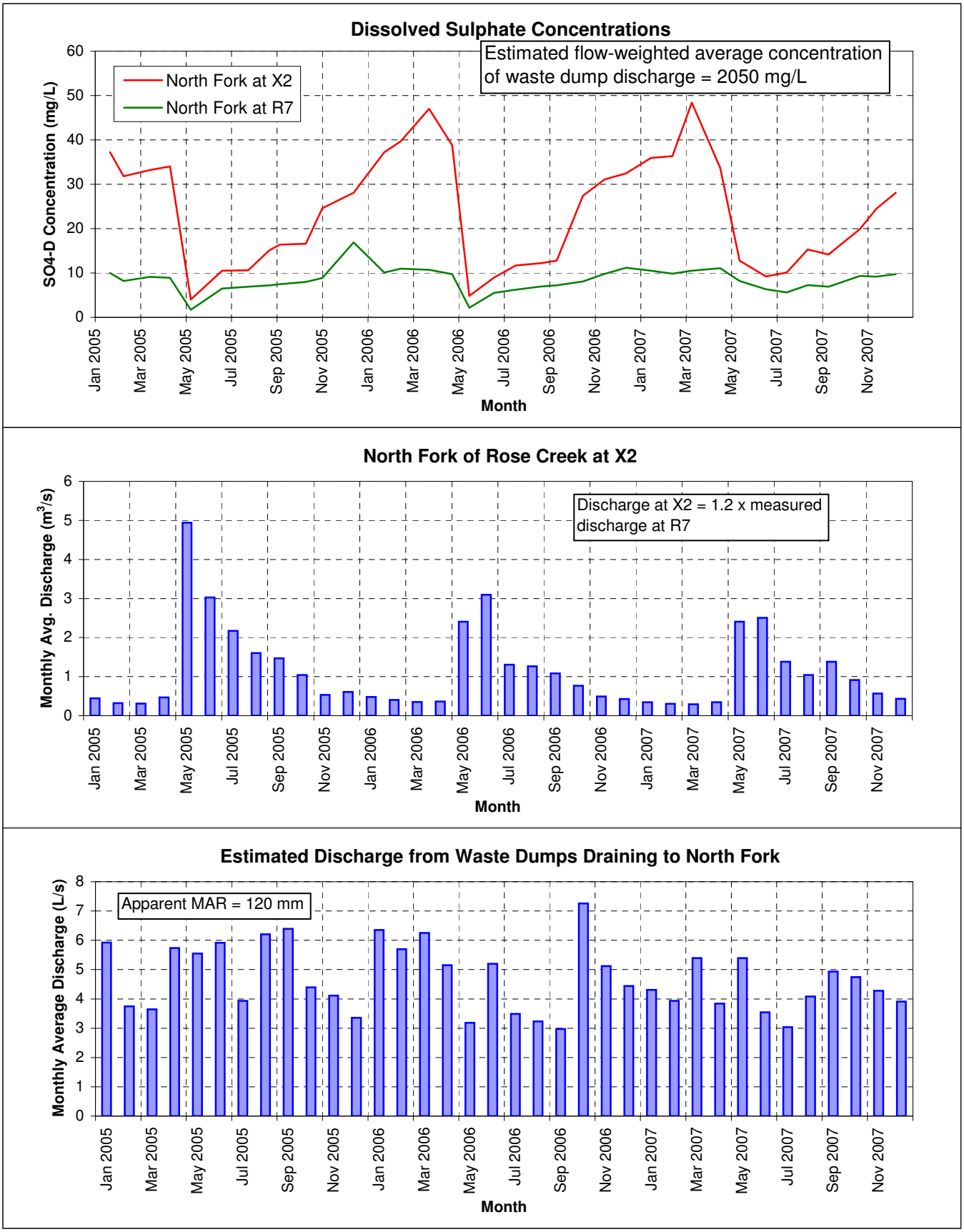


Figure 3.1-26 Estimation of Waste Dump Runoff to North Fork Using a Two-Component Mixing Model

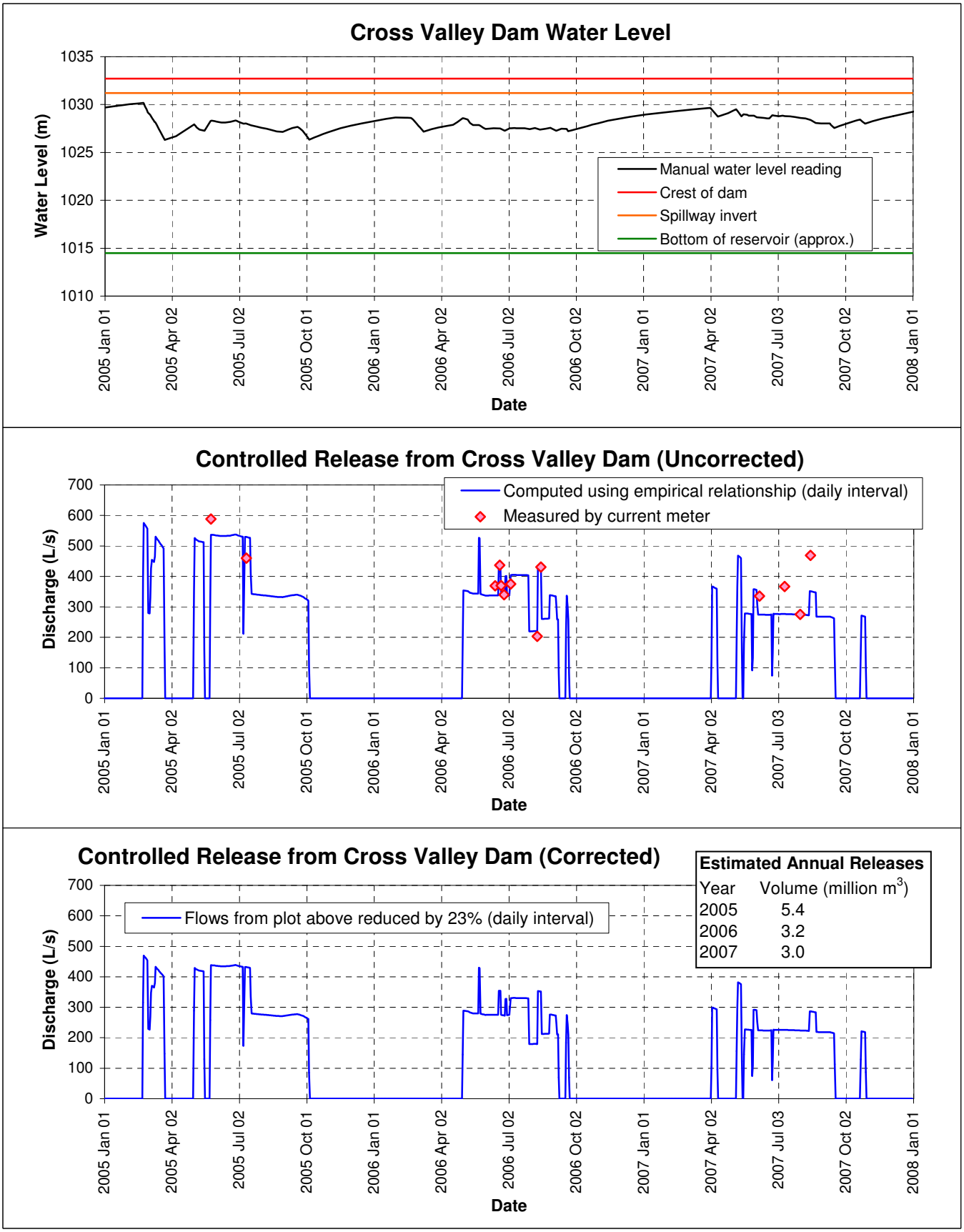
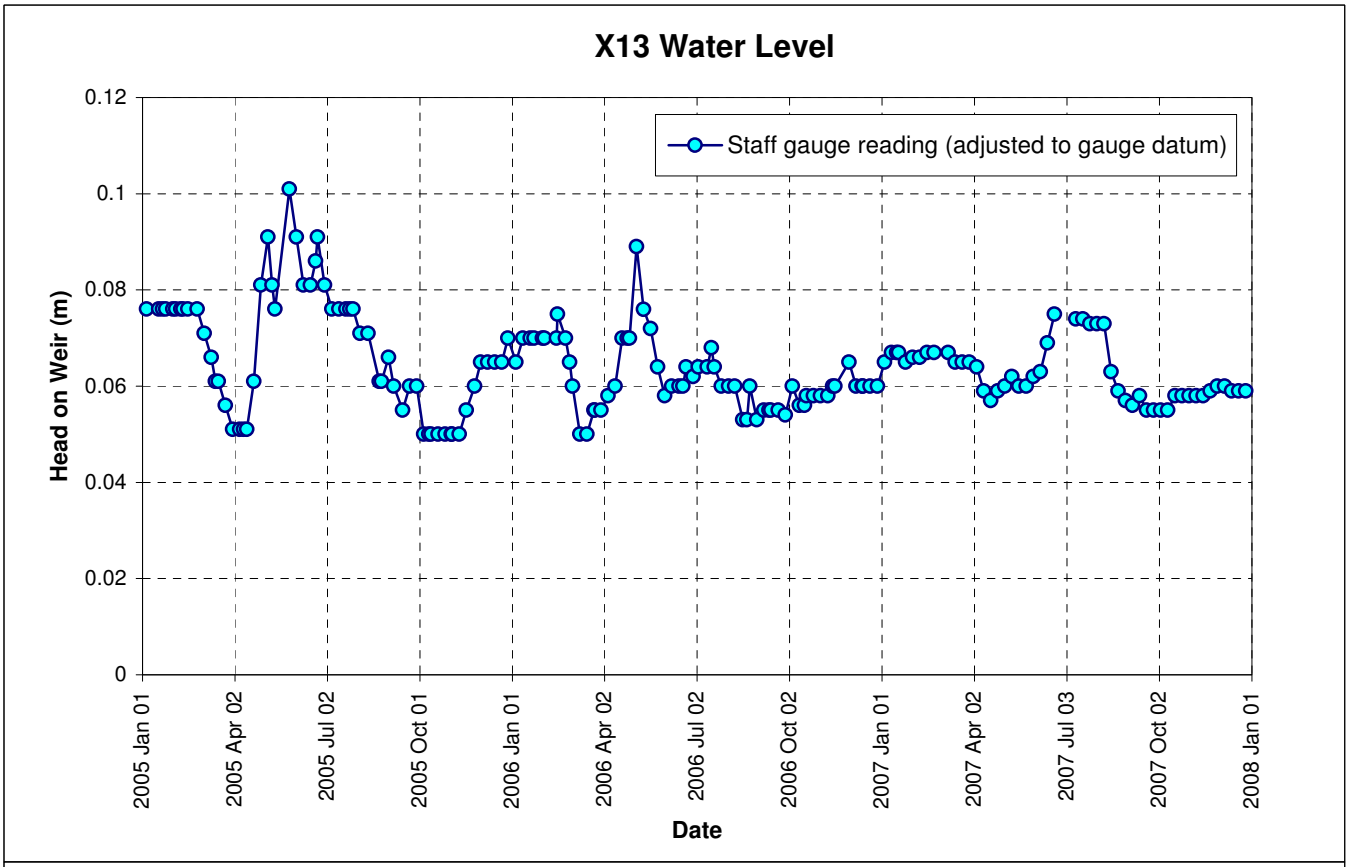


Figure 3.1-27 Reservoir Water Level and Controlled Release Records for Cross Valley Dam (2005 to 2007)



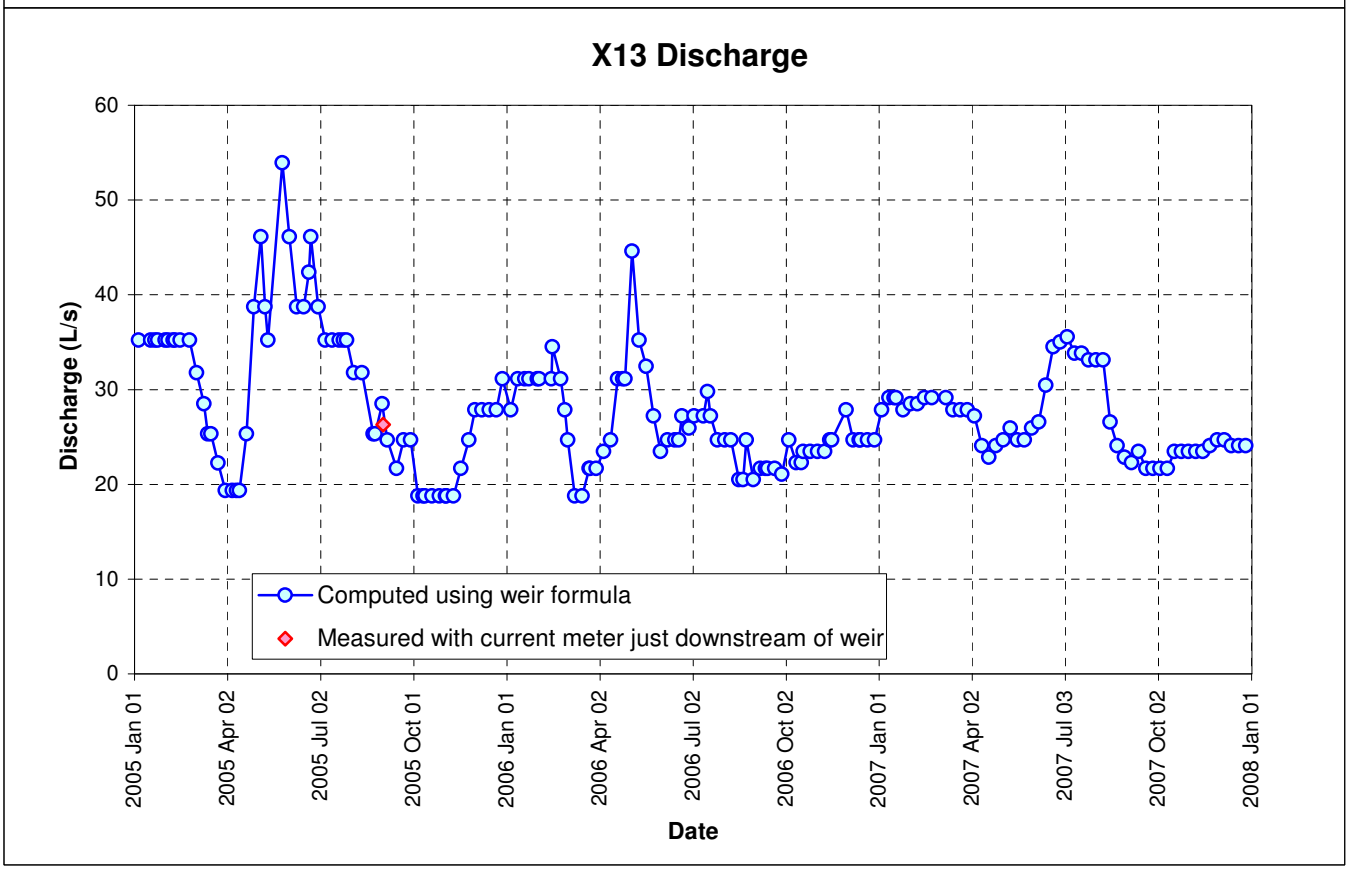


Figure 3.1-28 Weekly Spot Measurements of Dischage at X13 (2005 to 2007)

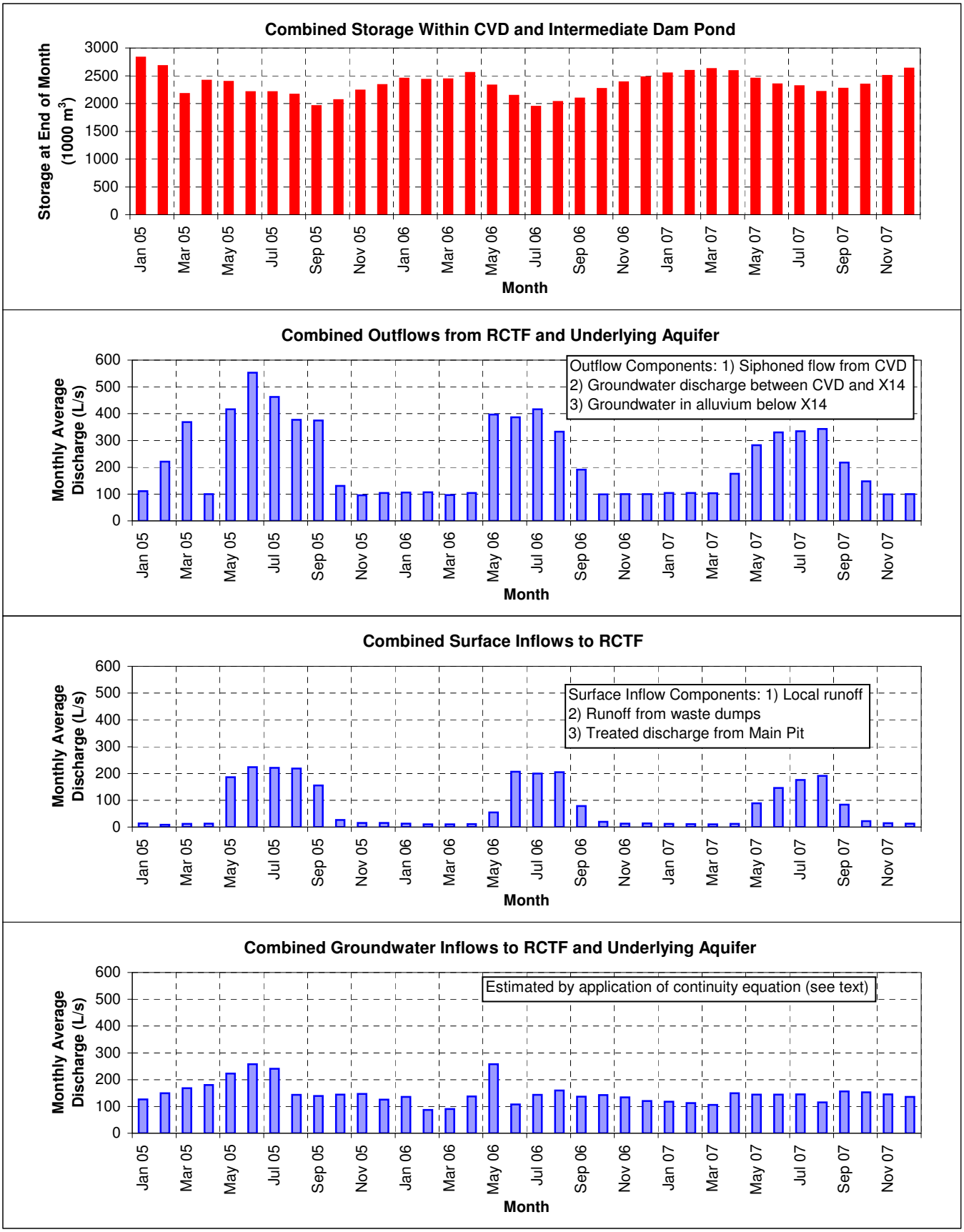


Figure 3.1-29 Water Balance for Rose Creek Tailings Facility and Underlying Aquifer (2005 to 2007)

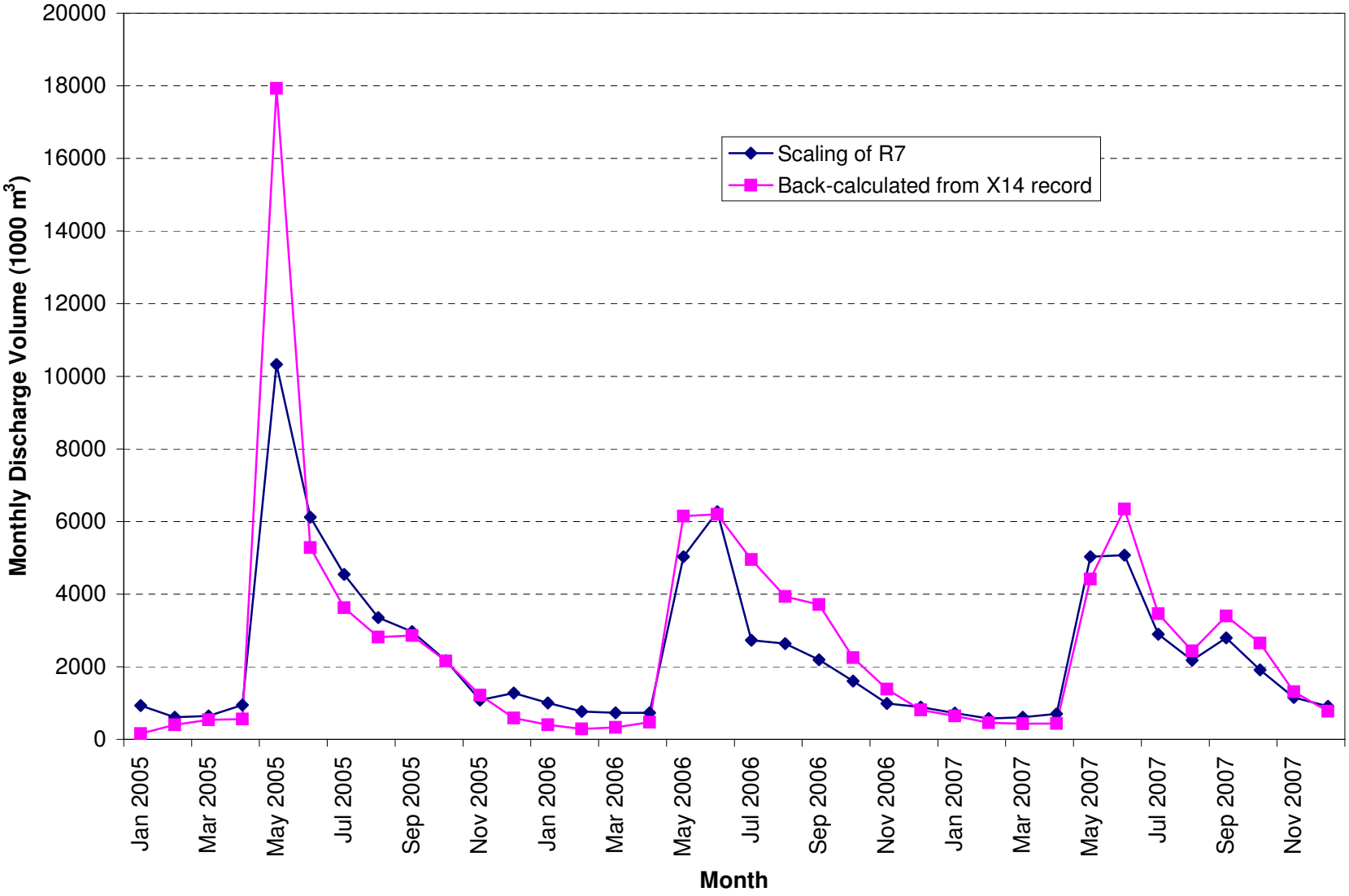


Figure 3.1-30 Estimated Runoff Generated by Subcatchment G

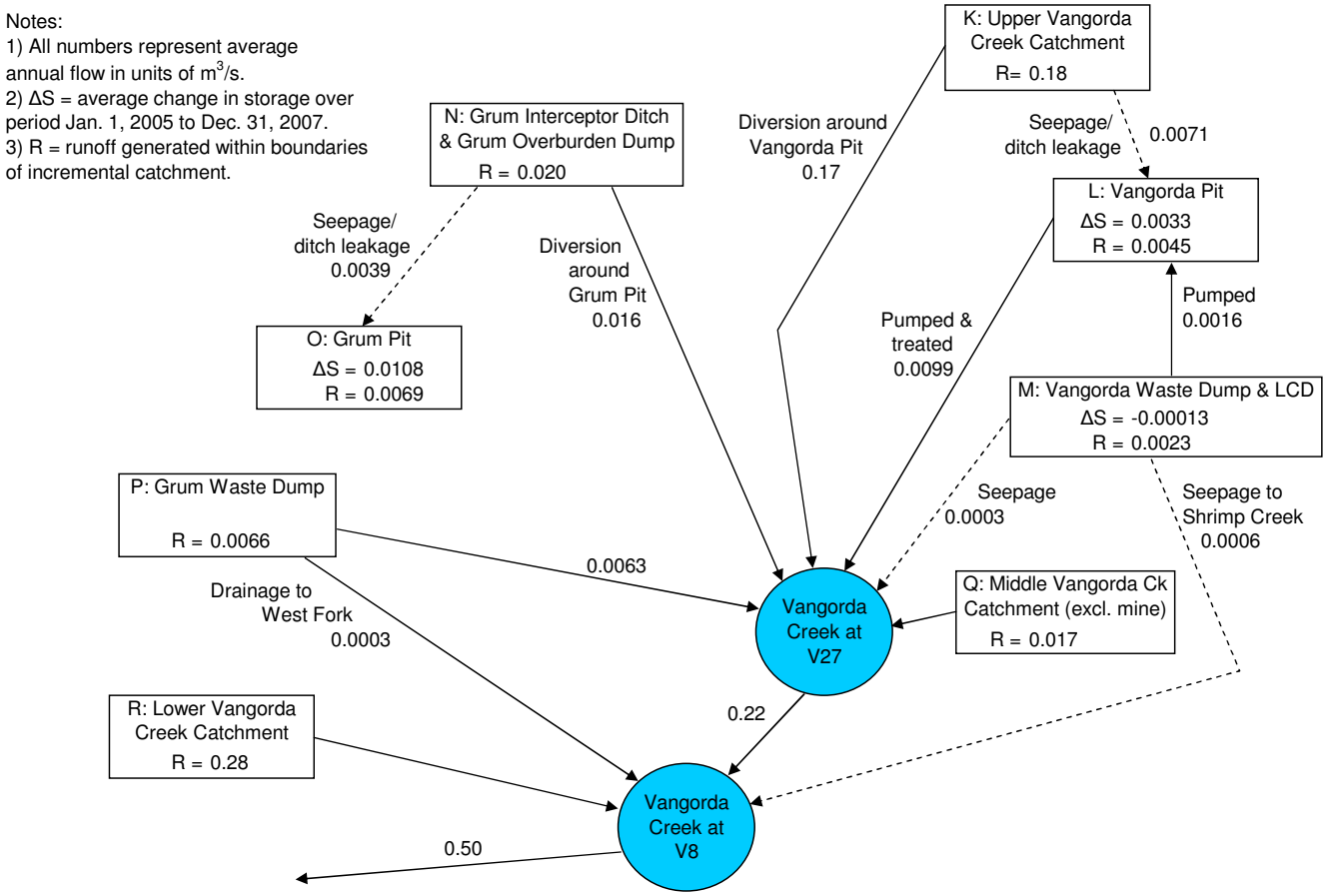


Figure 3.1-31 Average Annual Water Balance for Vangorda Creek Catchment (2005 to 2007)

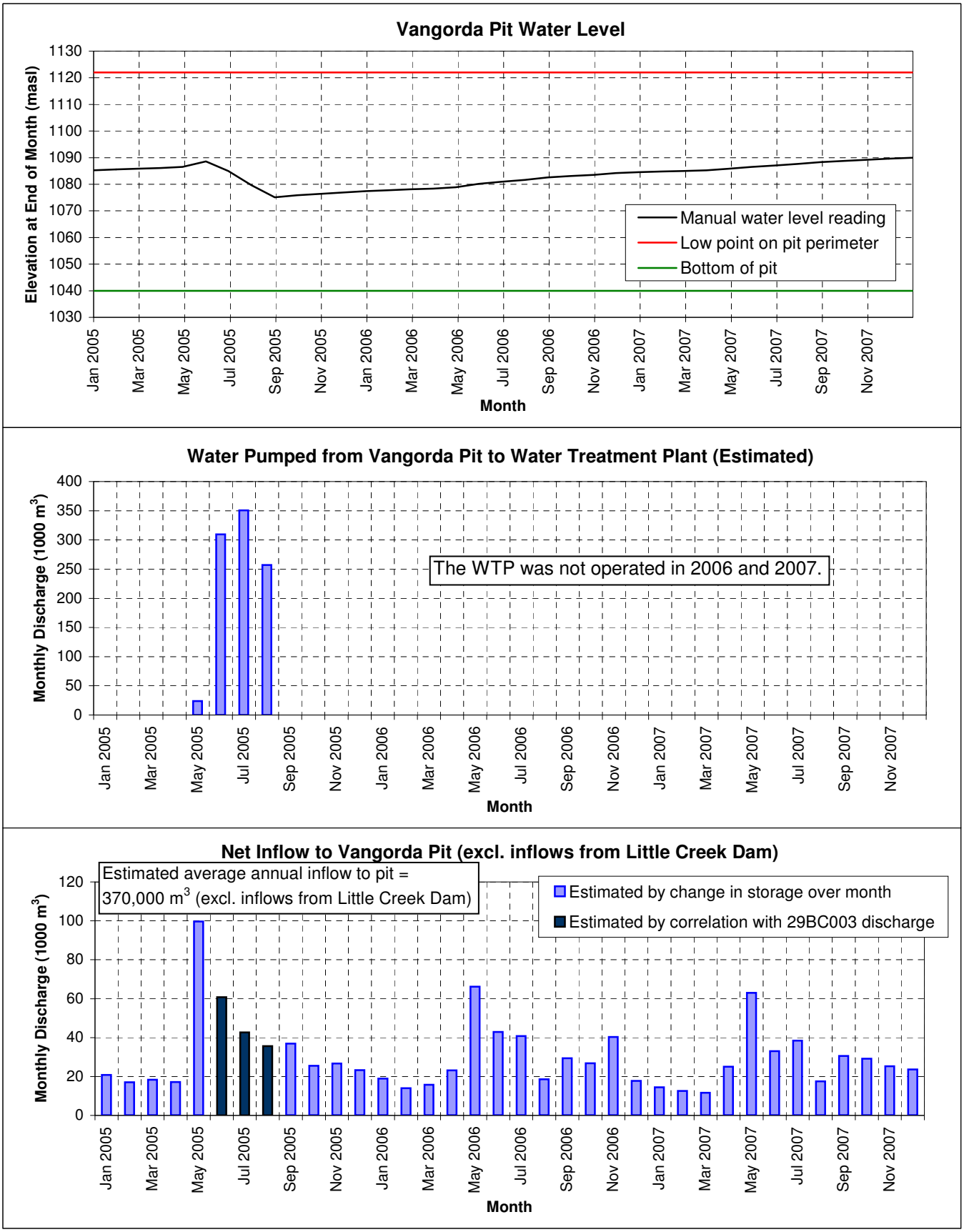


Figure 3.1-32 Water Balance for Vangorda Pit (2005 to 2007)

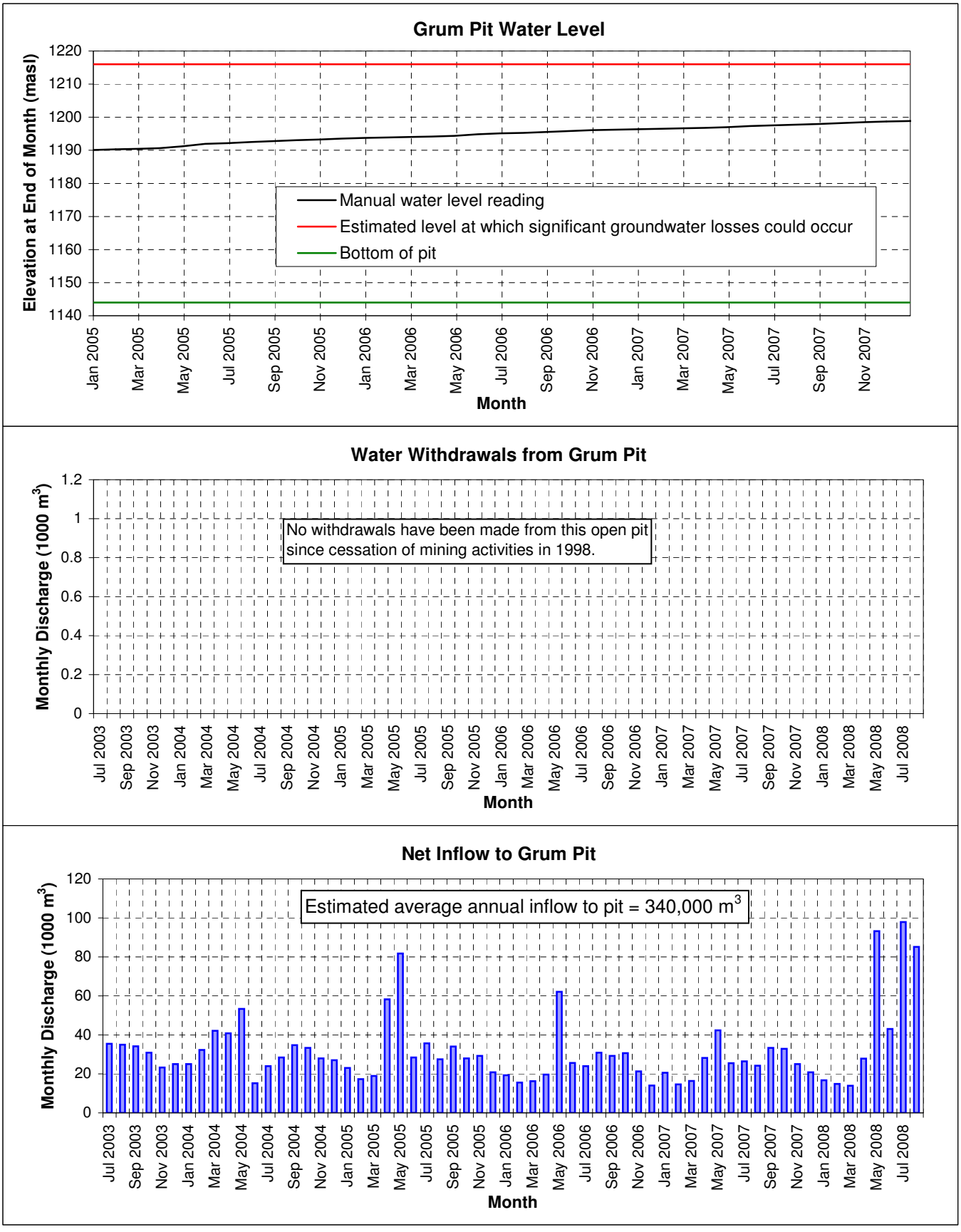


Figure 3.1-33 Water Balance for Grum Pit (2005 to 2007)

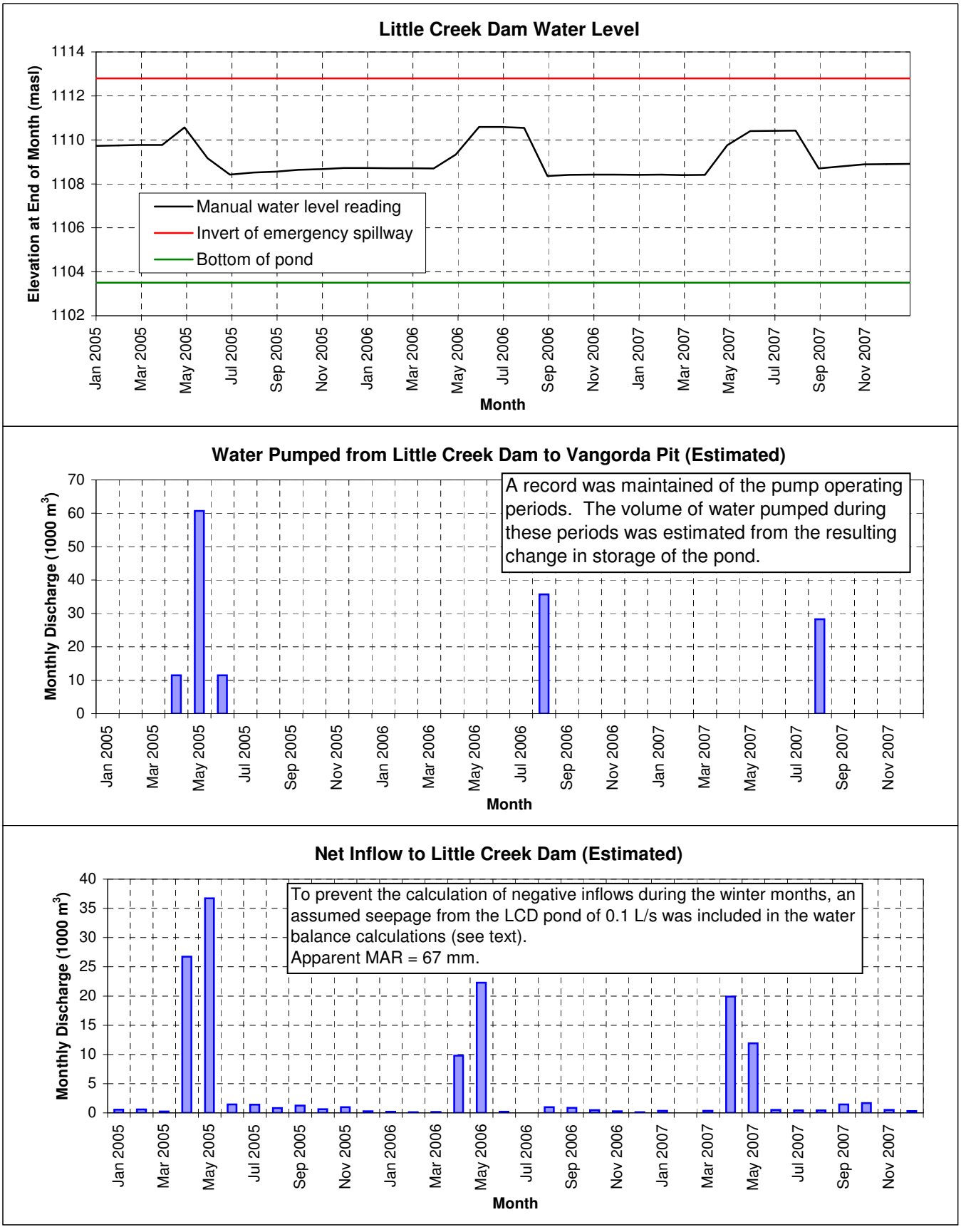


Figure 3.1-34 Water Balance for Little Creek Dam (2005 to 2007)

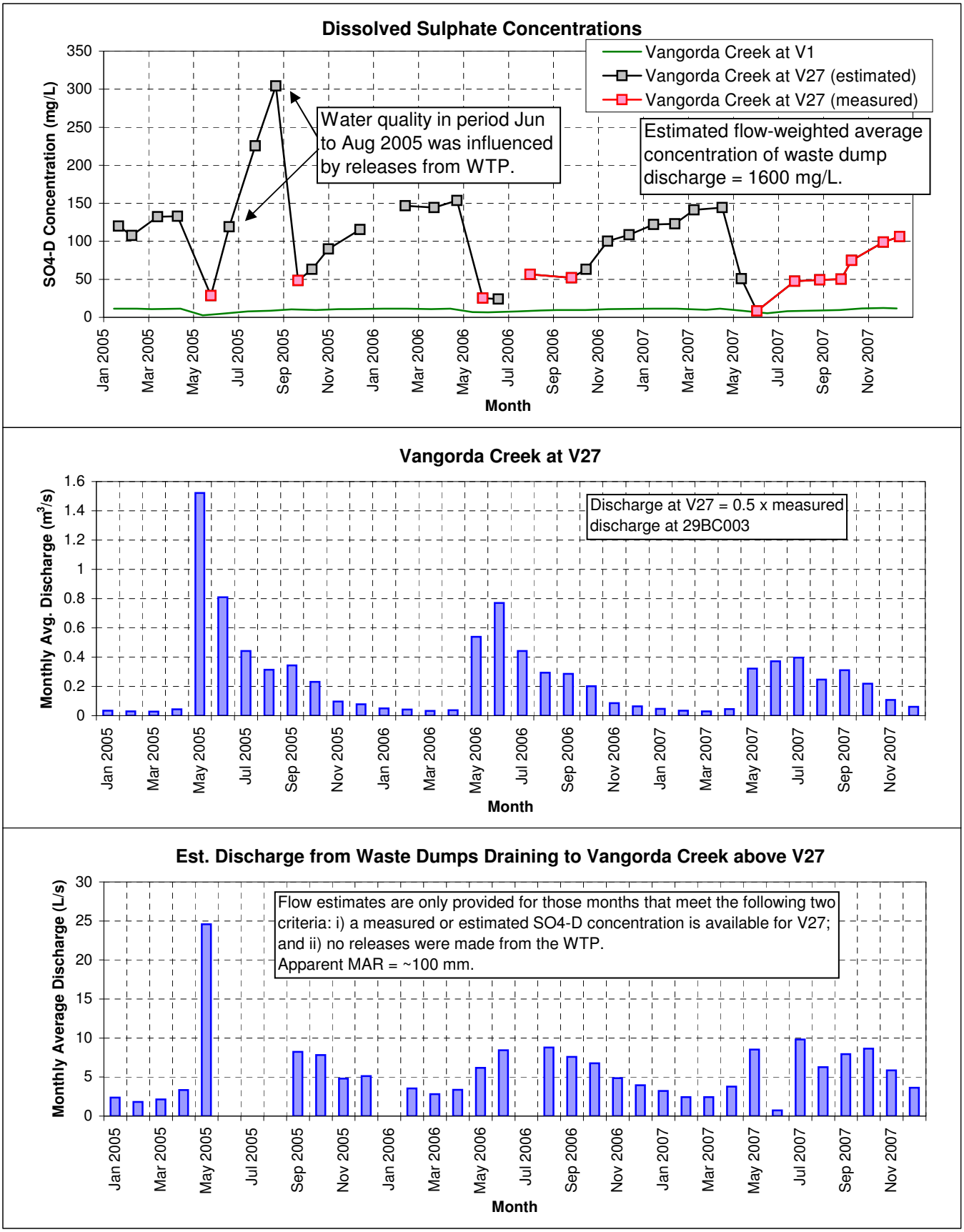


Figure 3.1-35 Estimation of Waste Dump Runoff to Vangorda Creek Using a Two-Component Mixing Model

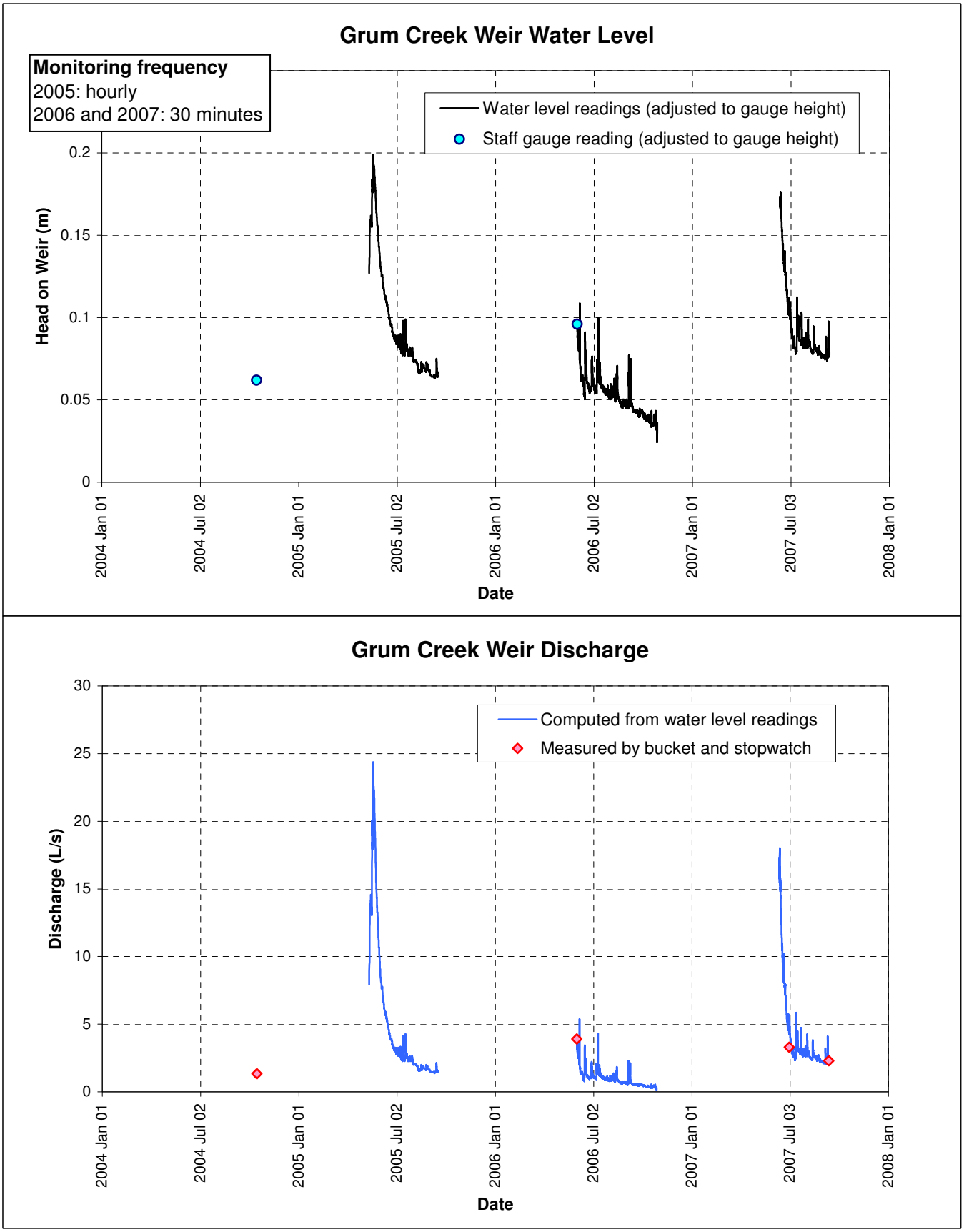


Figure 3.1-36 Stage and Flow Records for Grum Creek above Road Crossing

Table 3.1-1 Details of Streamflow Gauging Stations Operated by WSC and EY

Streamflow Gauging Station		Period of Record	Catchment Area	Catchment Median Elevation	Mean Annual Runoff For Period 1966 - 1995	
ID No.	Name		(km^2)	(m)	(m^3/s)	(mm)
WATER SURVEY OF CANADA (Total Catchments, Year-round Operation)						
09AH003	Big Creek near the mouth	1974 - 2007	1750	1070	8.3	150
09AG001	Big Salmon River near Carmacks	1953 - 1996	6760	1300	67.7	316
09AH005	Drury Creek at km 469 Robert Campbell Highway	1994 - 2007	559 [1]	1250	5.37	303
09AC007	Ibex River near Whitehorse	1989 - 2007	457	n/a	1.99	137
09BB002	MacMillan River near the mouth	1984 - 1996	13800	1130	135	309
09AD001	Nisutlin River above Wolf River	1979 - 1995	8030	1260	88.5	348
09AH004	Nordenskiold River below Rowlinson Creek	1982 - 2007	6370	1090	14.9	74
09BA002	Pelly River below Fortin Creek	1986 - 1994	5020	1290	70.8	445
09BC002	Pelly River at Ross River	1954 - 1974	18400	1160	177	304
09BC004	Pelly River below Vangorda Creek	1972 - 2007	22100	1210	201	287
09BC001	Pelly River at Pelly Crossing	1952 - 2007	49000	1110	390	251
09BC003	Rose Creek below Faro Creek	1966 - 1969	208	1430	2.08	316
09BA001	Ross River at Ross River	1960 - 2007	7250	1130	67.2	293
09AD002	Sidney Creek at km 46 South Canol Road	1982 - 1994	372	1250	4.13	350
09AG003	South Big Salmon River below Livingstone Creek	1982 - 1996	515	1340	4.02	246
09BB001	South MacMillan River at km 407 Canol Road	1974 - 1996	997	1440	19.7	624
09BC005	Tay River near the mouth	1990 - 1995	3810 [1]	1160	24.7	205
09AA012	Wheaton River near Carcross	1956 - 2007	875	n/a	7.82	282
ENVIRONMENT YUKON (Total Catchments, Seasonal Operation)						
29BC004	Blind Creek near Faro	1992 - 2007	618	1180	3.32	170
29BA002	180 Mile Creek at km 295.8 North Canol Highway	1975 - 1993	97.9	1310	0.83	268
29BC003	Vangorda Creek at Faro Townsite Road	1977 -1985, 1989 - 2007	91.2	1210	0.55	190
WATER SURVEY OF CANADA (Incremental Catchments, Year-round Operation)						
09BC001 - 09BB002 - 09BC004 (Lower Pelly River catchment)		1984 - 1995 [2]	13100	1010	54	130
Lower Pelly R. catchment - 09BC005 (as above but excluding Tay R.)		1990 - 1995 [2]	9290	880	29.3	100
09BC004 - 09BA001 - 09BA002 (Middle Pelly River catchment)		1986 - 1994 [2]	9830	1200	63	202
09BB002 - 09BB001 (MacMillan R. catchment excluding headwaters)		1984 - 1995 [2]	12803	1100	115.3	284

Notes: 1) The Water Survey of Canada has not yet published official values for the catchment areas of these two new stations. The values presented in this table were measured from 1:250,000 scale topographic maps.

2) This is the period of overlap of the station records used to estimate the runoff from the incremental catchment.

Table 3.1-2 ARMC Flow Monitoring Network

Flow Monitoring Station		Period of Stage Monitoring	Drainage Area (km^2)	Control	No. of Direct Discharge Measurements	Comments
ID No.	Name					
R7	North Fork of Rose Creek above Faro Creek Diversion	1996 to present (year round)	95	Channel	57	The record of direct discharge measurements (by current meter or salt dilution) extends back to 1989, and includes measurements made during winter months.
FDU	Inlet of Faro Creek Diversion	2007 to present (open water)	14.3	Channel	6 since 2008	The baseline hydrology study only made use of the stage and discharge data collected during 2008.
X2	North Fork of Rose Creek at mine access road	2005 to 2007 (open water)	120	Channel	9	Only the direct discharge measurements were used in baseline hydrology study. The stream stage was monitored seasonally during open water.
RCDC	Inlet of Rose Creek Diversion Channel	2004 to present (open water)	197	Channel	10	Daily manual staff gauge readings are made during open water season.
FCS-4	Mouth of Faro Creek Canyon	Sep 2005 to Oct 2006 (year round)	1.8	Sharp-crested weir	18	This station monitors flow from remnant section of Faro Creek that lies downstream of Main Pit and is largely buried by waste dumps. Most of the direct flow measurements were made by bucket and stopwatch.
X5	Controlled releases from Cross Valley Dam	Water level in pond has been monitored since at least 1999 (typically on a weekly basis)	n/a	Siphon	13 in period 2005 to 2007	Site personnel maintain records of pond level, operating period of siphon, and percentage opening of siphon valve. These data, together with spot measurements of flow below siphon outlet, were used to develop an empirical relationship for estimating outflow rate from the siphon.
X13	Combined seepage from Cross Valley Dam	1986 to present (year round at weekly interval)	n/a	Sharp-crested weir	3 in period 2005 to 2008	Investigations have demonstrated that the valley aquifer continues to discharge downstream of Station X13.
X14	Rose Creek below Rose Creek Diversion Channel	1990 to present (periods of both year-round and seasonal operation)	232	Channel	121	The stage record has many gaps, due either to malfunction of monitoring equipment or seasonal operation of station. Record of direct discharge measurements extends back to 1988.
V1	Vangorda Creek above Blind Creek Road (and above inlet of Vangorda Creek Diversion)	Jun 2008 to present (open water)	18.7	Channel	7	This station is located about 120 m upstream of where the water quality samples are taken for Station V1.
n/a	Grum Creek above road crossing	2005 to 2007 (open water)	0.82	Sharp-crested weir	4	The boundary of the catchment controlled by this station is uncertain because most of the contributing area is buried in waste rock. The weir is located approx. 600 m downstream of where Grum Creek emerges from the toe of the Grum Dump.
V27	Vangorda Creek above Shrimp Creek	None	29.7	Channel	15	Spot measurements are made at this site as part of a biological and sediment monitoring program conducted on Vangorda Creek every second year.
V8	Vangorda Creek above fan apex (approx. 850 m upstream of Pelly River)	1990 to 1992, 1999 to present (open water)	90.5	Channel	59	Station V8 is located approx. 1.9 km downstream of the streamflow gauging station operated by Environment Yukon (29BC003). Owing to their close proximity, the two stations monitor very similar flow rates. The baseline hydrology study relied mostly on the data collected at Station 29BC003 because of that station's longer and more complete data record.

Table 3.1-3 Details of Regional and Site-Specific Climate Stations

Station Name	Period of Record	Elevation (m)	Mean Annual Precipitation (mm)	Authority [1]	Information Applicable to Study
Anvil	1967 - 1991	1158	368	MSC	Precipitation
Faro Airport	1978 - 2007	717	313	MSC	Precipitation
Faro Dump	Dec 2003 - 2007	1225	357	EY	Humidity/ air temperature/ solar radiation/ rainfall/ snowpack depth
Grum Dump	Dec 2003 - 2007	1220	369	EY	Humidity/ air temperature/ solar radiation/ rainfall/ snowpack depth
Mayo Airport	1925 - 2007	504	306	MSC	Humidity/ air temperature
Pelly Ranch	1951 - 2007	454	310	MSC	Pan evaporation
Rose Creek	1975-85 & 2005-07	1080	n/a	EY	Snowpack depth and density
Ross River Airport	1962 - 1994	705	264	MSC	Precipitation
Whitehorse Airport	1942 - 2007	706	261	MSC	Humidity/ air temperature/ solar radiation/ pan evaporation
Williams Creek	1994 - 2005	850	~350	EY	Humidity/ air temperature/ solar radiation

Note: 1) MSC = Meteorological Service of Canada; EY = Environment Yukon

Table 3.1-4 Estimated Orographic Effect on Snowfall

Winter	Inferred Start of Snowpack Accumulation		Snow Course Survey			Accumulated Precipitation at Faro Airport from Start of Snowpack Accumulation to Snow Survey Date (mm)	Ratio of Snowpack Water Content to Accumulated Precipitation at Faro Airport
	Date	Indicator	Location	Date	Water Content of Snowpack (mm)		
2003/04	2003 Oct 24	Start of snowpack at Faro A	Near Faro Dump weather station	2004 Mar 11	173	121.2	1.43
2004/05	2004 Oct 19	Start of snowpack at Faro A	Near Faro Dump weather station	2005 Apr 12	95.1	110.6	0.86
2004/05	2004 Oct 19	Start of snowpack at Faro A	Rose Creek snow course	2005 Feb 24	128	102.3	1.25
2005/06	2005 Oct 25	Start of snowpack at Faro A	Rose Creek snow course	2006 Feb 26	75	62.6	1.20
2006/07	2006 Oct 14	Start of snowpack at Faro A	Rose Creek snow course	2007 Feb 26	73	62.7	1.16
2003/04	2003 Oct 24	Start of snowpack at Faro A	Near Grum Dump weather station	2004 Mar 11	147	121.2	1.21
2004/05	2004 Oct 8	Start of snowpack at Grum Dump	Near Grum Dump weather station	2005 Apr 12	123	120.4	1.02
Average Ratio (excl. two estimates based on SWE taken in April, 2005)							1.25

Table 3.1-5 Method Used to Estimate Winter Precipitation at Waste Dump Weather Stations

Month	Faro Airport			Faro Dump		Grum Dump	
	Water Equivalent of Snowfall (mm)	Rainfall (mm)	Precipitation (mm)	Precipitation (mm)	Dump/ Faro A	Precipitation (mm)	Dump/ Faro A
Jan 2004	31.1	0	31.1	38.9 +	1.25	38.9 +	1.25
Feb 2004	11.4	0	11.4	14.3 +	1.25	14.3 +	1.25
Mar 2004	42.6	2.4	45	55.8 +	1.24	55.9 +	1.24
Apr 2004	2.4	1.6	4	4.7 +	1.18	4.8 +	1.19
May 2004	6.4	12.4	18.8	14.7	0.78	28.7	1.53
Jun 2004	0	34	34	50.8	1.49	50.8	1.49
Jul 2004	0	13.5	13.5	31.8	2.35	30.7	2.28
Aug 2004	0	38	38	20.1	0.53	27.4	0.72
Sep 2004	7	41.5	48.5	61.5	1.27	62.2	1.28
Oct 2004	12	21.6	33.6	38.1 +	1.13	38.8 +	1.15
Nov 2004	9.8	0	9.8	12.3 +	1.25	12.3 +	1.25
Dec 2004	45	0	45	56.3 +	1.25	56.3 +	1.25
Jan 2005	26.7	0	26.7	33.4 +	1.25	33.4 +	1.25
Feb 2005	12.4	0	12.4	15.5 +	1.25	15.5 +	1.25
Mar 2005	2.6	0	2.6	3.3 +	1.25	3.3 +	1.25
Apr 2005	14.4	5.1	19.5	23.5 +	1.20	23.6 +	1.21
May 2005	0	58.6	58.6	36.1	0.62	48.3	0.82
Jun 2005	0	41	41	51.1	1.25	34.0	0.83
Jul 2005	0	83.8	83.8	76.7	0.92	77.0	0.92
Aug 2005	0	38.6	38.6	26.7	0.69	33.0	0.86
Sep 2005	0	36.6	36.6	32.8 +	0.90	38.9 +	1.06
Oct 2005	5.4	7.6	13	14.9 +	1.14	15.1 +	1.16
Nov 2005	29.6	0.4	30	37.4 +	1.25	37.4 +	1.25
Dec 2005	11.2	0	11.2	14.0 +	1.25	14.0 +	1.25
Jan 2006	10.8	0	10.8	13.5 +	1.25	13.5 +	1.25
Feb 2006	6	0.2	6.2	7.7 +	1.24	7.7 +	1.25
Mar 2006	12.4	0	12.4	15.5 +	1.25	15.5 +	1.25
Apr 2006	10.4	0.2	10.6	13.2 +	1.25	13.2 +	1.25
May 2006	1	42	43	30.0	0.70	43.7	1.02
Jun 2006	0	51.4	51.4	47.0	0.91	59.9	1.17
Jul 2006	0	27.9	27.9	38.6	1.38	49.0	1.76
Aug 2006	0	43.2	43.2	48.0	1.11	58.7	1.36
Sep 2006	0	26.6	26.6	25.1	0.95	29.2	1.10
Oct 2006	11.6	3.1	14.7	17.8 +	1.21	17.9 +	1.22
Nov 2006	21.4	0	21.4	26.8 +	1.25	26.8 +	1.25
Dec 2006	10.3	0	10.3	12.9 +	1.25	12.9 +	1.25
Jan 2007	11.2	0	11.2	14.0 +	1.25	14.0 +	1.25
Feb 2007	10	0	10	12.5 +	1.25	12.5 +	1.25
Mar 2007	12.2	0	12.2	15.3 +	1.25	15.3 +	1.25
Apr 2007	1.4	0.2	1.6	2.0 +	1.23	2.0 +	1.23
May 2007	12.6	4.8	17.4	13.7	0.79	19.8	1.14
Jun 2007	0	52	52	91.4	1.76	64.5	1.24
Jul 2007	0	43.5	43.5	60.5	1.39	62.7	1.44
Aug 2007	0	33.5	33.5	40.4	1.21	29.5	0.88
Sep 2007	11	41.1	52.1	77.0	1.48	68.6	1.32
Oct 2007	32.2	3.2	35.4	43.7 +	1.23	43.8 +	1.24
Nov 2007	8.2	0	8.2	10.3 +	1.25	10.3 +	1.25
Dec 2007	19.3	0	19.3	24.1 +	1.25	24.1 +	1.25
Average Annual (2004 to 2007)			**320**	**366**	**1.14**	**377**	**1.18**

Note: Patched values are denoted by a plus sign (+).

Table 3.1-6 Monthly Discharge Record for North Fork of Rose Creek at Station R7

Month	Monthly average discharge in m^3/s for:												Average (mm)
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
Jan		0.08	0.26	0.14	0.17	0.33	0.17	0.31		0.37	0.40	0.29	7.1
Feb		0.06	0.23	0.10	0.15		0.15	0.26		0.27	0.34	0.25	5.2
Mar		0.06	0.20	0.12	0.13		0.13	0.25		0.26	0.29	0.24	5.2
Apr		0.23	0.20		0.12			0.27		0.39	0.30	0.29	7.0
May		2.26	2.18	2.83	1.32	1.40		2.56		4.12			67.1
Jun			1.30	3.40	2.96	4.42	2.96	1.35		2.52		2.09	71.6
Jul			0.86	1.11	1.62	1.78	1.66	0.81		1.81		1.15	38.1
Aug		1.31	0.85	0.67	2.14	0.78	2.12	1.22		1.34	1.05	0.87	34.8
Sep		0.70	0.74	0.66	2.51			1.55		1.22	0.90	1.15	32.2
Oct											0.68		19.1
Nov													
Dec	0.13	0.25			0.53		0.39		0.38		0.35		9.5
Annual													**> 297.0**

Note: Before estimating this monthly record, the computed daily flows were subjected to a screening process to identify erroneous data caused by ice conditions. However, some errors may still exist. Caution should be exercised when using the winter flows (December to April) of this record to characterize the low flow regime o the North Fork of Rose Creek, particularly for winters when no direct discharge measurements were made.

Table 3.1-7 Monthly Discharge Record for Rose Creek at Station X14

Month	Monthly average discharge in m^3/s for:																Average (mm)
	1990	1991	1992	1993	1994	1995	1996	1997	1999	2000	2001	2002	2004	2005	2006	2007	
Jan		0.55	0.56								0.28						5.3
Feb		0.59	0.62				0.23	0.16		0.09							3.6
Mar		0.56	0.53	0.15			0.21	0.08		0.07	0.12			0.19			2.7
Apr		0.95	0.81	0.65			0.26	0.52		0.08		0.30					5.7
May		5.64		8.17	4.41	3.03	2.04	3.56		1.95		4.85			5.07	3.99	49.3
Jun		5.14		6.32	5.56	2.81	2.68	3.98		7.24		3.51		5.18	5.59	4.94	53.8
Jul		5.41		3.73	3.03	3.04	2.55	3.04	2.66	4.15				3.54	3.20	2.64	38.8
Aug		3.82		2.47	1.85	2.47	1.79	3.06	1.78	6.20				2.67	2.68	1.95	32.3
Sep		4.43		2.87	1.87	4.37	2.31	2.19	1.70	6.85			1.44	2.59	2.34	2.53	33.0
Oct	2.42	2.30		2.30	2.19	2.26	1.45	1.46		3.89					1.34	1.67	24.6
Nov	0.84	1.16			1.49	1.09		0.66		1.56							12.7
Dec	0.50	0.68						0.55			0.68						7.0
Annual																	**268.7**

Notes: i) For open water periods, a monthly average was only calculated for months with a maximum of 3 days of missing data. This criterion was relaxed for winter months, when flows undergo a slow recession.

ii) The flows in the winters of 1990/91 and 1991/92 include process water releases from the concentrator. Tailings deposition in the Faro Pit and process water recycle had not yet been implemented at the mine.

iii) Ice conditions can cause a significant alteration in the stream's relationship between stage and discharge, particularly during the occurrence of ice jams. Before estimating this monthly record, the computed daily flows were subjected to a screening process to identify erroneous data caused by ice conditions. However, some errors may still exist. Caution should be exercised when using the winter flows to characterize the low flow regime of Rose Creek, particularly for those periods when no or limited direct measurements are available to validate the flows computed from the pressure transducer readings.

iv) No complete months of data are available for Years 1998 and 2003.

Table 3.1-8 Validation of Patched Winter Flows for Station 29BC003

Date	Spot Measurement of Flow at V8	Patched Daily Average Flow at 29BC003
	(m^3/s)	(m^3/s)
1992 Jan 17	0.284	0.119
1992 Feb 28	0.153	0.094
1992 Mar 16	0.202	0.085
1992 Dec 22	0.10	0.097
2009 Jan 15	0.16	n/a
2009 Feb 05	0.12	n/a

Table 3.1-9 Estimated 7-Day and 365-Day Low Flows at Regional Streamflow Gauging Stations

Water Survey of Canada Streamflow Gauging Station		Period of Record	Drainage Area (km^2)	Mean Annual Runoff (mm)	Annual Minimum 7-Day Discharge ($L/s/km^2$) for Return Period of:				Annual Minimum 365-Day Discharge ($L/s/km^2$) for Return Period of:			
ID Number	Name				2 Years	10 Years	20 Years	50 Years	2 Years	10 Years	20 Years	50 Years
09AC007	Ibex River near Whitehorse	1989 - 2007	457	137	0.81	0.59	0.54	0.49	4.2	3.0	2.7	2.4
09AD001	Nisutlin River above Wolf River	1979 - 1995	8030	365	1.66	1.31	1.23	1.14	11.1	8.9	8.4	7.9
09AH004	Nordenskiold River below Rowlinson Creek	1982 - 2007	6370	70	0.39	0.25	0.22	0.19	2.0	1.2	1.0	0.9
09BC001	Pelly River at Pelly Crossing	1952 - 2007	49000	251	0.95	0.70	0.64	0.58	7.8	6.1	5.7	5.3
09BC004	Pelly River below Vangorda Creek	1972 - 2007	22100	284	0.97	0.69	0.61	0.52	9.0	6.9	6.2	5.6
09BA001	Ross River at Ross River	1960 - 2007	7250	287	0.82	0.59	0.53	0.47	9.0	7.0	6.5	6.0
09AD002	Sidney Creek at km 46 South Canol Road	1982 - 1994	372	361	1.82	1.15	0.98	0.80	11.0	8.8	8.3	7.8
09AG003	South Big Salmon River below Livingstone Creek	1982 - 1996	515	246	0.62	0.28	0.21	0.16	7.4	5.2	4.7	4.3
09BB001	South MacMillan River at km 407 Canol Road	1974 - 1996	997	636	1.19	0.62	0.49	0.38	20.1	16.2	15.1	14.0
09BC005	Tay River near the mouth	1990 - 1995	3810	238	1.01	0.71	0.64	0.55	7.9	5.1	4.3	3.4
09AA012	Wheaton River near Carcross	1956 - 2007	875	282	1.47	0.88	0.70	0.51	8.8	6.9	6.4	5.9

Table 3.1-10 Details of Subcatchments for Historical Water Balance Analysis

Subcatchment ID	Subcatchment Description	Drainage Area (km^2)	Catchment Median Elevation (mm)	Preliminary Estimate of MAR (mm)
ANVIL CREEK WATERSHED				
A	Drainage area controlled by Faro Creek Diversion (to point approx. 0.9 km upstream of the diversion outlet)	15.7	1520	353
B	North Fork of Rose Creek above X2 (excl. mine development and drainage area controlled by Faro Creek Diversion)	103	1450	325
C	Incremental catchment of Main Pit	2.15	1260	247
D	Incremental catchment of Zone II Pit	0.33	1160	206
E	Footprint of waste dumps draining to North Fork above X2	1.18	1150	202
F	Footprint of waste dumps draining to Rose Creek between X2 and X14 (incl. complete catchment of Station FCS-4 and contributing areas upstream of waste dumps)	2.5	1180	214
G	South Fork of Rose Creek and incremental drainage areas controlled by Rose Creek Diversion Channel and North Wall Interceptor Ditch (incl. reach of Rose Creek between CVD and X14)	102	1370	292
H	Incremental area controlled by Rose Creek Tailings Facility (excl. footprint of waste dumps)	4.1	1050	161
I	Incremental catchment of Rose Creek between X14 and the mouth	105	1280	255
J	Anvil Creek catchment excluding drainage area of Rose Creek	643	1310	267
VANGORDA CREEK WATERSHED				
K	Drainage area controlled by Vangorda Creek Diversion	20.2	1570	374
L	Incremental catchment of Vangorda Pit	0.80	1160	206
M	Catchment of Little Creek Dam (including drainage area controlled by Vangorda Waste Dump Collector Ditch)	0.72	1130	193
N	Drainage area controlled by Grum Interceptor Ditch (including Grum Overburden Dump and drainage area controlled by Vangorda Northwest Interceptor Ditch)	3.2	1300	263
O	Incremental catchment of Grum Pit	1.0	1300	263
P	Footprint of Grum Waste Dump (including contributing areas upstream of waste dump)	2.0	1250	243
Q	Incremental catchment of Vangorda Creek above V27 and below Vangorda Creek Diversion (excl. footprints of waste dumps, footprints of open pits and drainage area controlled by Grum Interceptor Ditch)	3.0	1130	193
R	Incremental catchment of Vangorda Creek between V27 and V8 (includes Shrimp Creek, West Fork and drainage area controlled by Vangorda Northeast Interceptor Ditch)	59.6	1130	193

Table 3.1-11 Estimated Flow-Weighted Average Sulphate Concentration for Waste Dumps Draining to North Fork

Item	Units	Northeast Waste Dump	Zone II Pit Waste Dump	Intermediate Waste Dump	Total
Stations used to characterize SO4-D concentrations emanating from waste dumps	n/a	NE1, NE2, W5, BH-12, BH-13 and BH-14	X26	S1, S2 and S3	n/a
Arithmetic average of SO4-D concentrations from above list of stations (C)	mg/L	508 [a]	2835	2914 [a]	n/a
Planimetric area of waste dump within catchment of North Fork (A)	km^2	0.44	0.33	0.74	1.51
Estimated proportion of waste dump effluent that reaches North Fork (f)	%	100	16 [b]	100	n/a
Effective catchment area draining to North Fork = A x f	km^2	0.44	0.05	0.74	1.23
Weighted concentration = C x A x f	$mg/L\text{-}km^2$	224	150	2156	2530
Estimated flow-weighted average SO4-D concentration	**mg/L**				**2052** [c]

Notes: a) The estimation of the average SO4-D concentration was a two step process. Firstly, an average concentration was computed for each water quality station listed in the first row of the table, using all SO4 determinations made during 2006. Secondly, an average of the station averages was determined to estimate typical quality of water discharging from the given waste dump.

b) The long-term average volume of water pumped from the Zone II Pit to the Main Pit is 1.6 L/s, based on reconstruction of this pit's historical water balance from 2005 to 2007. Based on application of Darcy's Law, the estimated seepage from the Zone II Pit to the North Fork is approximately 0.3 L/s (2005/06 Task 20e report prepared by SRK and RGC). Thus, the estimated proportion of total waste rock dump effluent discharging to North Fork = 0.3/(1.6 + 0.3) x 100 = 16%.

c) All waste dumps were assumed to generate the same average annual yield. Accordingly, effective catchment area could be used as a proxy for flow rate. To obtain a flow-weighted average concentration for all waste dumps draining to the North Fork, the concentration from each of the three waste dumps was weighted according to effective catchment area (i.e., Σ (C x A x f) / Σ (A x f)). For purpose of two-component mix model, the flow-weighted outflow concentration was assumed to remain constant year round and not exhibit an increasing trend over the period January 2005 to December 2007.

Attachment 6F-3
Fiscal Year 2012 Water Modelling Analysis Report (Section 2)

SECTION 2

Surface Water Flow Modelling

2.1 Surface Water Modelling Objectives

The FY12 objective of the SW flow modelling task was to develop a dynamic hydrological model of the FMC that would be used to provide a better understanding of the FMC hydrological characteristics and support FMC future design and investigation activities. A number of FMC design and investigative activities will be supported by the SW modelling efforts including, but not limited to:

- Stream channel diversion designs
- Regulatory-related information for the Yukon Environmental and Socio-economic Assessment Board (YESAB) project proposal
- Geochemistry and water quality evaluations
- Hydrogeology and GW interceptor designs
- Waste piles and tailings hydrology evaluations
- Water treatment evaluations
- Dam design and other major structures evaluations
- Environmental monitoring and reporting
- Revegetation and reclamation evaluations

Building on the CSM Report (CH2M HILL, 2012), the SW flow models have been used to define precipitation-runoff processes throughout the FMC. Existing physical site characteristics, meteorological data, and SW flow monitoring data were used to develop and calibrate the models. The models were then used to assist in characterizing the occurrence, conveyance, and management of SW within the FMC under varying assumptions of land use and meteorological conditions.

The main objective of the current SW flow modelling effort is to develop a calibrated tool that can be used to simulate precipitation-runoff processes from the FMC on a continuous, multiyear simulation basis. The focus of this model is to simulate the timing and magnitude of runoff events throughout the year, ranging from low-flow (i.e., base flow) conditions to peak flow conditions that occur during the spring freshet.

In addition to development of the hydrological model, the FWMT team is also currently completing hydraulic analyses of portions of the FMC, including the Rose Creek Diversion (RCD) and Cross Valley Dam (CVD). These analyses, including details related to hydraulic model development and results, are included in separate documents.

2.2 Surface Water Modelling Approach

The following tasks summarize the overall approach used to develop continuous SW flow models for the FMC:

1. Gathering and processing available information
2. Delineating regional and local FMC SW catchments
3. Developing SW flow models
4. Calibrating SW flow models

The following sections provide details regarding each of the modelling approach tasks.

2.3 Surface Water Data Sources and Review

2.3.1 Available Data and Sources

The development of a hydrological model involves three main categories of data. The first category consists of meteorological data, which are used to characterize precipitation processes including rainfall distribution and intensity, snow accumulation, and snowmelt. The second category consists of input data related to the definition of the catchment's physical characteristics, and the third category consists of flow data, which are used to calibrate precipitation-runoff processes that are derived from the first two categories of data.

Development and calibration of a hydrological model requires coincident meteorological and SW flow data. A preliminary review of available SW flow and meteorological data for the FMC indicated that the most suitable record of coincident data was available from approximately 2000 to present; therefore, compilation and analysis of data for the current SW flow model development effort focused on this timeframe, as described herein.

2.3.1.1 Meteorological Data

Meteorological data are available for two FMC stations that are operated by the site care and maintenance contractor. These stations are referred to as the Faro and Grum Dump stations, both of which were installed in 2003 and record the following parameters:

- Air temperature
- Relative humidity
- Incoming, outgoing, and net radiation
- Wind speed and direction
- Rainfall
- Snow depth
- Soil moisture
- Soil temperature and heat flux

In February 2008, instrumentation to record total precipitation (i.e., rainfall and snowfall) was added to each FMC meteorological station. Processed hourly data for the two stations; however, substantial gaps were identified in the data sets, as later sections of this report describe.

In addition to the Faro and Grum Dump stations, data were compiled from a station operated by Environment Canada at the nearby Faro Airport. Precipitation and air temperature were key parameters from this station that were used to develop the hydrological model. Figure 2-1 illustrates the locations for each of the aforementioned meteorological stations.

2.3.1.2 Surface Water Catchment Physical Data

Definition of physical catchment parameters includes data related to subcatchment area, vegetation cover, and subsurface soil conditions. These data are used to support the simulation of water cycle processes, including evapotranspiration (ET), evaporation, and infiltration. General geological mapping is available for the regional area; however, detailed information on vegetation and soil conditions for the FMC is limited, especially for the upper reaches of the regional catchment area. Available data were incorporated into the initial catchment parameterization, which formed the basis from which the calibration process was completed. Subsequent sections of this report provide details about physical catchment parameters.

2.3.1.3 Flow Monitoring Data

The following locations, shown on Figure 2-2, provide continuous flow monitoring within the Rose Creek drainage basin:

- FCD-1 at the head of the Faro Creek Diversion (FCD)
- R7 in the North Fork Rose Creek (NFRC) upstream from the FMC
- X2 in the NFRC upstream from the tailings facility

- X14 in Rose Creek, downstream from the tailings facility
- X23/FCS-1 below the Faro Valley waste rock dump (WRD)

The following locations, shown on Figure 2-2, provide continuous flow monitoring within the Vangorda Creek drainage basin:

- V1 in Vangorda Creek, upstream from the Vangorda Pit
- V8 in Lower Vangorda Creek at the footbridge
- V27 in Vangorda Creek, upstream from the confluence with Shrimp Creek

In addition to operating continuous SW flow monitoring stations, the care and maintenance staff have implemented a field program that includes collecting spot-flow measurements at various locations throughout the FMC monthly during the ice-free season. Data from this monitoring program were also incorporated into the development and calibration of the FMC hydrological models.

2.3.2 Data Review

Available physical catchment, meteorological, and flow data were reviewed in detail to determine the quality and suitability of this information for the development of the hydrological models. Observations and conclusions from this review are detailed in this subsection.

2.3.2.1 Faro Mine Complex Meteorological Station Data Review

The review of the FMC meteorological station data focused on the reported air temperature, rainfall, snow depth, and precipitation records.

Air Temperature Record

The air temperature records were reviewed from a data quality perspective, primarily to identify significant data gaps and to identify potential data errors through comparison with concurrent data recorded at the Faro Airport station. Based on this review, the air temperature data record for the Faro Dump and Grum Dump meteorological climate stations was determined to be stable and within climate normals for the region. Several significant gaps in the air temperature record were identified during this data review, primarily in the fall of 2008 and fall of 2009.

Rainfall Record

Both the Faro Dump and Grum Dump meteorological stations record rainfall. The rainfall record provided for these stations was reviewed for significant data gaps and extreme events significantly (i.e., greater than 30 percent) outside of climate normals. Outliers identified within the two records were compared with measurements recorded at the Faro Airport Station, regional climate normals, extreme events of record onsite, and records from the FMC continuous flow monitoring stations. Outliers were also compared to available reports that document extreme events at the FMC for the purposes of design work. Previous work indicates that the FMC can experience precipitation events greater than those recorded at the Faro Airport. For this analysis, events that were 30 percent greater than regional climate normals (as reported by Environment Canada at the Faro Airport Station) were flagged for further investigation. A decision was made whether to remove an outlier from the record only after further investigation and comparison with available data. This approach was deemed to be a reasonable approach for the purposes of constructing input data sets for the hydrological model. This review identified several data gaps and outliers requiring additional investigation.

Snow Depth Record

The Faro Dump and Grum Dump meteorological stations do not record snowfall in water equivalents but do record the total snow depth using an ultrasonic sensor. This record was reviewed to determine whether it was sufficient to estimate the contribution of snow to the total precipitation record at the FMC. The snow depth sensor record reports the depth of the snow pack hourly but does not report accumulated snowfall values. When processed to determine the hourly and daily accumulation of snowfall, negative values in snow depth accumulation are frequently reported. The negative values in the snow depth accumulation record were compared with the station's air temperature record to determine whether these events were potentially associated with melt events (i.e., when air temperature is greater than 0 degrees Celsius [°C]). In many cases, it

was determined that negative snow depth was not likely to have accumulated based on greater than zero temperature events. Therefore, the FWMT determined that this record contained too much variability and "noise" in the recorded data to accurately estimate the daily contribution of snow to the precipitation record.

Total Precipitation Record

Total precipitation (i.e., rain and snow) was not recorded at the FMC meteorological stations until February 2008. Total precipitation data, collected hourly between February 2008 and 2010, were obtained and reviewed. These data were processed to determine hourly and daily variations in total precipitation. Similar to the snow depth record, it was determined that negative hourly and daily precipitation totals were often included within the data set. Unlike the snow pack data, which could be influenced by melting conditions and therefore have negative values, total daily precipitation cannot be less than zero; therefore, the FWMT determined that this record could not be used for the development of the meteorological data input record.

In addition to reviewing the unprocessed meteorological data, the 2010 and 2011 FMC annual reports prepared by Denison Environmental Services (DES) were reviewed (DES, 2011, 2012a). These reports include daily total precipitation data and figures that illustrate hourly cumulative precipitation. These annual reports confirm the findings of the data review. The 2010 annual report identified that it is likely that the reported precipitation record is underestimating the total precipitation occurring at the FMC (DES, 2011).

2.3.2.2 Environment Canada Climate Database (Faro Airport Station)

A meteorological station is operated by Environment Canada at the Faro Airport. The location of this station is included on Figure 2-1. This station is located at elevation 717 metres (m), which is 508 m and 503 m below the Faro Dump and Grum Dump meteorological stations, respectively. Data from this station are available over a period between 1978 to present. To correspond with the period in which flow monitoring and meteorological data are available at the FMC, air temperature, rainfall, snowfall, and total precipitation data from the Faro Airport record, as well typical climate normals, were downloaded from Environment Canada. The data downloaded from this database are considered to be reliable because Environment Canada subjects field data to a quality control program prior to making the data available for download. The level of Environment Canada's quality review is documented within the data package.

The Faro Airport Station data set was reviewed for significant data gaps, as well as the station's suitability for filling data gaps in the FMC meteorological station data records. A large data gap in the FMC meteorological station data records was identified from 2002 to 2003, in addition to several month-long gaps. The Faro Airport record was compared to the Faro Dump and Grum Dump meteorological stations and was determined to be a suitable source for filling large data gaps within the FMC records.

2.3.2.3 Continuous Flow Monitoring Data

Continuous SW flow monitoring data were reviewed to determine their suitability for use in the hydrological model calibration. The location of the continuous flow monitoring stations is included on Figure 2-2. Table 2-1 summarizes the continuous SW flow monitoring data available and indicates years where significant data gaps exist during critical periods (e.g., spring freshet and significant precipitation events). The X marks that are highlighted in orange indicate years when gaps within the spring freshet and summer period exist, whereas rows that do not have an X mark indicate that no data are available at the given station in the given year. Rows with plain X marks indicate data that are adequate for model calibration.

TABLE 2-1
Continuous Flow Monitoring Data Available for the Surface Water Modelling Task
Faro Mine Remediation Project

Year	R7	X2	X14	X23/FCS-1	V1	V8
2011	X	X	X		X	X
2010	X		X		X	X
2009	X		X		X	X
2008			X	X	X	X
2007	X		X	X		
2006	X		X	X		
2005	X		X	X		
2004	X		X			
2003	X					
2002	X		X			
2001	X		X			
2000						

2.3.2.4 Summary of Available Data

As discussed, developing and calibrating a hydrological model requires coincident records of meteorological and flow data. Based on the review of various data sources described, Figure 2-3 summarizes available coincident data.

2.4 Surface Water Model Construction

2.4.1 Surface Water Model Code Selection

Hydrological models of the FMC were developed using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) Version 3.5 (USACE, 2010). This is a publicly available code that is widely used and is designed to simulate the precipitation-runoff processes of dendritic drainage basins. HEC-HMS is designed to apply to a wide range of geomorphic conditions and to solve a wide range of surface routing scenarios. The hydrological models were used to estimate SW runoff from the Rose Creek and Vangorda Creek drainage basins and from smaller subbasins within the FMC. Hydrographs produced by HEC-HMS will be used to forecast SW availability at downgradient locations of interest within the modelling domain.

2.4.2 Surface Water Model Domain

When developing hydrological models, the domain is defined by the overall catchment area tributary to the receiving point of interest. For the FMC, the domain is defined by flow monitoring station X14 in the Rose Creek drainage basin and by V8 in the Vangorda Creek drainage basin, as shown on Figure 2-4. Some catchment areas downstream from these monitoring stations were also delineated to account for all SW generated from the FMC. These regional basin delineations define the lateral boundaries for the SW flow models.

2.4.3 Surface Water Model Parameters

Using HEC-HMS, the FWMT developed a continuous hydrological model to simulate rainfall-runoff and snowmelt processes in both the Rose Creek and Vangorda Creek drainage basins under the existing FMC operational

conditions. The model was set up to compare runoff hydrographs at key locations in the system with available SW flow data. The calibration process involved adjusting subbasin parameters to best match the magnitude and duration of runoff events observed in the field.

The development of an HEC-HMS model includes selecting one or more meteorological models and one or more basin models. A meteorological model includes the air temperature and precipitation data, monthly ET, and snowmelt parameters that apply to a specific basin. A basin model is a physical representation of the watershed and may include elements such as: subbasins, channel reaches, storage elements, junctions, diversions, sources, and sinks. Subbasin elements are further defined by the various parameters that will affect runoff generation such as: surface and canopy losses, infiltration losses, precipitation-to-runoff transform methods, and base flow contributions. Channel reaches can be described using various geometries and hydraulic routing methods.

To analyze the FMC, two meteorological models were created: one for Rose Creek drainage basin and one for Vangorda Creek drainage basin. Four basin models were also created: one each for the Rose Creek and Vangorda Creek drainage basins during the winter period and one each for the Rose Creek and Vangorda Creek drainage basins during the summer period. The difference between the two meteorological models is reflected in the precipitation and melt-rate functions, whereas the difference between the two basin models for each mine site is related to the soil infiltration parameter.

The following subsections describe the processes applied to develop the input parameters for the HEC-HMS models. These parameters include the catchment area development, the meteorological record development (including air temperature, precipitation, evaporation and snowmelt data), and the physical catchment parameter development (including the precipitation loss parameters, runoff transform parameters, and base flow inputs).

2.4.3.1 Surface Water Catchment Development

The first step in the basin model development process was to delineate local FMC and regional catchments within the surface water model domain. Detailed light detection and ranging (LiDAR) data were available for the FMC, while only standard topographic information was available for the surrounding regional area. The elevation data for the FMC were collected at a resolution of 1 square metre (m^2) per pixel. The regional elevation data were not available at a similar resolution; therefore, the catchment development process was conducted in two stages.

LiDAR data were collected for the FMC on two separate occasions in 2012. These data provided a high-resolution data set of the FMC (1 m^2 per pixel). These data were used to develop a raster elevation data set, which was processed using the Flow Direction Spatial Analyst algorithm in ArcGIS Version 10.0. This resulted in a gridded data set that represents the flow direction from each raster cell to its steepest downslope neighbour. The flow direction data set was then processed using a Flow Accumulation Spatial Analyst algorithm to obtain a data set containing the accumulated flow in each raster cell. This process identifies likely SW drainage paths.

“Pour points,” representing known SW flow monitoring locations, were applied to the raster grid of SW flow paths. The ArcGIS tool calculated the boundaries for the area that is tributary to each pour point. The catchments were refined by repeating this process and adding or relocating pour points to reflect the known site conditions. Additional pour points were used to account for onsite conditions that may not have been reflected in the elevation data (e.g., culverts between catchments). This resulted in the delineation of a number of subdivided catchments to define onsite conditions. These were grouped together to form subcatchments reflecting the known site conditions. An attempt was made to select pour point locations and catchment boundaries that best fit the locations of continuous SW flow monitoring locations. This was done to better enable the calibration of the hydrological models using the existing SW flow records. The local catchments for the Faro and Vangorda/Grum areas are illustrated on Figures 2-5 and 2-6, respectively.

The most recent elevation model for the region surrounding the FMC predates the mining activity and is a lower resolution than the LiDAR data for the FMC. For this reason, the local FMC catchments were delineated first. The local FMC LiDAR data were merged into the regional elevation data to produce a hybrid elevation data set. This data set was processed as described in the previous section, resulting in a flow accumulation data set for the regional area, as well as the local catchments.

Pour points were selected in similar locations to those selected for the local catchment delineation exercise. In some cases, the same pour locations could not be used because of the differences in the pre- and post-mining elevations. The regional catchments were overlaid with those delineated for the FMC, and several iterations were performed until the regional catchment boundaries were optimized against the local catchment boundaries delineated earlier.

Where exact boundary matches were not made using the geographic information system (GIS) algorithms, manual adjustments were made using available topographic information and aerial photography. When combined with the catchments delineated earlier for the FMC, the final catchments represent the areas draining to pour points; these, in turn, represent continuous SW flow monitoring locations. Figure 2-7 shows the final catchments used to develop the hydrological model.

Figure 2-8 and 2-9 depict node diagrams illustrating the conceptual hydrological model development for both the Rose Creek and Vangorda Creek drainage basin model, respectively. These node diagrams illustrate the interconnection of various subbasins, as well as key routing elements included in the model.

The basin models developed for the analysis only included subbasins and channel reaches. Attenuation provided by overland storage has not been explicitly modelled by a distinct storage element. Section 2.5.4 provides a discussion supporting this decision, specifically for the Rose Creek drainage basin.

The Rose Creek model consists of eight unique subbasins covering an overall catchment area of 23,163 hectares (ha). Note that nine subbasins are included on Figure 2-5, but that Subbasin RC9 is downstream of continuous flow station X14 and is therefore not included in the current model domain. Subbasin RC1, which at 9,874 ha is the largest subbasin, was used as the main calibration subbasin for the Rose Creek model because continuous SW flow data are available at station R7. R7 is located at the downstream point of this subbasin. The discharge from the Faro Water Treatment Plant (WTP), which is a tributary to the CVD Polishing Pond, was included in the form of a constant monthly hydrograph and represents the input for Subbasins RC8a and RC8b.

The Vangorda Creek models consist of five unique subbasins covering an overall catchment area of 8,737 ha. Subbasin VC1, which is 2,007 ha, was used as the main calibration subbasin for the Vangorda Creek model because continuous SW flow data are available at station V1. V1 is located at the downstream point of the subbasin.

2.4.3.2 Surface Water Routing

A simplified approach to routing was applied to the development of the hydrological model. The following reaches were simulated in the Rose Creek model, as illustrated in Figure 2-8:

- NFRC between Station R7 and the Haul Road
- NFRC between Station X2 and the confluence with the South Fork
- Rose Creek Diversion Channel (RCDC)/Rose Creek between the confluence of the North and South Forks and Station X14

The following reaches were simulated in the Vangorda Creek model, as illustrated in Figure 2-9:

- Vangorda Creek Diversion Channel
- Vangorda Creek downstream of the Diversion Channel to Station V27
- Vangorda Creek between Station V27 and Station V8

For each reach, several cross sections were generated based on LiDAR data. From these reaches, a representative, or average cross section was developed. LiDAR is unable to penetrate water; therefore, for channels that had standing water, cross sections were extrapolated by a depth of 0.3 m below the constant plane that represents the water surface elevation. The longitudinal slope of the reach was also calculated based on LiDAR data. Cross sections are coarsely represented in HEC-HMS via eight points (i.e., distance-elevation coordinates) to include both the channel and the adjacent floodplain. A Manning's roughness coefficient of 0.03 was applied to all sections in the model.

The simplified routing approach applied to development of the HEC-HMS model is considered suitable for the current analysis because a more detailed hydraulic model will be developed in subsequent stages of the FMC project to which hydrographs generated from the hydrological model will be routed.

2.4.3.3 Air Temperature Record

Two temperature records were developed for the FMC: one based on data collected at the Faro Dump Station and another for data collected at the Grum Dump Station. The temperature record for input to the hydrological model must represent a continuous daily record for an entire calendar year. Data gaps identified during the review process were filled using several methods and a number of steps, depending on the type of data gap.

The first step was to fill gaps in the Faro and Grum Dump stations air temperature records with the air temperature recorded at the Faro Airport Station. Where there were gaps in the FMC meteorological station records, for which there was no coincident data recorded at the Faro Airport Station, data gaps were filled as follows:

1. Data gaps consisting of 1 week to 1 month of consecutive missing data were patched using average daily air temperature from the period immediately before and after the data gap period.
2. Data gaps consisting of no more than 6 consecutive days of missing data were patched using the air temperature from adjacent days keeping the trend before and after the missing data point(s). For example, if the air temperature trend is increasing before and after the missing data point, the higher of the two adjacent data points was used to fill the data gap.

Work completed by Lewkowicz and Bonnaventure (2009) investigated the influence of topography on permafrost distribution and ground surface lapse rates at various sites throughout the Yukon Territory (YT), including Faro. They found that, although summer air temperatures shows normal lapse rates close to the standard environmental lapse rate of -6.5 °C per kilometre (km), winter lapse rates were found to be inverted by as much as +11 °C per km. They concluded that air temperature trends in the YT are influenced by topography at a variety of scales, with significant seasonal differences. Given the lack of temperature data at various locations throughout the regional catchment area, combined with potential temperature lapse rate inversions, the proposed methodology of temperature record development is considered appropriate for the current model development. Figures 2-10 and 2-11 show the complete air temperature records for input to the hydrological model, indicating the data points from each source for the Faro and Grum Dump stations, respectively.

2.4.3.4 Precipitation Record

This section describes the methodology applied to the development of the precipitation data set. As with the air temperature record, the precipitation input to the hydrological model must be on a continuous daily basis for a calendar year. Because of the limitations of the rainfall and snowfall records discussed in Section 2.3.2, various methods were applied to construct a complete precipitation record for input into the hydrological model. The precipitation record consists of the rainfall and snowfall (as rainfall water equivalent) records which, when combined, represent the total precipitation on site. Two precipitation data sets were developed, one for each area of the site (Faro Dump and Grum Dump stations).

Rainfall Record

The preferred data source is data collected at the FMC meteorological stations. The data collected at the Faro and Grum stations were converted to daily rainfall totals and reviewed for data gaps, as discussed in Section 2.3.2. These gaps were filled using the daily rainfall record from the Faro Airport Station. In the *Faro Mine Complex Closure and Reclamation–Project Proposal, Current Environmental Conditions Supporting Document* (AECOM Canada Ltd [AECOM], 2009), relationships were developed between the Faro Airport Station and the Faro Dump and Grum Dump stations. These correlations indicate that the Faro Dump and Grum Dump stations receive 6.79 percent and 10.01 percent more rainfall, respectively, than the Faro Airport Station. These correlations are limited to rainfall occurring between May and September; as such, they were only applied to fill gaps in the FMC rainfall records for that timeframe. If rainfall occurred at the Faro Airport Station between October and April, the correlation was not applied, and the unchanged Faro Airport rainfall record was used to fill data gaps occurring during that timeframe. This was compared with the air temperature record to confirm that rainfall was plausible during this period based on air temperature. Figures 2-12 and 2-13 show the rainfall records developed for the Faro Dump and Grum Dump stations, respectively.

Snowfall Record

As discussed in Section 2.3.2, the Faro and Grum Dump stations do not record snowfall. AECOM (2009) compares snowpack water content at the Faro and Grum Dump stations with accumulated snowfall at the Faro Airport Station. This analysis indicated that the dumps receive about 25 percent more snowfall (as a water equivalent) than the Faro Airport. It is recognized that orographic effects and impacts of blowing snow influence snow accumulation at the FMC; however, information beyond that provided in the 2009 AECOM report is not available to better estimate such effects. Therefore, to construct a snow record at the Faro and Grump Dump stations, snow depth recorded at the Faro Airport was increased by 25 percent and applied to both stations.

The following assumptions were made while developing the snowfall (as water equivalent) record:

1. To convert the snowfall (reported in centimetres [cm]) recorded at the Faro Airport Station to water equivalents, it is reasonable to assume a snow density of 1 cm equals 1 millimetre (mm) of water equivalent.
2. Where snowfall data are missing for winter months, it is reasonable to patch the data with average-day snowfall from the period of record for the missing dates.
3. It is reasonable to assume that, when snowfall data are missing during summer months (i.e., June to September), no snowfall occurred.

Where gaps exist in the Faro Airport Station records, the average day snowfall was used to patch data gaps. Figure 2-14 illustrates the snowfall record developed for the FMC.

Total Precipitation Estimate

The rainfall and snowfall data sets developed, using the described methodology, were used to compile complete precipitation data sets for each of the two FMC meteorological stations. The precipitation data for the Faro and Grum stations at the FMC are shown on Figures 2-15 and 2-16, respectively. When these data sets were reviewed, several outliers were identified and are shown on these figures.

Outliers were identified through comparison with climate normals reported by Environment Canada for the Faro Airport Station. If an extreme event occurred that was not documented in the available site records, it was determined to be a likely outlier. Where possible, these events were compared with the available continuous flow monitoring data collected on the FMC. If a similar increase in SW flow was not reflected in the data, the event was corrected using rainfall and snowfall data from one of the nearby stations.

Table 2-2 compares daily precipitation estimates, developed as described, for the Faro and Grum areas of the FMC, with climate normals for the region as reported by Environment Canada. This table also presents the percent difference from the Faro Airport Station for each area of the FMC.

TABLE 2-2
Comparison to Climate Normals
Faro Mine Remediation Project

		FMC – Faro Area		FMC – Grum Area	
Description	**Faro Airport**	**Estimate**	**% Difference**	**Estimate**	**% Difference**
Average Yearly Rainfall (mm)	214	215	0	225	5
Average Yearly Snowfall (cm)	112	162	37	162	37
Average Total Precipitation (mm)	316	377	17	387	20
Extreme Daily Rainfall (mm)	24.8	28	11	29	14
Extreme Daily Snowfall (cm)	12.8	17	27	17	27

Notes:
Faro Airport climate normals are for 1971 to 2000.
FMC Area comparison values are for the data available between January 2000 and December 2011 (excluding 2001 and 2002).

Some differences between the Faro Airport and FMC are expected due to elevation and orographic effects. The precipitation record is considered a reasonable estimate for this modelling exercise if the total annual precipitation is within 20 percent of climate normals recorded at the Faro Airport Station. The average total precipitation is 17 percent for the Faro Dump Station and 20 percent for the Grum Dump Station. The average yearly rainfall depths for all three locations are consistent. The key difference between the Faro Airport and the FMC data sets is related to the snowfall estimate. Snowfall is expected to be approximately 25 percent greater at the FMC as water equivalent; however, because of the procedures used to patch data gaps, the total snowfall in units of cm is approximately 37 percent greater. Because the total annual precipitation numbers are within 20 percent of the climate normals, this was determined to be acceptable.

The extreme daily rainfall and extreme daily snowfall climate normals were used to determine the outliers, as previously discussed. The comparison to climate normals shown in Table 2-2 does not include the data points identified as outliers. The extreme daily rainfall for both the Faro Dump and Grum Dump stations are between 10 and 15 percent greater than those reported at the Faro Airport Station. The FMC extreme daily snowfall is approximately 27 percent greater than those reported at the Faro Airport Station.

2.4.3.5 Evapotranspiration Data

ET, expressed in terms of total depth per month, is a combination of evaporation from the ground surface and transpiration by vegetation. The monthly ET data used in the model were obtained from AECOM (2009), as summarized in Table 2-3 for the Rose Creek Model and the Vangorda Creek Model.

TABLE 2-3
Monthly Evapotranspiration Data
Faro Mine Remediation Project

Month	Rose Creek Model ET (mm)	Vangorda Creek Model ET (mm)
January	0	0
February	0	0
March	10	10
April	30	32
May	48	47
June	50	56
July	48	57
August	26	30
September	20	20
October	5	4
November	0	0
December	0	0

2.4.3.6 Snowmelt Parameters

A variety of parameters are required to define the snowpack accumulation and snowmelt processes that can be simulated by HEC-HMS. In response to the atmospheric conditions, this accumulation and melt is simulated, and the resulting liquid water available at the soil surface is available as a hyetograph for the subbasin.

The Temperature-Index method was used for snowpack simulation within HEC-HMS, which is an extension of the degree-day modelling approach. The degree-day approach typically applies a fixed amount of snowmelt for each degree above freezing. The Temperature-Index method instead allows for a dynamic computation of the melt rate based on current atmospheric conditions and past conditions of the snow pack, which improves the

representation of the ripening of the snow pack. Through use of a cold-content parameter, this method also allows for liquid water to potentially freeze as it enters the snow pack, a result of the snow pack's existing cold content. The following points describe the snowmelt model parameters according to HEC-HMS User's Manual:

- **Px Temperature (°C) = 1 °C.** The Px temperature is used to discriminate between precipitation falling as rain or snow. The discrimination temperature is usually 1 to 2 degrees above freezing.
- **Base Temperature (°C) = 0 °C.** The difference between the base temperature and the air temperature defines the temperature index used in calculating snowmelt. The melt rate is multiplied by the difference between the base temperature and the air temperature to estimate the snowmelt amount. If the air temperature is less than the base temperature, then the snowmelt is zero. Typically, the base temperature should be 0 °C or close to it.
- **Wet Melt Rate (mm/°C-day) = 4.2 mm/°C-day.** The wet melt rate is used during times of precipitation when the precipitation is falling as rain at rates greater than the rain rate limit. It represents the rate at which the snow pack melts when it is raining on the snow pack.
- **Rain Rate Limit (mm/day) = 1 mm/day.** The rain rate limit discriminates between dry melt and wet melt. The wet melt rate is applied as the melt rate when it is raining at rates greater than the rain rate limit. If the rain rate is less than the rain rate limit, the melt rate is computed as if there were no precipitation.
- **Antecedent Temperature Index (ATI) Melt Rate Coefficient = 0.98.** The ATI melt rate coefficient is used to update the ATI melt rate index from one time interval to the next. A typical coefficient value is 0.98.
- **ATI Melt Rate Function.** The ATI melt rate function defines the melt rate values to use over the range of melt rate indexes that will be encountered during the simulation. Table 2-4 presents the ATI melt rate functions used in this analysis for the Rose Creek and Vangorda Creek models. The melt rate was found to have a significant impact on the shape of the hydrograph and therefore was used as a main calibration parameter.

TABLE 2-4
Meteorological Model ATI Melt Rate Functions
Faro Mine Remediation Project

ATI (°C-day)	Rose Creek Model Melt Rate (mm/°C-day)	Vangorda Creek Model Melt Rate (mm/°C-day)
0	0.80	0.80
50	0.80	0.80
100	0.65	0.50
150	0.65	0.50
500	0.65	0.50

Cold Limit (mm/day) = 20 mm/day. The cold limit accounts for rapid changes in temperature that the snow pack undergoes during high precipitation rates. When the precipitation rate exceeds the specified cold limit, the antecedent cold content index is set to the temperature of the precipitation. If the temperature is above the base temperature, the cold content index is set to the base temperature. If the temperature is below the base temperature, the cold content index is set to the actual temperature. If the precipitation rate is less than the cold limit, the cold content index is computed as an antecedent index. A typical cold limit value is 20 mm per day.

ATI Cold Rate Coefficient = 0.84. The cold content antecedent temperature index coefficient is used to update the antecedent cold content index from one time interval to the next. A typical coefficient is 0.84.

ATI Cold Rate Function. This function defines appropriate cold contents to use over the range of cold content index values that will be encountered in a simulation. The function used was provided as a default starting point from USACE personnel (Scharffenberg, 2011, personal communication). Unlike the melt rate function, the cold

rate function was not used as a significant calibration parameter. Table 2-5 summarizes the ATI cold rate function used for the Rose Creek and Vangorda Creek models.

TABLE 2-5
Rose Creek and Vangorda Creek Meteorological Model ATI Cold Rate Functions
Faro Mine Remediation Project

ATI (°C-day)	Cold Rate (mm/°C-day)
0	1.32
50	1.32
100	1.32
150	1.32
500	1.32

Water Capacity (%) = 5 percent. The maximum liquid water capacity specifies the amount of melted water that must accumulate in the snowpack before the liquid water becomes available at the soil surface for infiltration or runoff. Typically, the maximum liquid water held in the snow pack is on the order of 3 to 5 percent of the snow water equivalent, although it can be higher.

Ground Melt (mm/day) = 0 mm/day. Heat from the ground can cause snow melt, especially if the snow pack accumulates on ground that is only partially frozen or completely unfrozen. In these cases, the warm ground is insulated by the snow pack, and heat from the warm ground will cause the snow pack to melt. It was assumed that zero ground melt occurs at the FMC.

Published literature reflects uncertainty in winter sublimation in northern environments, with estimates ranging from 10 to 45 percent (Scenarios Network for Alaska and Arctic Planning, 2011). Water balance work completed on the FMC waste dumps indicated that sublimation was insignificant (Janowicz et al., 2006, 2008). In general, sublimation is more significant in areas where snow is intercepted by canopy. Snow depth information and data required to estimate sublimation are not available for much of the overall FMC catchment area. The HEC-HMS model does not quantify sublimation specifically. However, effects of sublimation have been accounted for in the model calibration process, as discussed in Section 2.5. During the calibration process, input parameters were varied, and resultant modelled runoff hydrographs were compared to observed data. Certain parameters had a more significant effect on the calibration processes than others. Any losses due to sublimation are accounted for via “overcompensation” of one or a combination of the various calibration parameters.

2.4.3.7 Canopy Storage

Canopy storage represents intercepted precipitation that is stored in the vegetation layer, which will evaporate during storm events. The canopy storage will first consume the potential ET, and unused ET will then be transferred to the surface and soil components. Once the canopy storage is filled, the remainder of the precipitation falls to the surface storage. If there is no representation of surface storage, or if the surface storage is filled up, it falls directly to the soil.

A final effective canopy storage value of 10 mm was applied to all subbasins within the models. This was determined through a calibration process that examined values higher and lower than 10 mm. There was considered to be no initial storage percentage already used at the beginning of the simulation.

2.4.3.8 Surface Storage

The surface storage parameter represents the depression ground surface volume where water can accumulate. Precipitation fall-through from the canopy layer or direct precipitation will accumulate in the surface storage and infiltrate up to the soil capacity. Runoff occurs when the precipitation rate exceeds the soil infiltration rate and the surface storage is fully used. Precipitation residing in the surface storage can infiltrate after the precipitation stops and is subject to potential ET after the ET from the canopy layer is used.

A final effective surface storage value of 10 mm was applied to all subbasins within the models. This was determined through a calibration process that examined values higher and lower than 10 mm. There was considered to be no initial storage percentage already used at the beginning of the simulation.

2.4.3.9 Soil Infiltration Loss Method

HEC-HMS provides 12 different methods describing soil infiltration losses. Some of the loss methods are more suitable for continuous simulations (e.g., Deficit and Constant and Soil Moisture Accounting methods), whereas others are more suitable for event based simulations (e.g., Soil Conservation Service [SCS] Nurve Number and Green and Ampt methods). By design, certain loss methods require a more detailed level of information in regard to the subbasin characteristics. The absence of this information can introduce a great deal of uncertainty into the calibration and can complicate the model calibration process. For this model, the Deficit and Constant Loss method was used. The Deficit and Constant loss method is suitable for continuous simulations and requires four input parameters. The parameters required in the Deficit and Constant Loss method are the initial and maximum deficits, the constant rate, and the percent imperviousness. The initial and maximum deficits are the initial and maximum amount of water the soil can hold; both are specified as depths. The constant rate (mm per hour [mm/hr]) defines the infiltration rate when the soil layer is saturated and can be approximated by the hydraulic conductivity of the soil as a starting point. Lastly, the percent of directly connected imperviousness area is required because no loss calculations are carried out on the impervious area. A final, directly connected impervious value of 10 percent was applied to all subbasins within the models. This was determined through a calibration process that examined impervious values from 0 to 10 percent. The final soil loss parameters that were developed through calibration for each subbasin are listed in Table 2-6.

TABLE 2-6
Rose Creek and Vangorda Creek Models Deficit and Constant Soil Loss Parameters
Faro Mine Remediation Project

Model	Initial Deficit (mm)	Maximum Deficit (mm)	Constant Infiltration Rate (mm/hr)	Imperviousness (percent)
Rose Creek Model (Winter)	0	10	0.1	10
Rose Creek Model (Summer)	0	10	0.35	10
Vangorda Creek Model (Winter)	0	10	0.02	10
Vangorda Creek Model (Summer)	0	10	0.35	10

2.4.3.10 Precipitation-runoff Transform

HEC-HMS provides seven different runoff transform methods. The runoff transform methods describe how excess precipitation is transformed into point runoff in the subbasin. The available runoff transform method choices include various unit hydrograph transformations, a kinematic wave transformation, and a linear quasi-distributed method. Again, the requirement of subbasin specific parameters influenced the decision to employ the most simplified runoff transform method possible—the SCS Unit Hydrograph—because the only parameter required was a hydrograph lag time. There is discussion around the suitability of each transform method for the type of expected simulation and nature of hydrograph in the HEC-HMS User's Manual (USACE, 2010). The application of SCS Unit Hydrograph may not be entirely supported for this case; however, the model results were found to be well calibrated to the observed results. The runoff transform method and parameters also did not prove to be a very powerful calibration parameter when compared to the precipitation loss parameters discussed previously. The SCS hydrograph lag time used for all subbasins was 50 minutes.

2.4.3.11 Base Flow

There are five different options for accounting for base flow into the model. Constant monthly base flow was chosen because the availability of continuous flow data provided an opportunity to observe the actual base flow in certain subbasins. Tables 2-7 and 2-8 summarize the base flow values applied to each of the subbasins in the Rose Creek and Vangorda Creek models, respectively. The continuous flow data sets for R7 and V1 were

examined, and representative base flow values were then applied to subbasins Rose Creek RC1 and Vangorda Creek VC1. These patterns were then factored to the other subbasins according to their relative areas compared to RC1 and VC1. Note that base flow rates and monthly distributions were selected based on analysis of multiple years of low-flow data at various flow monitoring stations. These values are not adjusted annually, which could result in a potential over- or underestimation of base flow contribution during dry or wet years, respectively.

TABLE 2-7
Rose Creek Model Monthly Base Flow Estimates
Faro Mine Remediation Project

Rose Creek Model Catchments	Area (ha)	Constant Monthly Base Flow (m^3/sec)
RC1	9,874	Dec-Apr: 0.3 May-Nov: 1.0
RC2	1,589	Dec-Apr: 0.05 May-Nov: 0.16
RC3	992	Dec-Apr: 0.03 May-Nov: 0.1
RC4	7,253	Dec-Apr: 0.22 May-Nov: 0.73
RC5	124	Dec-Apr: 0.003 May-Nov: 0.0125
RC6	1,842	Dec-Apr: 0.06 May-Nov: 0.18
RC7	637	Dec-Apr: 0.02 May-Nov: 0.06
RC8a and RC8b (Siphon)	852	0.4 (monthly)

Note:
m^3/sec = cubic metre per second

TABLE 2-8
Vangorda Creek Model Monthly Base Flow Estimates
Faro Mine Remediation Project

Vangorda Creek Model Catchments	Area (ha)	Constant Monthly Base Flow (m^3/sec)
VC1	2,007	Sept-Apr: 0.30 May-Aug: 0.40
VC2	742	Sept-Apr: 0.11 May-Aug: 0.15
VC3	276	Sept-Apr: 0.04 May-Aug: 0.05
VC4	1,360	Sept-Apr: 0.20 May-Aug: 0.27
VC5	4,352	Sept-Apr: 0.65 May-Aug: 0.87

2.4.4 Surface Water Model Initial Conditions

Initial parameter conditions were chosen as a starting point in the model prior to calibration. The sensitivity of basin model loss parameters (i.e., canopy storage, surface storage, soil loss method) and snowmelt parameters was evaluated, and if a given parameter proved to be a useful calibration parameter, it was modified during the

calibration process to a final optimized value. If a parameter did not prove to be a useful calibration parameter, it was returned to its default, or initial, condition. The final parameter values used in the Rose Creek and Vangorda Creek models were listed in Section 2.4.3. The initial conditions of the parameters that were used in the calibration process are described in this subsection.

Because limited information is available for the catchment area, the initial conditions for canopy storage and surface storage were taken as 200 mm each as an arbitrary starting point. The calibration process ultimately led to the use of canopy and surface storage depths of 10 mm each.

The soil information available for the study area (Robertson GeoConsultants Inc. [RGC], 1996) describes a mix of both well-drained and poorly drained soils. As a starting point in the calibration process for the constant soil infiltration parameter, a typical value for the hydraulic conductivity of soils was used based on a soil type that lies between the classification of a good aquifer and a poor aquifer. A good aquifer is described by clean sands and a mixture of clean sands and gravel with hydraulic conductivity ranging from approximately 16.8 to 1,697 mm/hr (5×10^{-4} to 5×10^{-2} centimetres per second [cm/sec]). A poor aquifer is described by very fine sands and mixture of sand, silt and clay, glacial till, and stratified clays, with hydraulic conductivity ranging from slightly lower than 0.01 to 16.8 mm/hr (2×10^{-4} to 5×10^{-2} cm/sec) (Chow, 1964). The calibration process ultimately led to the use of constant infiltration parameters that fall within the classification of poor aquifers (0.02 to 0.35 mm/hr or 6×10^{-7} to 1×10^{-5} cm/sec).

The initial condition for the percent imperviousness was set to 0 percent. The calibration process ultimately led to the use of a percent imperviousness of 10 percent.

It is recognized that the final calibrated values for the canopy, surface, and soil loss parameters may not be consistent with theoretical or expected values based on existing physical characteristics of the subcatchments. However, the specific combination of values derived during the calibration process produced the best match of observed versus modelled runoff hydrographs for the duration of the simulation.

The initial condition for the ATI melt rate function was used from a reference document provided by USACE personnel (Scharffenberg, 2011, personal communication). This initial melt rate function is summarized in Table 2-9.

TABLE 2-9
Rose Creek Meteorological Model Initial Conditions ATI Melt Rate Function
Faro Mine Remediation Project

ATI (°C-day)	Melt Rate (mm/°C-day)
0	1.09
50	1.32
100	2.23
150	1.77
500	1.77

The ATI melt rate function was a powerful calibration parameter, and the final calibrated values were provided in Section 2.4.3.6.

As mentioned in Section 2.4.3.1, runoff from subbasins RC8a and RC8b are represented in the form of a constant monthly hydrograph. Runoff and seepage from catchment area RC8a is tributary to the Faro Pit, whereas runoff and seepage from catchment area RC8b is ultimately captured above the Intermediate Dam. This runoff and seepage is ultimately stored in the Faro Pit or in the Intermediate Dam Pond for subsequent treatment at the Faro WTP. Discharge from the WTP is tributary to the CVD Polishing Pond. Water is discharged from the CVD Polishing Pond via a siphon equipped with a control valve. As such, direct runoff from these catchment areas was not

routed through the hydrological model. Rather, a manual hydrograph with monthly time steps was developed to represent controlled discharge through the siphon. Review of available discharge data indicates that flow through the siphon occurs through most months of the year and ranges from 0.0 to approximately 0.4 m^3/sec. For model development, an average monthly discharge estimate of 0.4 m^3/sec was applied and is considered to be a conservative (i.e., high) value for the purposes of model development. Given the relatively low flow rate associated with discharge from the CVD compared with flows coincident at the next downstream model node (i.e., the 23,163 ha X14 catchment area), it is not anticipated that the assumed siphon flow will significantly impact downstream flows from a volume perspective during peak flow events. It would be necessary to further refine this hydrograph, based on additional field data, to better estimate impacts of controlled releases on the receiving watercourse flow regime during low-flow, interevent periods.

2.4.5 Surface Water Model Boundary Conditions

The catchment delineation, described in Section 2.4.3.1 and illustrated in Figures 2-5 and 2-6, provides a no-flow boundary condition for the Rose Creek and Vangorda Creek SW flow models.

When developing hydrological models, the domain is defined by the overall catchment area tributary to the receiving point of interest. For the FMC, the domain is defined by flow monitoring station X14 in the Rose Creek drainage basin and by V8 in the Vangorda Creek drainage basin, shown on Figure 2-4.

Time series and paired data also define boundary conditions in the development of hydrological and meteorological models. For the current model development, time-series data for meteorological parameters (including precipitation and air temperature) were developed. Similarly, time-series data for base flow contribution and flow monitoring data were used. The model was run from January 1, 2004 until December 31, 2011. This period corresponds with the time when the most flow and meteorological data were available for model development and calibration.

2.4.6 Surface Water Model Time Discretization

The SW flow models were discretized to run daily time steps from January 1, 2004 until December 31, 2011. Although certain meteorological data are available hourly, some of it is only available over a 1-day period. HEC-HMS can process time-series data with time steps ranging from 1 minute to 1 day. Given that the models are developed to run continuously for multiple years, a time step of 1 day was selected for run definition. As well, given the relative times of concentrations for the catchments of the Rose Creek and Vangorda Creek models, runoff processes are better represented in terms of days rather than hours.

2.5 Surface Water Model Calibration

The intent of the calibration process was to match the simulated hydrograph peak flows and volumes as closely as possible to the observed data from the various flow monitoring locations over the years of recorded data available.

2.5.1 Surface Water Model Calibration Approach

The flow monitoring stations that were used in the calibration process, and the locations at which they are compared in the model, are summarized herein. Refer to Figure 2-2 for monitoring locations and Figures 2-8 and 2-9 for node and junction definitions, respectively.

Rose Creek Model

- **R7 NFRC above FCD:** Compared to output from node RC1 (total of 9,874 ha contributing catchment area)
- **X2 NFRC Upstream from Mine Access Road:** Compared to output from node Junction RC3, which includes flows from RC1, RC2, and RC3 (total of 12,455 ha contributing catchment area).
- **X14 Rose Creek Downstream from the RCDC:** Compared to output from node Junction RC5, which is the most downstream point in the model that includes flow from the entire catchment area (total of 23,163 ha contributing catchment area)

Vangorda Creek Model

- **V1 Vangorda Creek Upstream from the FMC and Blind Creek Road:** Compared to output from node Vangorda VC1 (total of 2,007 ha contributing catchment area)
- **V27 Vangorda Creek, Just Upstream from Shrimp Creek (DES, 2011):** Compared to output from node Junction VC1 (total of 3,025 ha catchment area)
- **V8 Lower Vangorda Creek at the Footbridge:** Compared to output from Junction VC3 (total of 8,737 ha contributing catchment area)

The calibration process started with the most upstream subbasins from each model (i.e., Rose Creek RC1 and Vangorda VC1). For each of these subbasins, continuous flow data were available at the respective discharge points. This allowed for the comparison and subsequent calibration of the subbasin-specific models. Once the subbasin parameters were appropriately calibrated for these catchments, subsequent downstream catchments were added to the models, with results compared to available continuous and spot flow data.

2.5.2 Surface Water Model Calibration Targets

For the winter models, the magnitude and duration of spring freshet was the key calibration target because this is the event that defines peak annual runoff hydrographs for the system. For the summer models, the frequency and magnitude of runoff events was the key calibration target because runoff hydrographs, in this case, are not influenced by longer-duration melt periods, as is the case with the winter models, but rather shorter duration runoff events with a more frequent return period. The shape of the hydrograph, in terms of the lag during the spring freshet, as well as during more frequent summer runoff events, was a particularly important calibration target because it dictated the volume of SW being simulated by the model annually.

2.5.3 Surface Water Model Calibration Process

After an initial sensitivity analysis was performed on parameters, those that exhibited the most influence on model results were selected for further analysis. These parameters included the ATI melt rate index function, the constant infiltration parameter, the surface storage depth, and the canopy storage depth.

The most significant effect on the hydrograph volume during the spring freshet resulted from calibrating the ATI melt rate index function value. Adjusting the melt rate values higher or lower and varying the melt rate value within the range of the ATI function itself either increased or decreased the extent of the hydrograph lag during the melt. Table 2-4 lists the final ATI melt rate index functions that best suited the simulations. The melt rate function was calibrated in conjunction with the calibration of the precipitation loss parameters because, although these parameters govern different aspects of the simulation, they interact with one other.

The most significant effect on the magnitude of peak flows resulted from varying the constant soil infiltration parameter. As mentioned earlier, two separate basin models were developed, one with the soil infiltration parameter calibrated for the snowmelt peak (which is typically the largest peak in the annual record) and one with the soil infiltration parameter calibrated to the later summer peaks. The soil infiltration parameters are presented in Table 2-6. The results of the snowmelt-calibrated model were used from the beginning of November until the end of June, and the results from the summer-calibrated model were used from the end of June until the end of October. The difference in soil infiltration parameter is intended to reflect the fact that during the snowmelt calibration period, the ground is frozen and the infiltration parameter can be expected to be lower than during nonfrozen periods of the year. During the summer calibration period, the ground has thawed, and the infiltration parameter can be expected to be slightly higher than during the frozen periods of the year. The modelling results support this reasoning; when the snowmelt-calibrated infiltration loss parameter was used, the peaks during the spring freshet were well-matched to the observed data; however, the simulated peaks in the later summer months (July through September) were much higher than those observed. Likewise, when the summer-calibrated infiltration loss parameter was used, the summer peaks were better calibrated to the observed data; however, the snowmelt peaks during the spring freshet (May through June) were much lower compared to those observed. As such, a two-model approach was developed to simulate the change in soil infiltration resulting from the change in temperature over the course of the different hydrological events. A difference was also found in the Rose Creek

model- and Vangorda Creek model-calibrated winter soil infiltration parameters, which could reflect different soil and land cover conditions between the two sites during the winter months (0.02 mm/hr versus 0.1 mm/hr [6×10^{-7} cm/sec versus 3×10^{-6} cm/sec]). The same summer-calibrated soil infiltration parameter was used for both areas (0.35 mm/hr [1×10^{-5} cm/sec]).

The modelled hydrographs at each flow station, provided in Section 2.5.4, are an amalgamation of the results from both of these models. The simulated behaviour during the potential overlap periods (end of June until early July and end of October until early November) was examined for each subbasin to determine whether the soil infiltration parameter for the snowmelt or summer period would be better suited for specific portions of this transition period. As a starting point, July 1 was initially taken as the date when the change in soil infiltration rates would occur. This remained as such for most of the years simulated, except for 2007 and 2011, where, upon examination, it appeared that there were precipitation events toward the end of June (June 25, 2007 and June 20, 2011) that were better simulated with the summer-calibrated soil infiltration parameter for these years.

Because certain years of continuous flow monitoring data are more complete than others (e.g., at times snowmelt period flow data were missing), the calibration process sometimes favoured certain years more than others. This was particularly true for the Vangorda Creek model at flow monitoring station V1. Although there are flow monitoring station V1 data available for 4 years (2008 through 2011), only the data from 2009 contains the snowmelt period of May and June; therefore, this year was relied on for the calibration process. Likewise, further downstream at station V8, although there are data available for 2008, 2010, and 2011, it is suspected that the data from 2010 and 2011 are inaccurate. As a result, only the 2008 data were used for the calibration process. The continuous 2010 and 2011 flow monitoring readings appear to be abnormally low. For verification, they were first compared to the spot-flow measurements from the 2010 and 2011 environmental monitoring reports (DES, 2011, 2012a) at the same station locations, and the values were found to agree fairly well with each other. However, the fact that the peak flow recorded at monitoring station V27 in 2011, which is located upstream of station V8, is slightly higher than that recorded at V8 (both are approximately 3 m^3/sec for the spring snowmelt peak) supports the hypothesis that the flow data in 2010 and 2011 at V8 may be compromised. Compared to V27, V8 would be expected to receive an additional 5,712 ha of catchment area; therefore, the peak flows at V8 would be expected to be higher than at V27. The model results at the location of V27 (Junction VC1) agree well with the observed data from the 2011 flow monitoring report (approximately 3 m^3/sec), whereas the modelled peak flows at the V8 location (Junction VC3) are approximately 7.5 m^3/sec.

2.5.4 Surface Water Model Calibration Results

Figures 2-17 through 2-21 compare the observed versus modelled hydrographs at flow monitoring stations R7, X2, and X14 (for the Rose Creek Model) and V1 and V8 (for the Vangorda Creek model), respectively, spanning the years of continuous flow data available for each station. Appendix A includes a separate figure for each flow monitoring station. In Appendix A, the continuous flow monitoring data are shown in black, whereas the modelled data from the winter-calibrated model are shown in green and the summer-calibrated model data are shown in orange.

As discussed, the models have been calibrated to generally match the peak flows and hydrograph volume across all years of available data. However, there are certain years where the modelled results better match the observed data as compared to others. For the Rose Creek model, years 2005, 2009, and 2011 are better calibrated to the observed hydrographs than in other years at both flow monitoring stations R7 and X14. For the Vangorda Creek model, 2009 is the best-calibrated year for V1, and 2008 is the best-calibrated year for V8.

Considering the fairly coarse resolution of the models, in terms of catchment delineation size and parameter estimation, the calibrated model appears to be adequate because it tends to achieve similar results to flow monitoring data at the most downstream end of both systems (X14 and V8, for Rose Creek and Vangorda Creek models, respectively). Nonetheless, model weaknesses include the fact that it does not succeed in replicating every event that was recorded in the continuous flow monitoring data (e.g., November 2005 and 2006 events). Further, the time lag in the spring freshet portion of the simulated hydrograph remains in general briefer than was observed. This remains true even after pushing the limits of calibration to extend it as much as possible without adversely affecting other aspects of the hydrograph. The timing of the simulated hydrograph is generally

coincident with the observed data, with the spring melt occurring on average within a few days of observed melt; however certain years match better than others. For 2005, the modelled and observed spring freshet peaks coincide well with each other around May 17. However, in 2007, the continuous flow monitoring data and spot-flow measurement data (Laberge Environmental Services [Laberge], 2007) show two peaks within the freshet period: one at the end of May (coinciding around the time of the main modelled peak) and another greater peak in early June. The model does simulate these two peaks; however, the first one is the largest, while the second peak is dampened.

It is acknowledged that base flow will vary both seasonally and annually; however, to develop a calibrated model that can be used in subsequent analyses, an average monthly base flow was applied. Because base flow varies by year, the average monthly base flow succeeded in better representing the observed base flow for certain years compared to others. For 2010, the estimated base flow is approximately double the observed base flow because this year was significantly drier than the others and experienced a smaller spring freshet. The implication of this is that, along with the base flow, the modelled events during the summer and autumn period in particular were higher than those observed.

As mentioned previously, a manual hydrograph with monthly time step was developed to represent controlled discharge from the CVD Polishing Pond. Peak flow rates from the siphon are relatively small compared with cumulative flows directly downstream in Rose Creek. Therefore, assumed discharges from the CVD Polishing Pond do not significantly impact downstream flows from a volume perspective during peak flow events. It is necessary to further refine this hydrograph, based on additional field data, to better estimate impacts of controlled releases on the flow regime of the receiving watercourse during low-flow, interevent periods.

The modelling results were calibrated against the continuous flow monitoring results and, whenever possible, the results were also compared to spot flow measurements available from other sources such as DES (2011, 2012a), Gartner Lee Limited (GLL) (2007, 2008), and Laberge (2005a, 2007). Figure 2-2 illustrates the location of the flow monitoring sites where spot readings were evaluated.

Of particular importance in the Rose Creek model was an analysis of potential attenuation effects upstream of the Haul Road Rock Drain. Based on anecdotal information, runoff appears to pool behind the rock drain during significant runoff events. Hydrographs generated from the calibrated model both upstream and downstream of the rock drain were compared to available continuous field data, as well as spot-flow measurements recorded by FMC care and maintenance operators. Based on the similarity in peak flows recorded by the continuous flow data and spot-flow measurements upstream and downstream of the Haul Road Rock Drain, as well as the general agreement between modelled and observed hydrographs from locations upstream and downstream of the rock drain, the Haul Road Rock Drain does not provide significant peak flow attenuation for events that were simulated between 2004 and 2011. To further corroborate this conclusion, the water surface elevations provided immediately upstream and downstream from the rock drain at locations NF1 and NF2 in DES (2012a) exhibit the same fluctuation over time. This suggests that the flow rates are the same over this period. In light of these observations, the model has been developed without specifically including the Haul Road Rock Drain as a separate hydraulic element. The increase in head that develops as water pools upstream of the rock drain may sufficiently maintain a constant peak flow through the structure. However, for events exceeding those that have been simulated in this modelled exercise, the rock drain would likely provide peak flow attenuation once the capacity through the porous structure was exceeded.

The spot-flow measurements in DES (2011, 2012a) typically did not coincide with significant hydrological events (such as a spring freshet or a peak summer storm). Therefore, the general comparison of these data sets to the model results was not always very telling but was nonetheless carried out. Laberge (2005a) provides more significant data because the spot-flow measurements were taken on May 11 and 12, 2005, which nearly coincides with the peak of the spring freshet (May 17, 2005). Measurements were taken at various locations along the NFRC and the RCD (at R7, X2, X14), and these were compared to both the model results and the observed continuous data, as summarized in Tables 2-10 and 2-11, respectively. Note that the nearest continuous flow monitoring station to Station RCDC4 that includes runoff from both the north and south forks of Rose Creek is X14. Although

the catchment area tributary to Station X14 is larger than that tributary to Station RCDC4, it is the most representative station to which peak flows reported by Laberge (2005a) can be compared.

TABLE 2-10
Comparison of May 12, 2005 Flow Rates
Faro Mine Remediation Project

Flow Monitoring Station	Location	Laberge (2005a)[a] (m^3/sec)	Continuous Flow Data (m^3/sec)	HEC-HMS Model (m^3/sec)
R7	NFRC	4.1	4.6	5.2
X2	NFRC Downstream from Tailings Facility	6.3	n/a	6.3
X14	Rose Creek Downstream from Tailing Facility	13.1	14.3	11.9
RCDC4	Entrance of RCDC	11.1	14.3[b]	11.9[b]

Notes:
n/a = not applicable
[a] instantaneous (i.e., spot) flow measurement
[b] based on data from continuous station X14

TABLE 2-11
Comparison of 2007 Spring Freshet Peak Flows
Faro Mine Remediation Project

Flow Monitoring Station	Location	Laberge (2007)[a] (m^3/sec)	Continuous Flow Data (m^3/sec)	HEC-HMS Model (m^3/sec)
R7	NFRC	13 (June 6)	6.5 (June 7)	6.3 (May 25)
X14	Rose Creek Downstream from Tailing Facility	30 (June 6)	17.6 (June 6)	14.3 (May 25)
V8	Lower Vangorda Creek at the Footbridge	10 (June 6)	n/a	7.5 (May 25)

Notes:
n/a = not applicable
[a] instantaneous (i.e., spot) flow measurement

2.6 Surface Water Model Application

As defined earlier in this report, the FY12 objective of the SW flow modelling task was to develop a dynamic hydrological model of the FMC that can be used to provide a better understanding of the hydrological characteristics of the FMC and support future FMC design and investigative activities. Building on the CSM Report (CH2M HILL, 2012), the SW flow models are used to define precipitation-runoff processes throughout the FMC and to assist in characterizing the occurrence, conveyance, and management of SW within the FMC under varying assumptions of land use and meteorological conditions.

The SW flow models described herein have been used to simulate rainfall-runoff processes from the FMC on a continuous, multiyear simulation basis to simulate the timing and magnitude of runoff events throughout the year ranging from low-flow (i.e., base flow) conditions up to the peak flows occurring during the spring freshet. To establish flow rates for diversion designs that exceed those produced by the freshet, a regional analysis will be used. This involves transposing flood data from regional flow gauging stations to the outlets of the respective diversion.

The SW flow models detailed in this report require further development to support the design of the SW diversion structures planned at the FMC and to support various other design activities at the FMC. The models also require further refinement to address YESAB requirements, as well as to analyze climate change scenarios. During these

efforts, the existing models will be revised to facilitate the evaluation of potential future hydrological and hydraulic stream diversion behaviour under a variety of flow conditions up to and including the probable maximum flood event (PMF). The SW flow models will be used primarily to develop stream diversion designs but will also be further integrated with the GW flow and water quality modelling efforts to support the FMRP. The following are key remedial design areas including the objective for each area:

- **FCD (East Valley).** Direct clean water around the Faro Pit and minimize seepage losses that could impact the stability of the Faro Pit walls and add to water treatment volumes.
- **North Wall Interceptor Ditch (NWID).** Remediate the existing NWID and discharge to a location below the CVD (instead of the Rose Creek Tailings Area [RCTA]).
- **Guardhouse Creek Water Management.** Intercept seepage from the mill pad and associated stockpiles and redirect this water to the Faro Pit.
- **Upgrade NFRC.** Protect the NFRC from potential sources of contamination.
- **Upgrade RCD Upstream from the Fuse Plug to PMF.** Enable the RCDC to accommodate an excess of the current 1-in-500-year flood event.
- **Breach North Fork Rock Drain.** Protect the NFRC from potential sources of contamination and restore channel.
- **Down Valley Interim Hydraulic Upgrades.** Increase the Intermediate Dam spillway capacity to pass PMF flows.
- **RCDC Fuse Plug Upgrades.** Design an RCD hydraulic structure to divert flows exceeding the 1-in-500-year flood event.
- **Upgrade of RCD Downstream of Existing Fuse Plug.** Address the freeboard inadequacy issues to enable the RCDC to pass the flow of Rose Creek on a year-round basis for all flows up to the 1-in-500-year flood event.
- **Construct New Vangorda Diversion.** Permanently realign Vangorda Creek around the Vangorda Pit to minimize leakage into Vangorda Pit and safely convey the PMF.
- **Upgrade Runoff Interceptor Ditch to Dixon Creek.** Divert uncontaminated surface runoff from the northeast side of the Vangorda to the south and into Dixon Creek via the Dixon Creek Diversion.

Associated efforts in future GW analysis and hydraulic/hydrological dam structure design tasks across the FMC will be integrated with the future SW flow modelling efforts to develop comprehensive remedial designs.

2.6.1 Surface Water Model Use and Limitations

As detailed earlier in this report, the hydrological models were developed and calibrated based on available meteorological and flow data collected at the FMC over a number of years and from additional data collected at offsite stations such as the Faro Airport Station. Modelled hydrographs compare well with those observed at the continuous monitoring stations for the duration of the analysis. However, continuous flow data were available at a relatively small number of stations, which resulted in the need to lump large catchment areas. The current SW flow models for the FMC are not sufficiently detailed to accurately develop the diversion design and stream channel upgrades. The deficiencies in the current models are based on the quality and quantity of the available data records and physical site data to adequately support model development and the current level of discretization applied to some critical basins. The proposed efforts, defined in this report, to collect additional data will facilitate further refinement and enhancement of the SW flow models. Additional flow data and site characteristics data will also allow for additional discretization of drainage catchment areas at the FMC. This additional detail will also allow for the models to be refined and the required diversion designs and stream upgrades to be better facilitated.



REGIONAL MAP



LEGEND

- Meteorological Station
- National Road Network Major Road

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 1,000 2,000 3,000 4,000

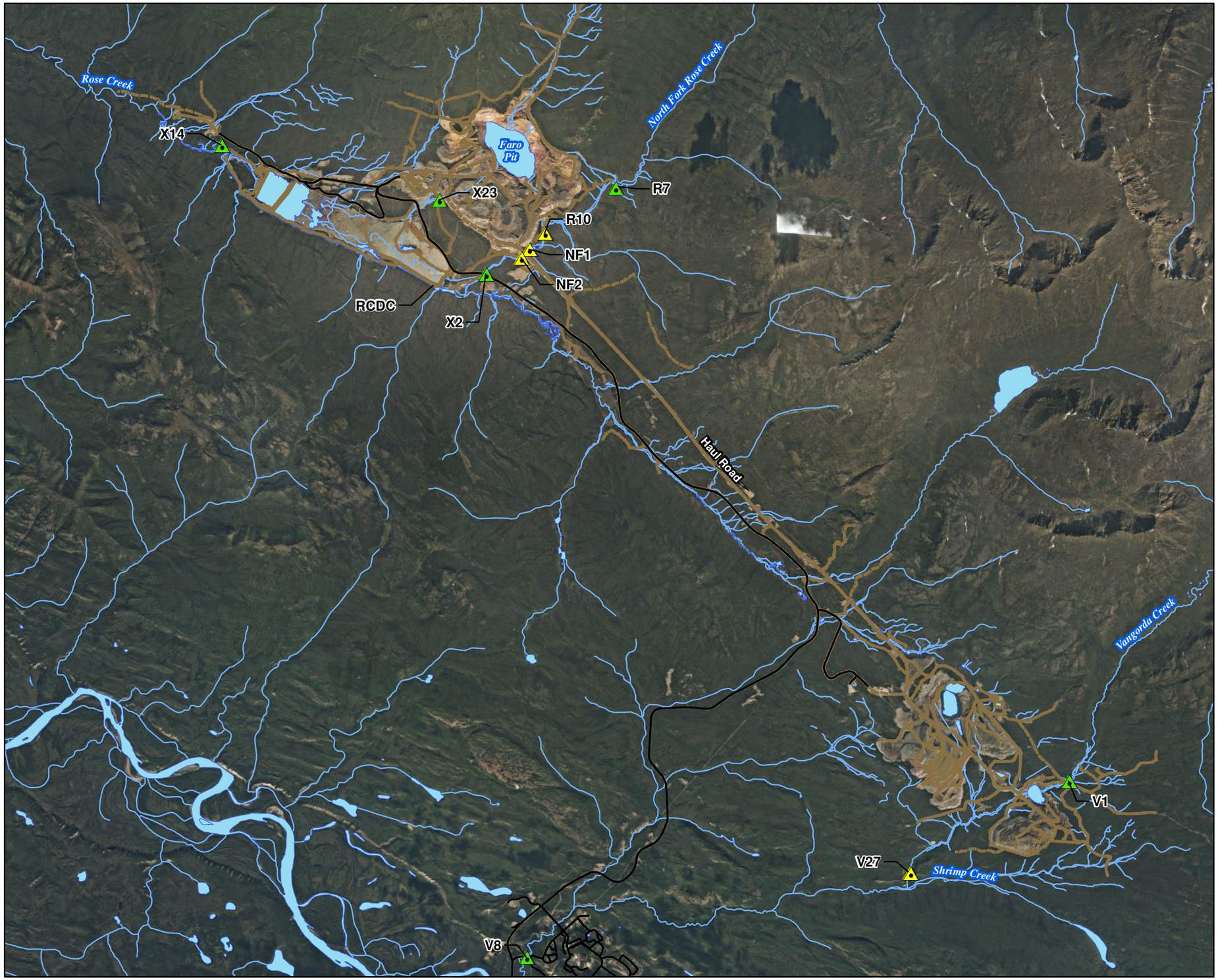
Metres

Created by: CRITIGEN

FIGURE 2-1

Site Area Meteorological Stations

Faro Mine Remediation Project



REGIONAL MAP



LEGEND

- Continuous Flow Monitoring Location
- Spot Monitoring Location
- National Road Network Major Road
- Faro Site Watercourse
- Roads Unpaved
- Faro Site Waterbody

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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Metres

Created by: CRITIGEN

FIGURE 2-2

Continuous Flow Monitoring Stations

Faro Mine Remediation Project

CH2MHILL

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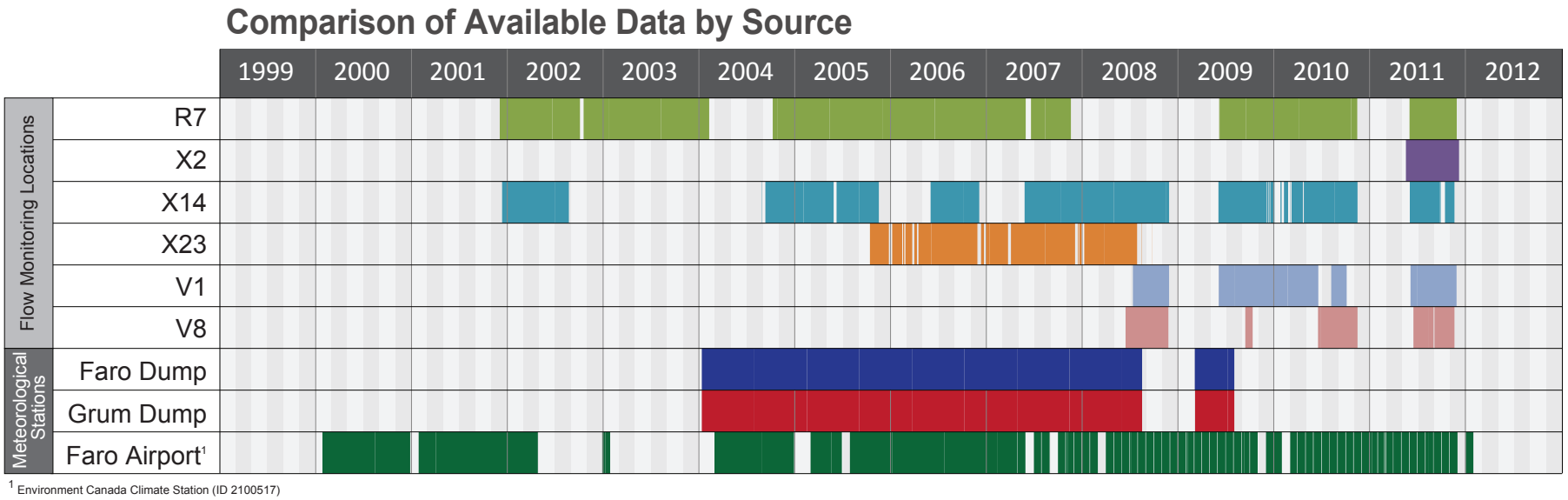
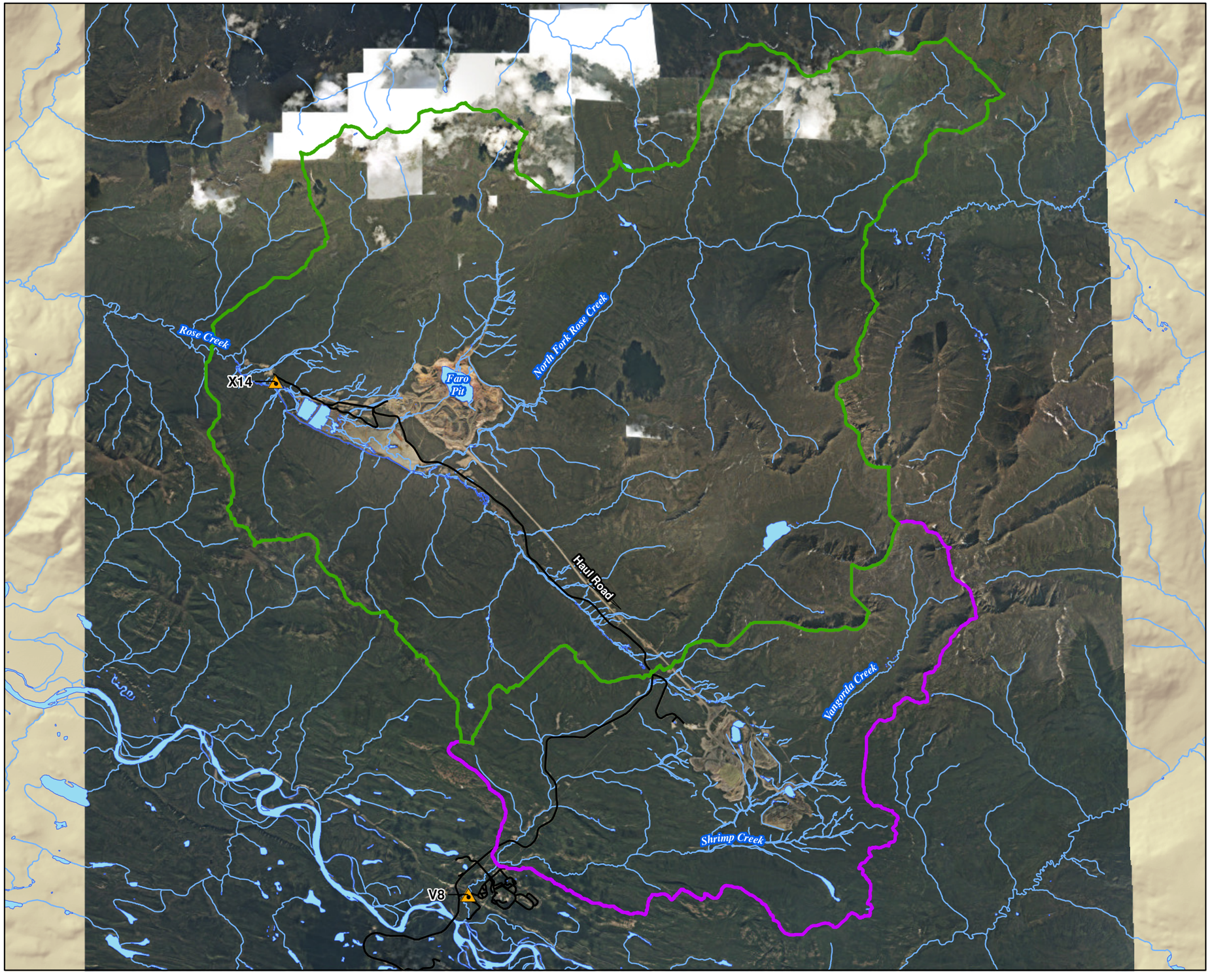


[1] Environment Canada Climate Station (ID 2100517)

FIGURE 2-3
Comparison of Available Data by Source
Faro Mine Remediation Project





LEGEND

- Flow Monitoring Location
- National Road Network Major Road
- Faro Site Watercourse
- Faro Site Waterbody
- Rose Creek Regional Catchment
- Vangorda Creek Regional Catchment

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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Metres

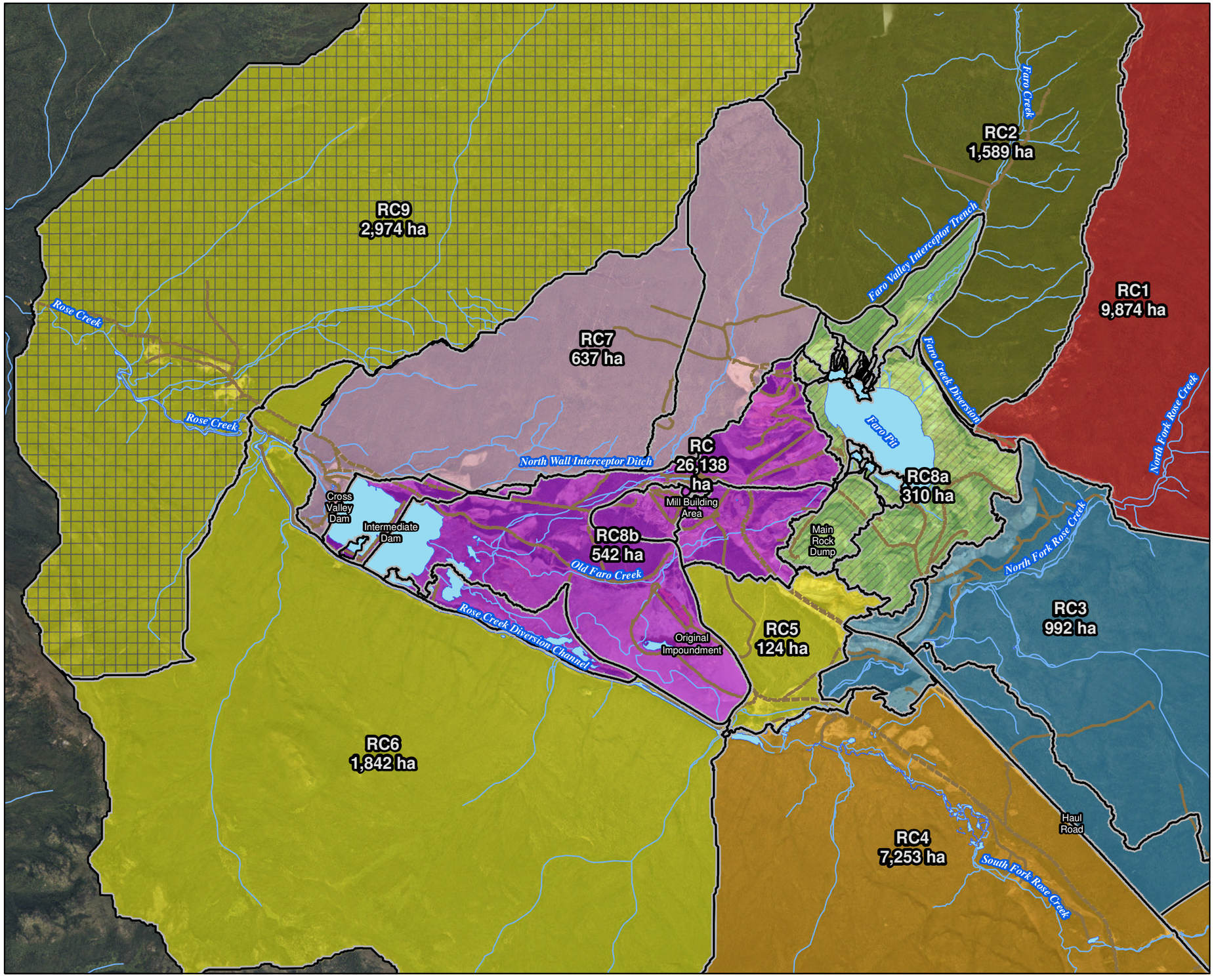
Created by: CRITIGEN

FIGURE 2-4

FMC Surface Water Catchment Boundary

Faro Mine Remediation Project

CH2MHILL



VICINITY MAP



LEGEND

- Roads Unpaved
- Faro Site Watercourse
- Faro Site Waterbody
- Catchment Boundary

Catchment Name

- North Fork Rose Creek (Upper) (RC1)
- Faro Creek & Faro Creek Diversion (RC2)
- North Fork Rose Creek (Lower) (RC3)
- South Fork Rose Creek (RC4)
- Rose Creek Diversion (RC5 + RC6)
- Upper Guardhouse Creek/North Wall Interceptor (RC7)
- Faro Pit (RC8a)
- Tailings Area (RC8b)
- Rose Creek (RC9)

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

0 320 640 960 1,280

Metres

Created by: CRITIGEN

FIGURE 2-5

Faro Dump Area: Local Surface Water Catchments

Faro Mine Remediation Project

RC4
7,253 ha

Haul Road

VC3
276 ha

Grum Pit

Grum Interceptor Ditch

VC1
2,007 ha

Vangorda Creek

VC5
4,352 ha

VC2
742 ha

Grum Creek

VC
8,737 ha

Vangorda Creek

Sheep Creek

Vangorda Waste Rock Dump

Shrimp Creek

VC4
1,360 ha

VICINITY MAP



LEGEND

- Roads Unpaved
- Faro Site Watercourse
- Faro Site Waterbody
- Catchment Boundary

Catchment Name

- South Fork Rose Creek (RC4)
- Vangorda Creek & Vangorda Diversion (VC1)
- Vangorda Creek & Shrimp Creek (VC2)
- Grum Pit (VC3)
- Shrimp Creek/Dixon Creek (VC4)
- Vangorda Creek (VC5)

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

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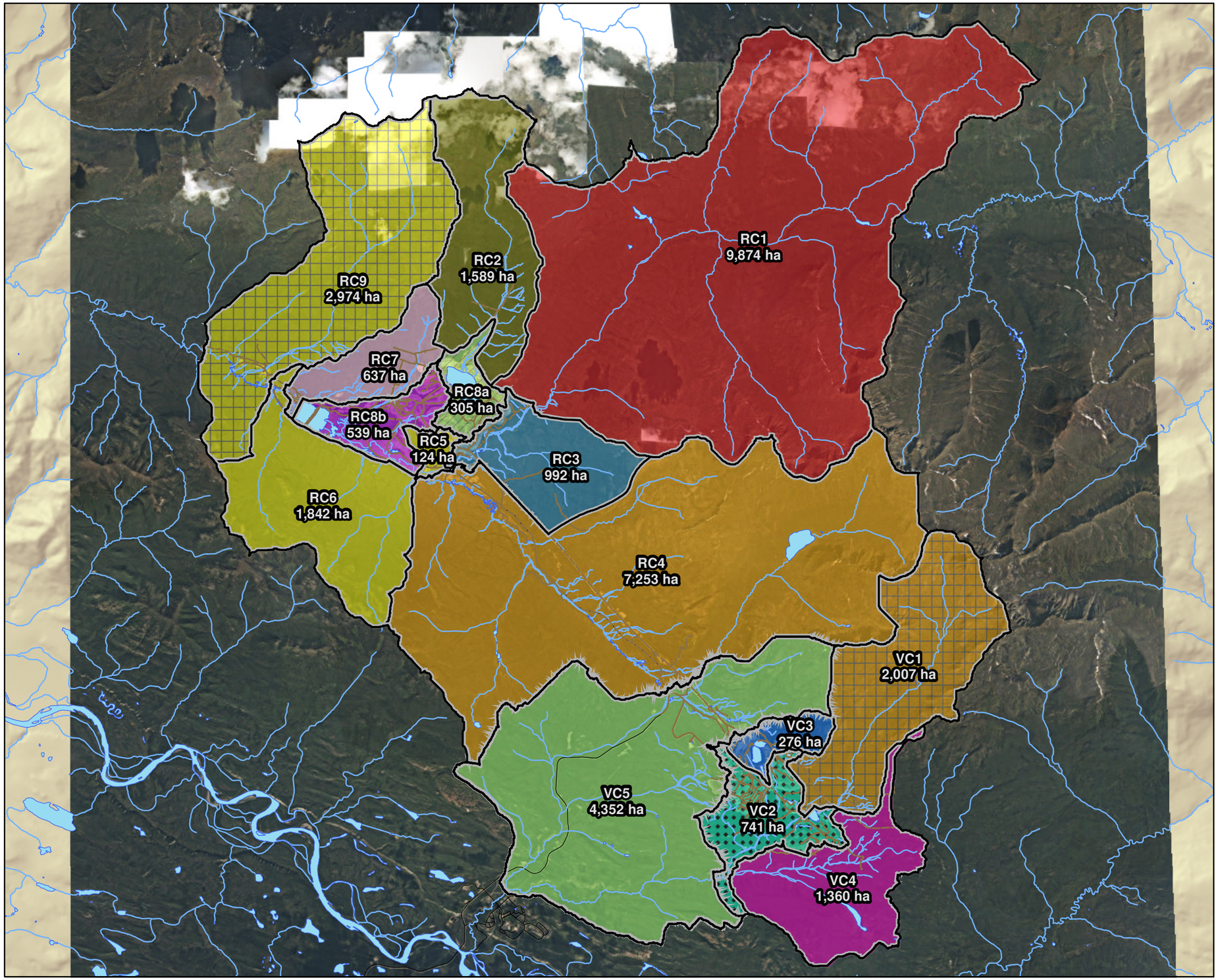
Metres

Created by: CRITIGEN

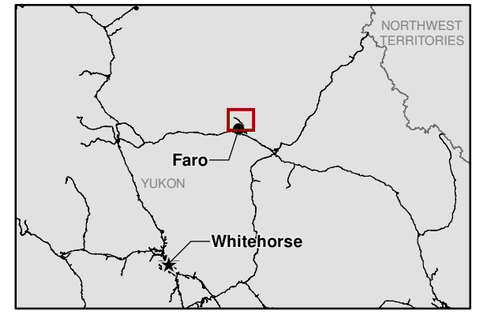
FIGURE 2-6

Grum Dump Area: Local Surface Water Catchments

Faro Mine Remediation Project



VICINITY MAP



LEGEND

- Roads Unpaved
- Faro Site Watercourse
- Faro Site Waterbody
- Catchment Boundary

Catchment Areas Tributary to Rose Creek

- North Fork Rose Creek (Upper) (RC1)
- Faro Creek & Faro Creek Diversion (RC2)
- North Fork Rose Creek (Lower) (RC3)
- South Fork Rose Creek (RC4)
- Rose Creek Diversion (RC5 + RC6)
- Upper Guardhouse Creek/North Wall Interceptor (RC7)
- Faro Pit (RC8a)
- Tailings Area (RC8b)
- Rose Creek (RC9)

Catchment Areas Tributary to Vangorda Creek

- Vangorda Creek & Vangorda Diversion (VC1)
- Vangorda Creek & Shrimp Creek (VC2)
- Grum Pit (VC3)
- Shrimp Creek/Dixon Creek (VC4)
- Vangorda Creek (VC5)

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

N

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Metres

Created by:
CRITIGEN

FIGURE 2-7
Regional Surface Water Subcatchments
Faro Mine Remediation Project

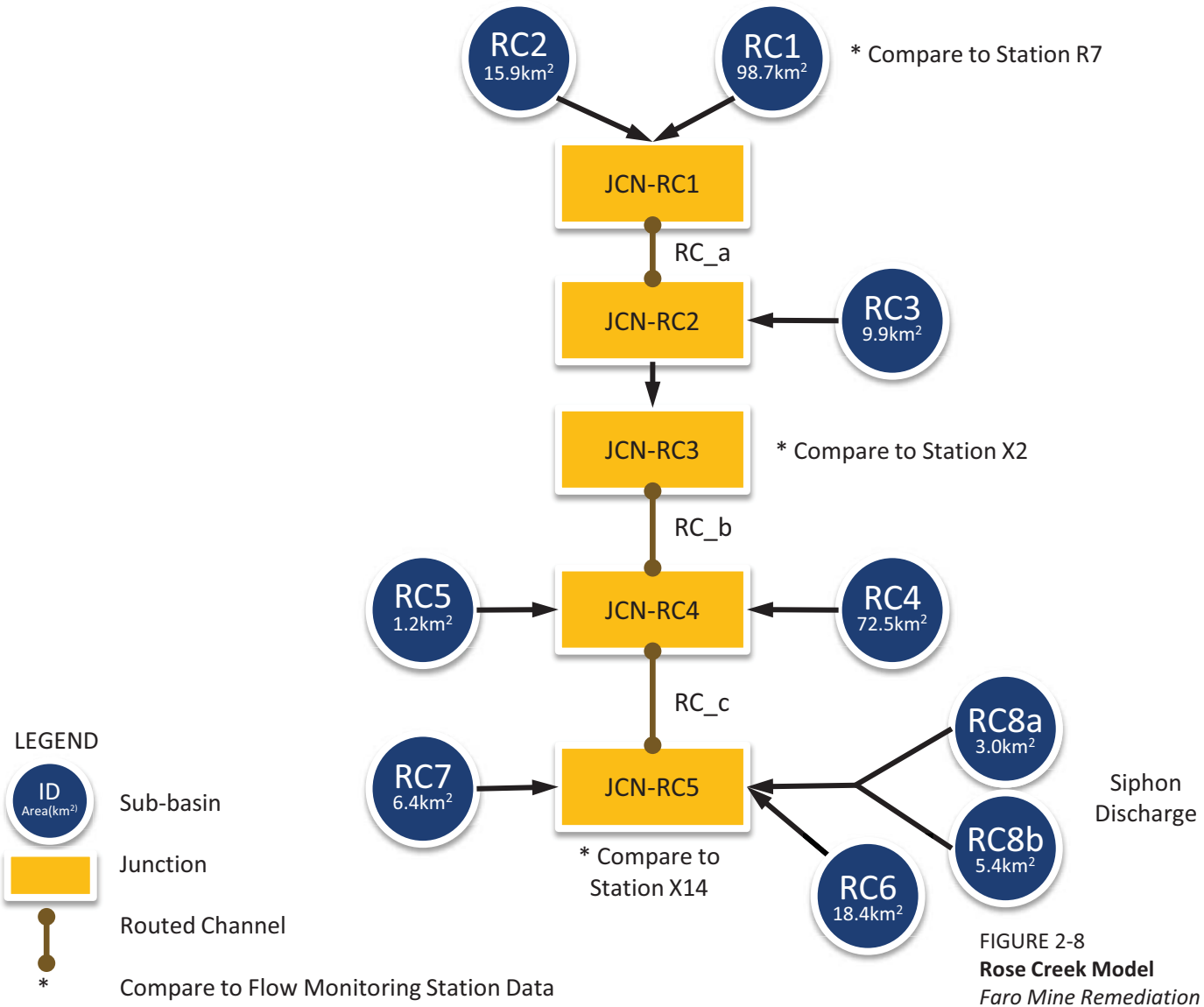

FIGURE 2-8
Rose Creek Model
Faro Mine Remediation Project

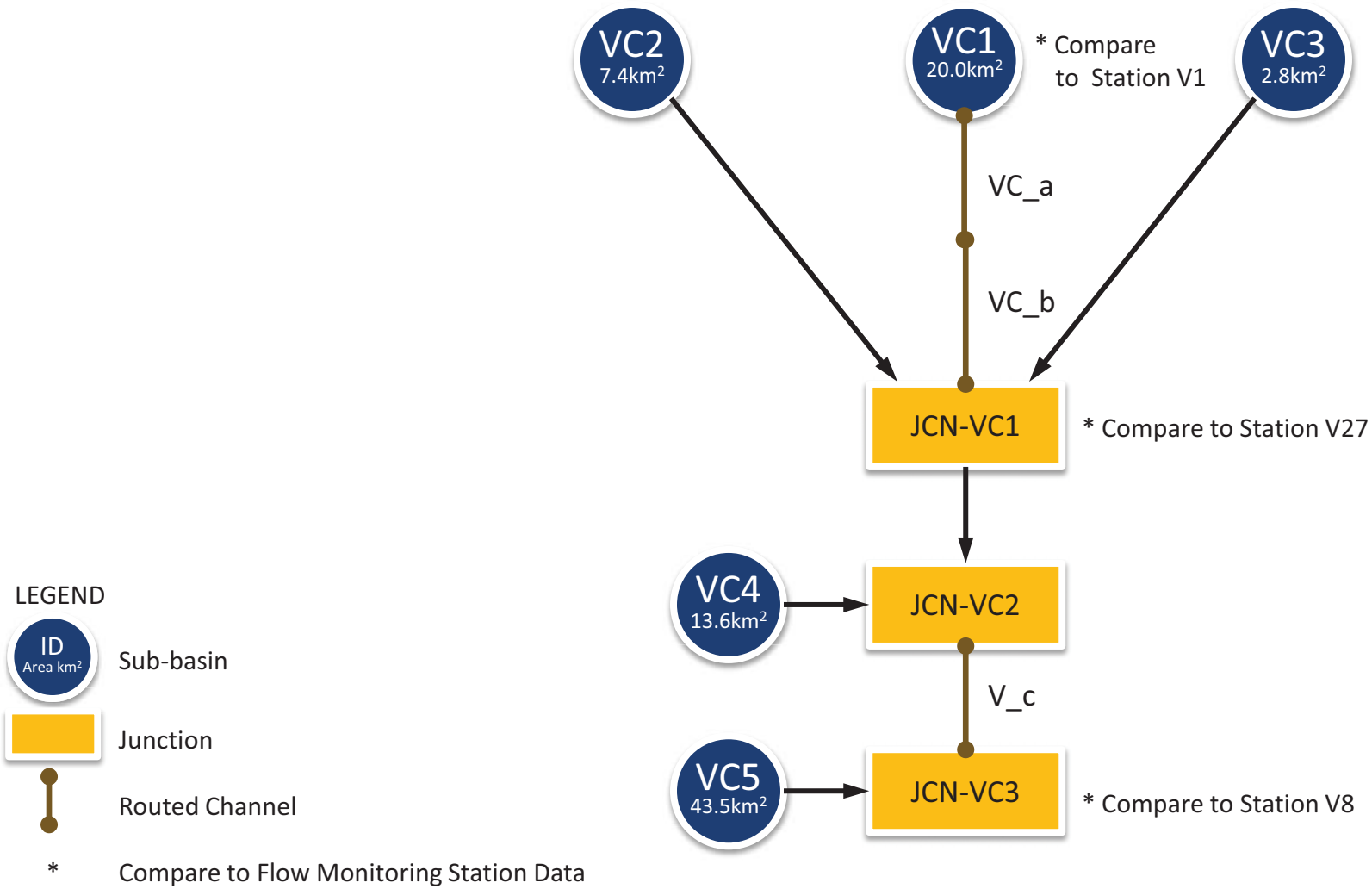

FIGURE 2-9
Vangorda Creek Model
Faro Mine Remediation Project

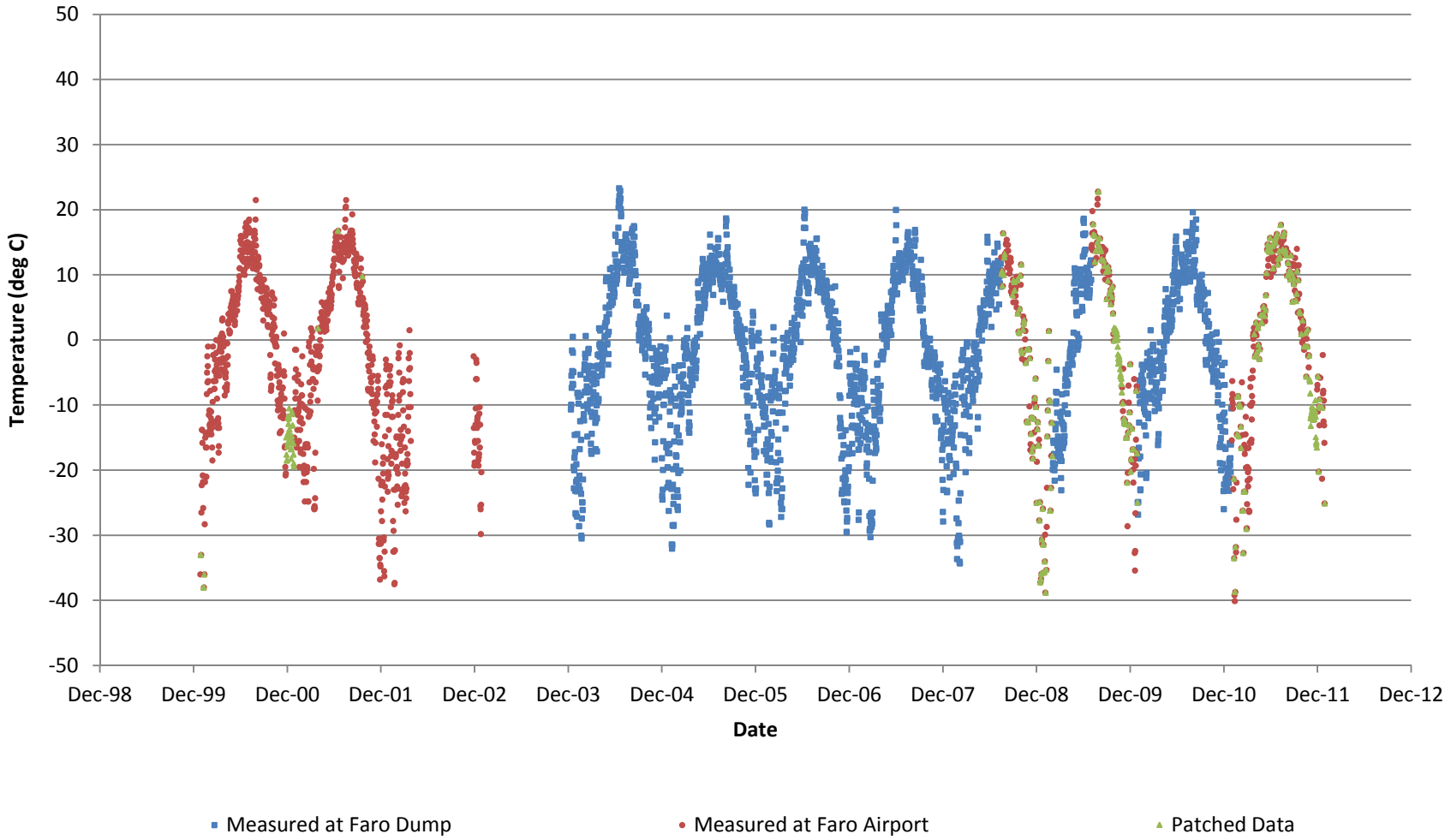

FIGURE 2-10
Faro Dump: Temperature Record by Data Source
Faro Mine Remediation Project

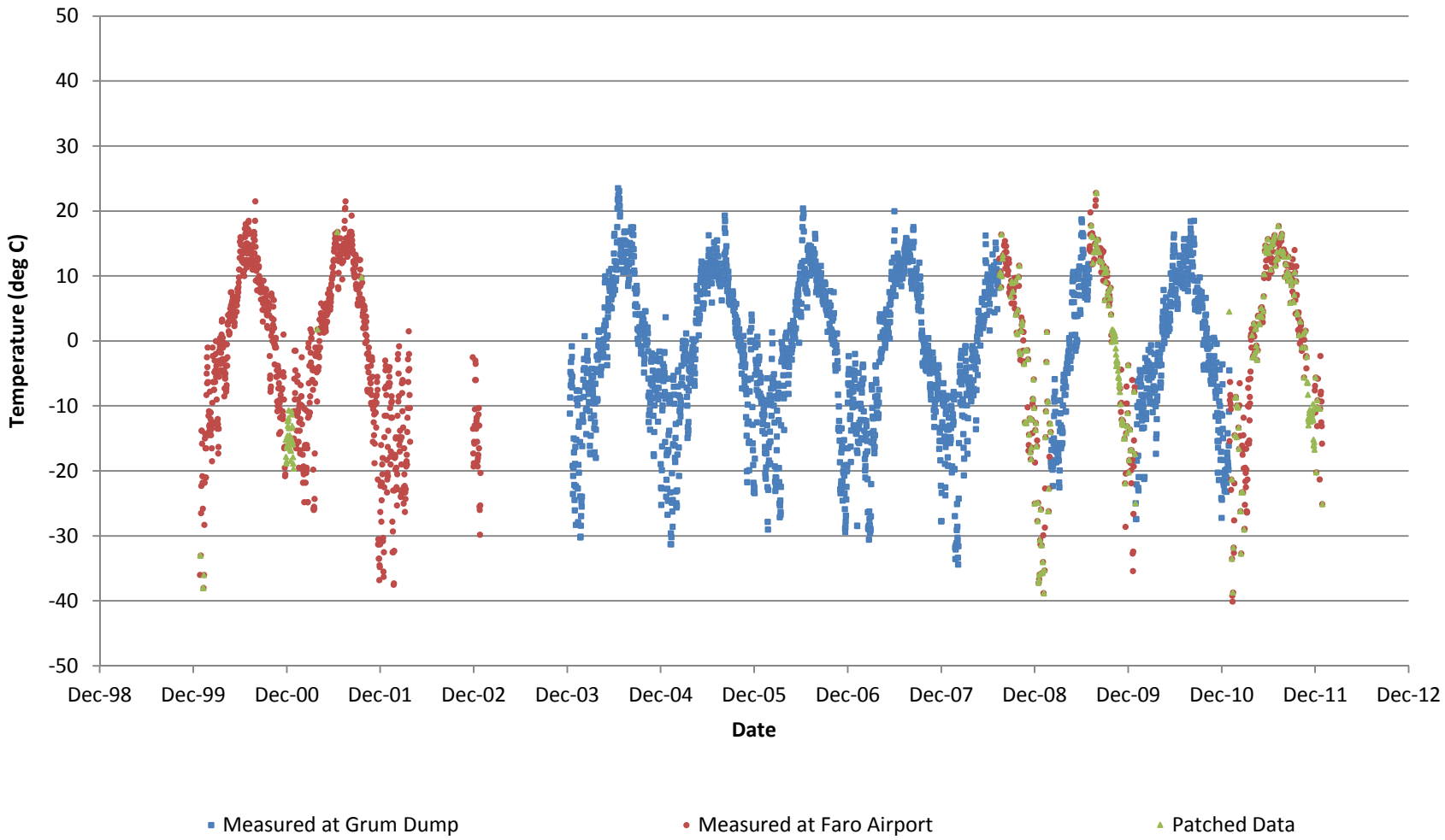

FIGURE 2-11
Grum Dump: Temperature Record by Data Source
Faro Mine Remediation Project

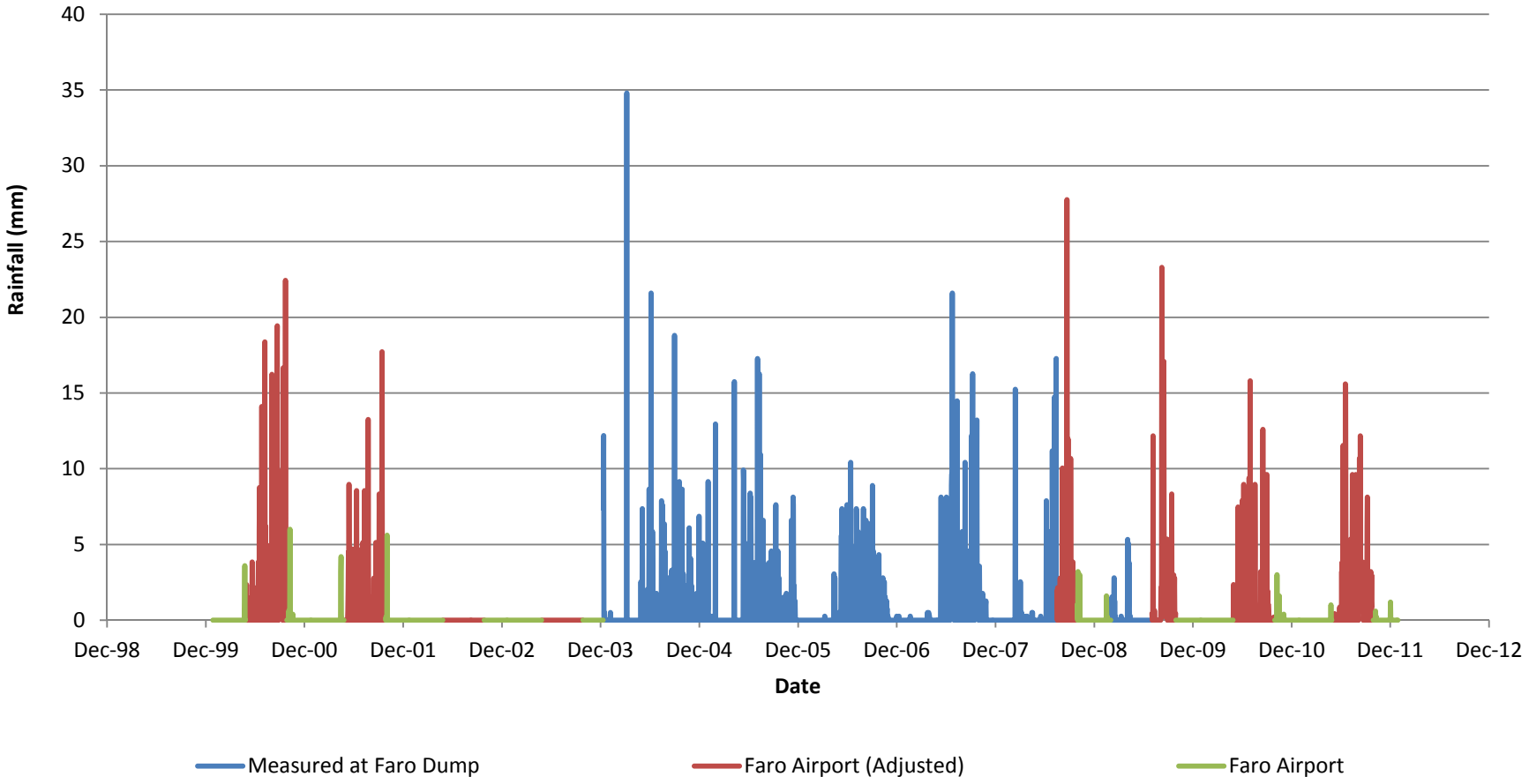

FIGURE 2-12
Faro Dump: Rainfall Record by Data Source
Faro Mine Remediation Project

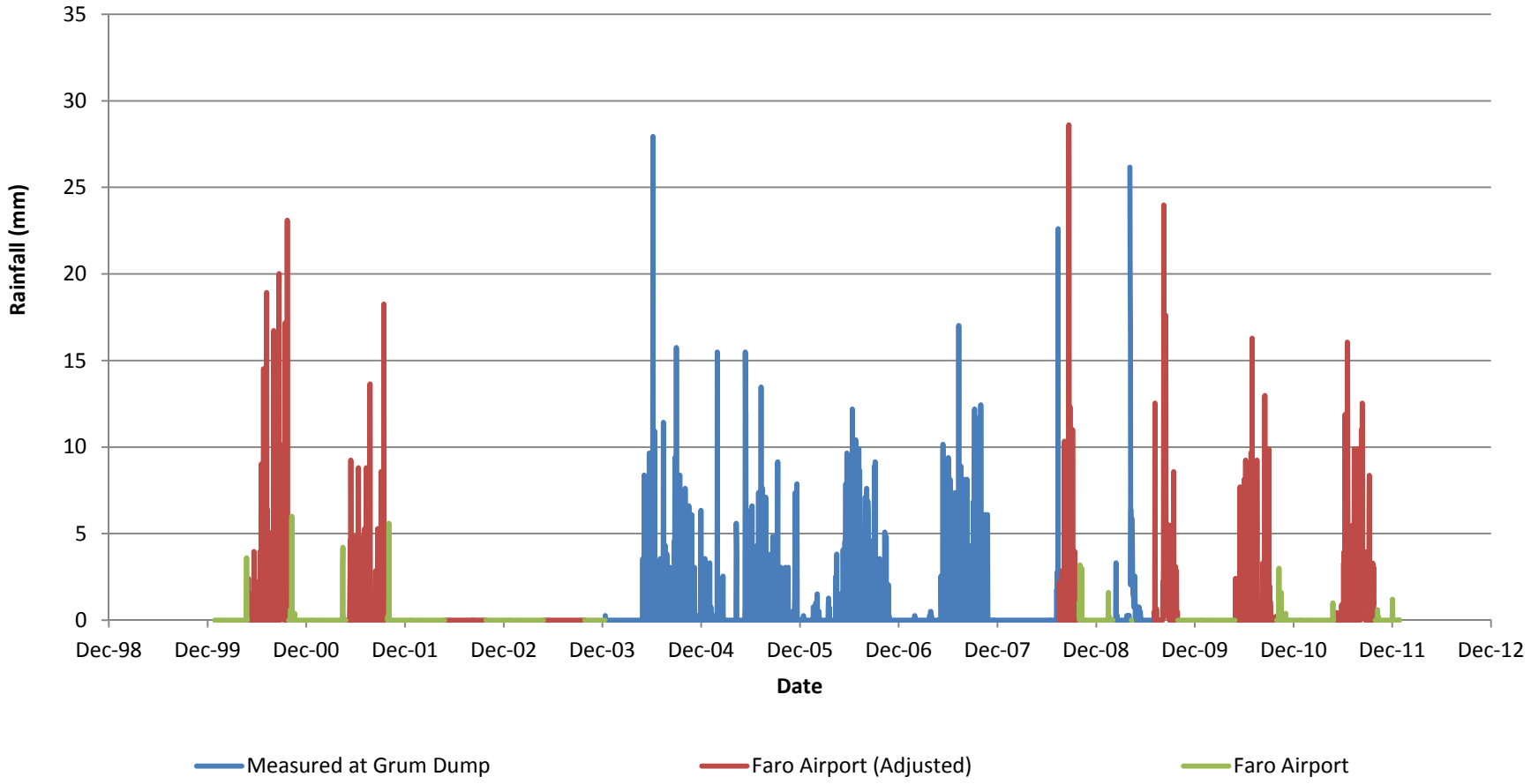

FIGURE 2-13
Grum Dump: Rainfall Record by Data Source
Faro Mine Remediation Project

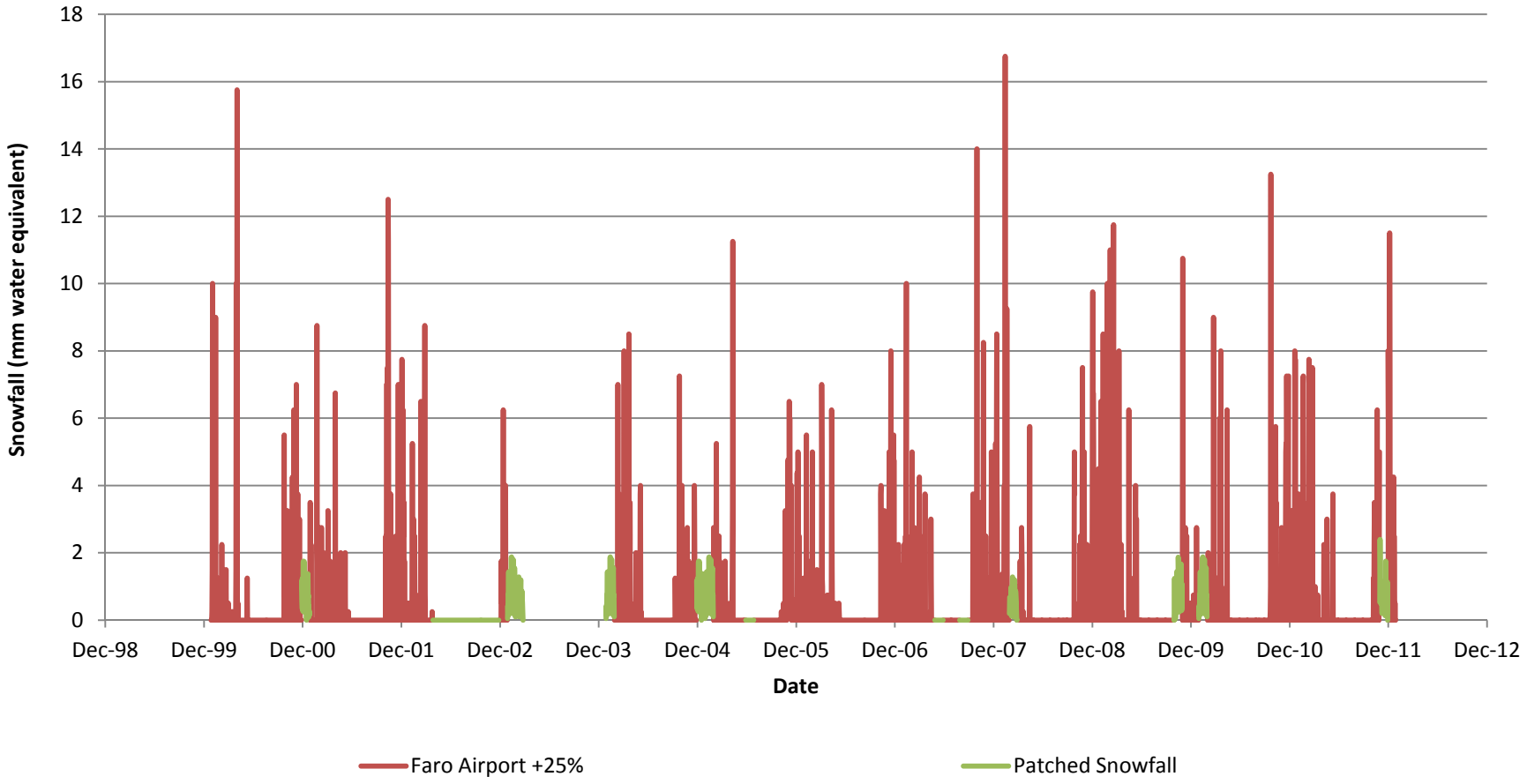

FIGURE 2-14
Faro Mine Complex Snowfall Estimate
Faro Mine Remediation Project

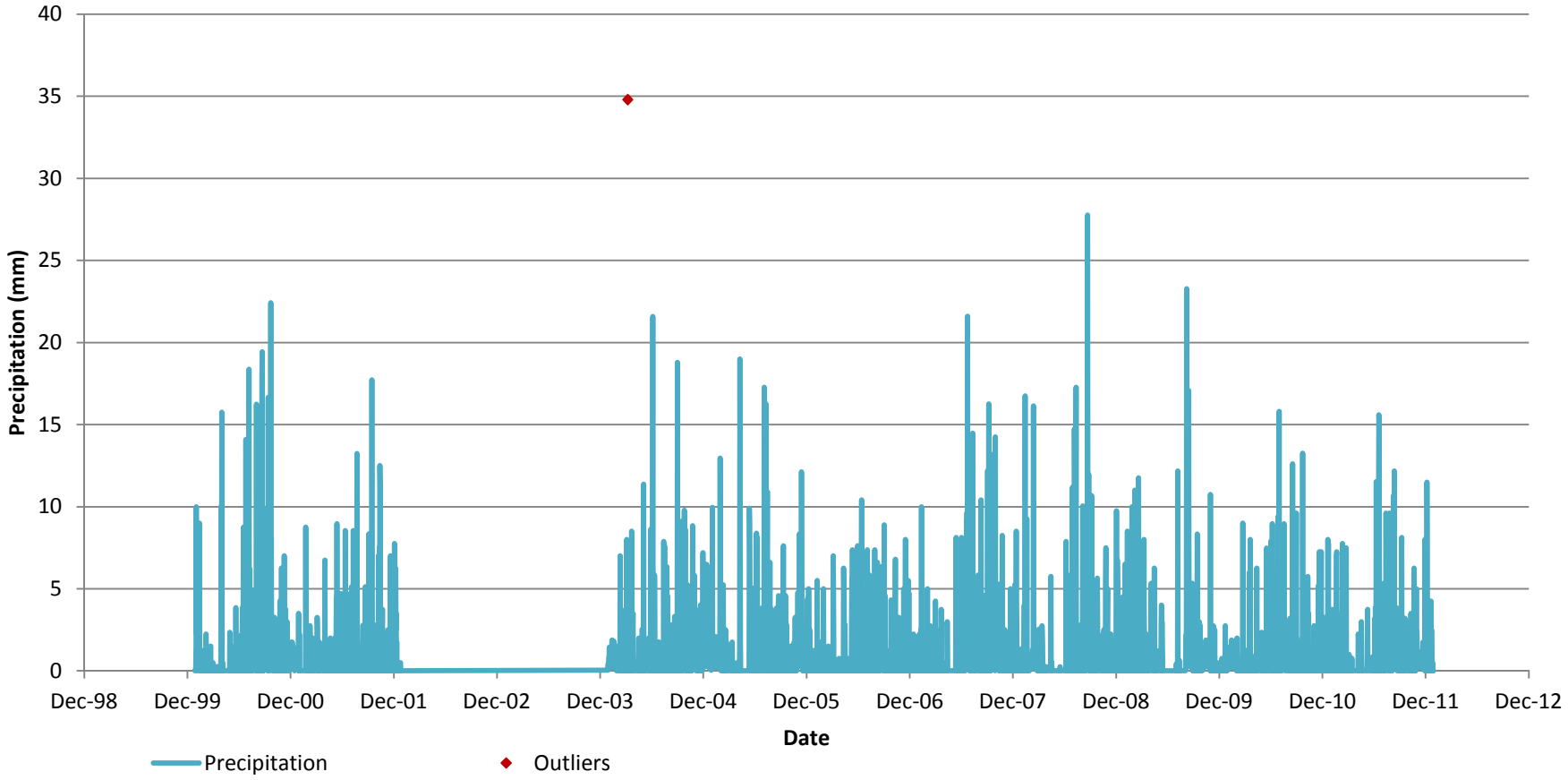

FIGURE 2-15
Faro Dump Area Daily Precipitation Estimate
Faro Mine Remediation Project

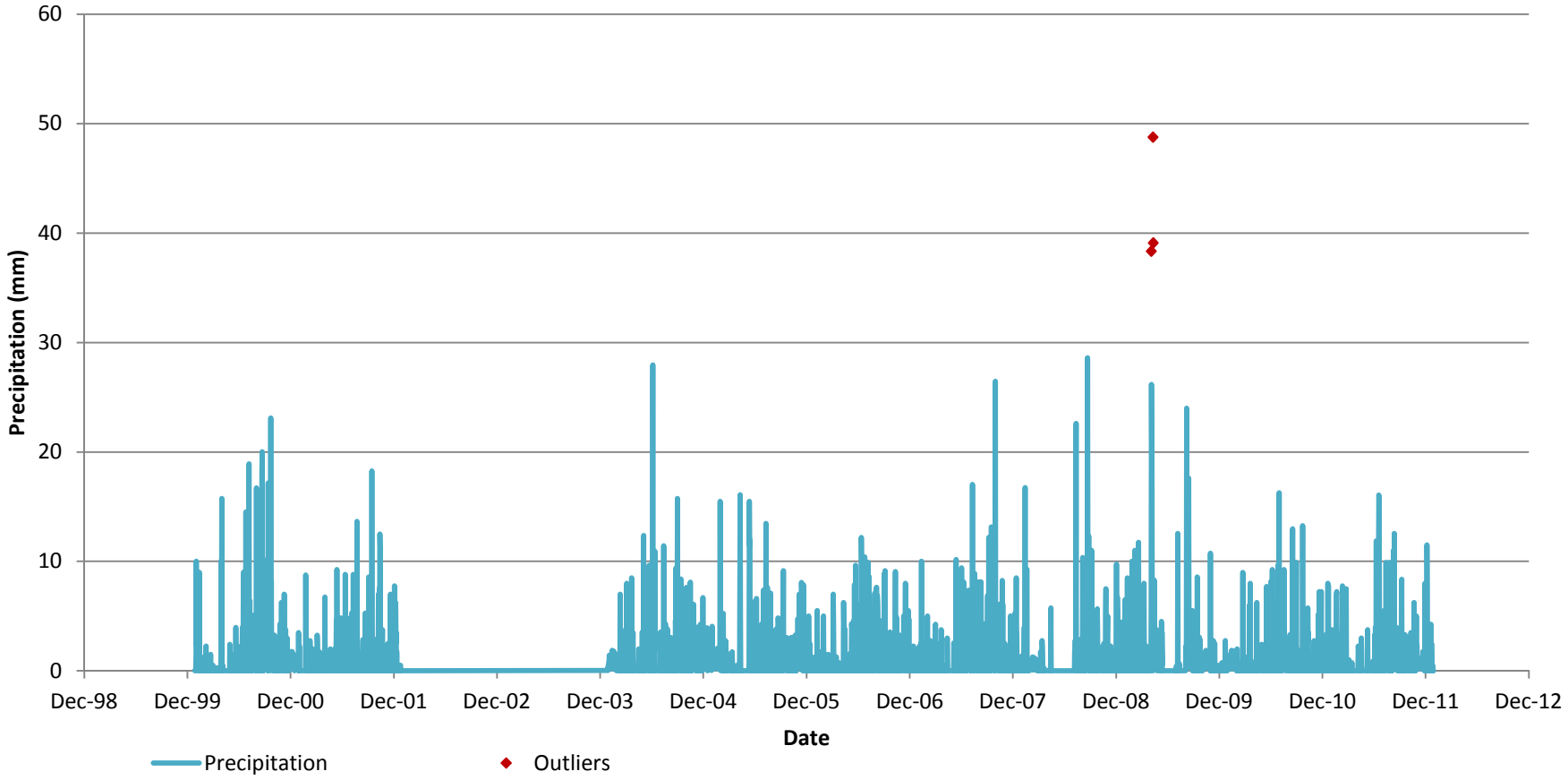

FIGURE 2-16
Grum Dump Area Daily Precipitation Estimate
Faro Mine Remediation Project

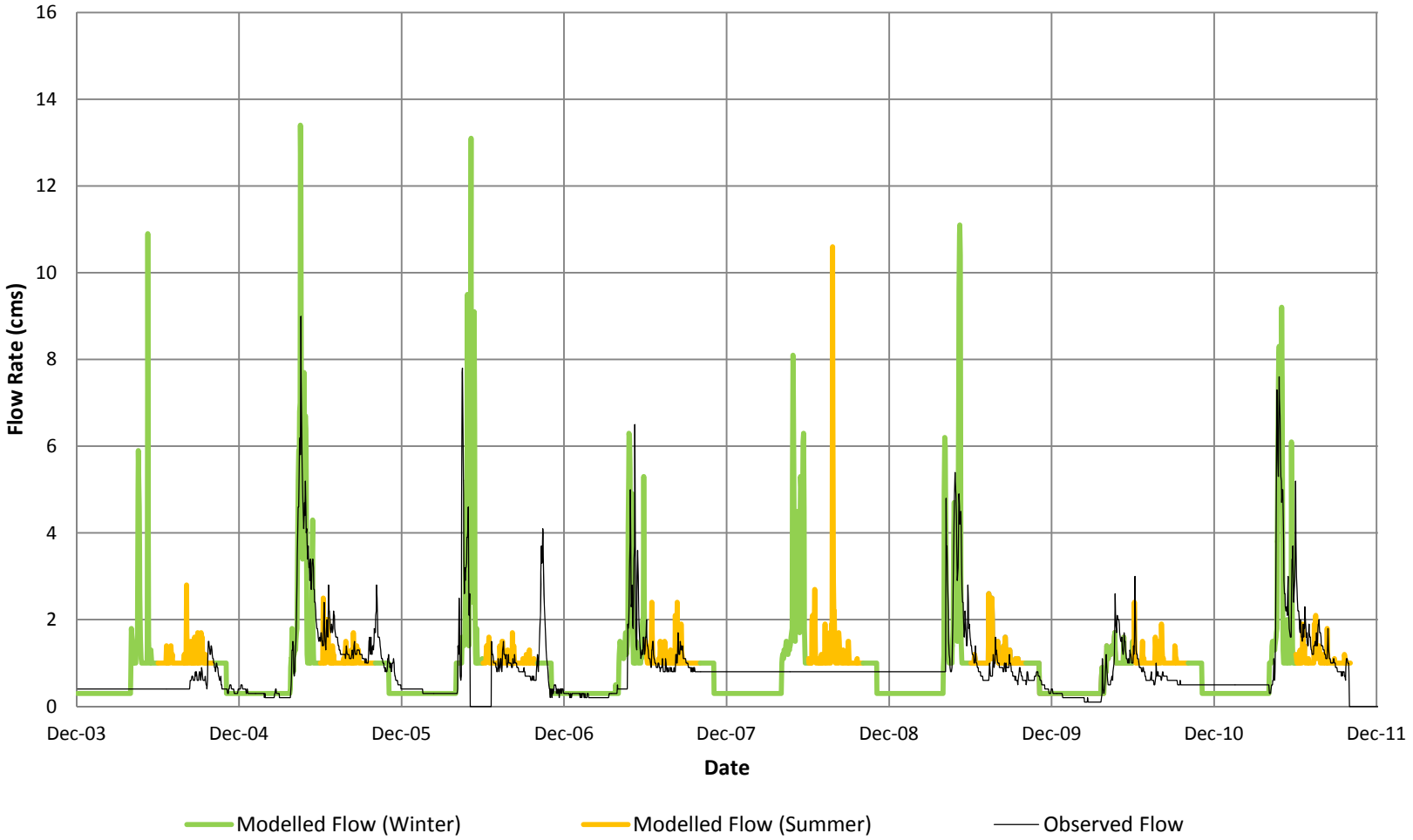

FIGURE 2-17
Modelled vs. Observed Flow at Station R7, 2004-2011
Faro Mine Remediation Project

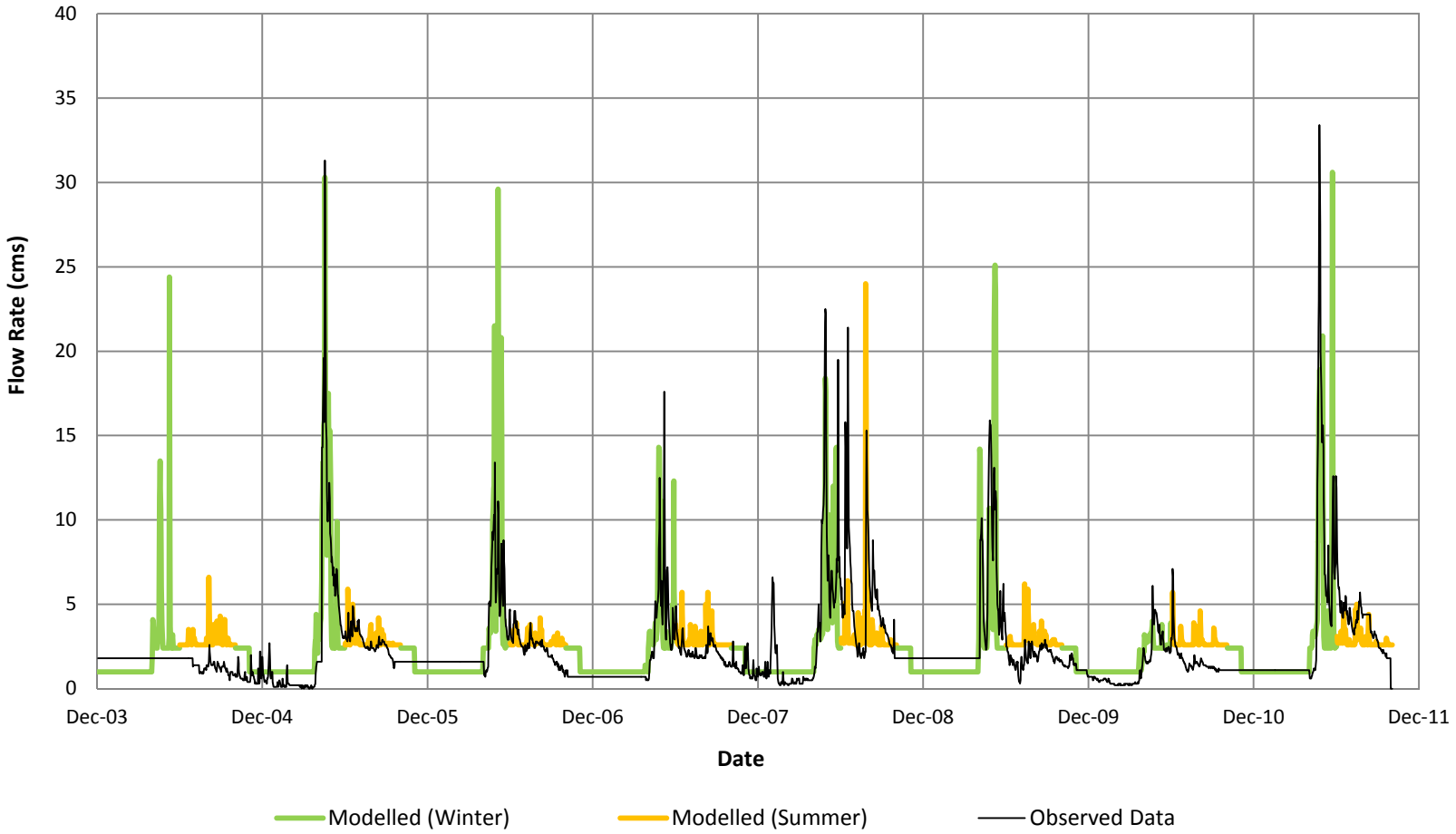

FIGURE 2-18
Modelled vs. Observed Flow at Station X14, 2004-2011
Faro Mine Remediation Project

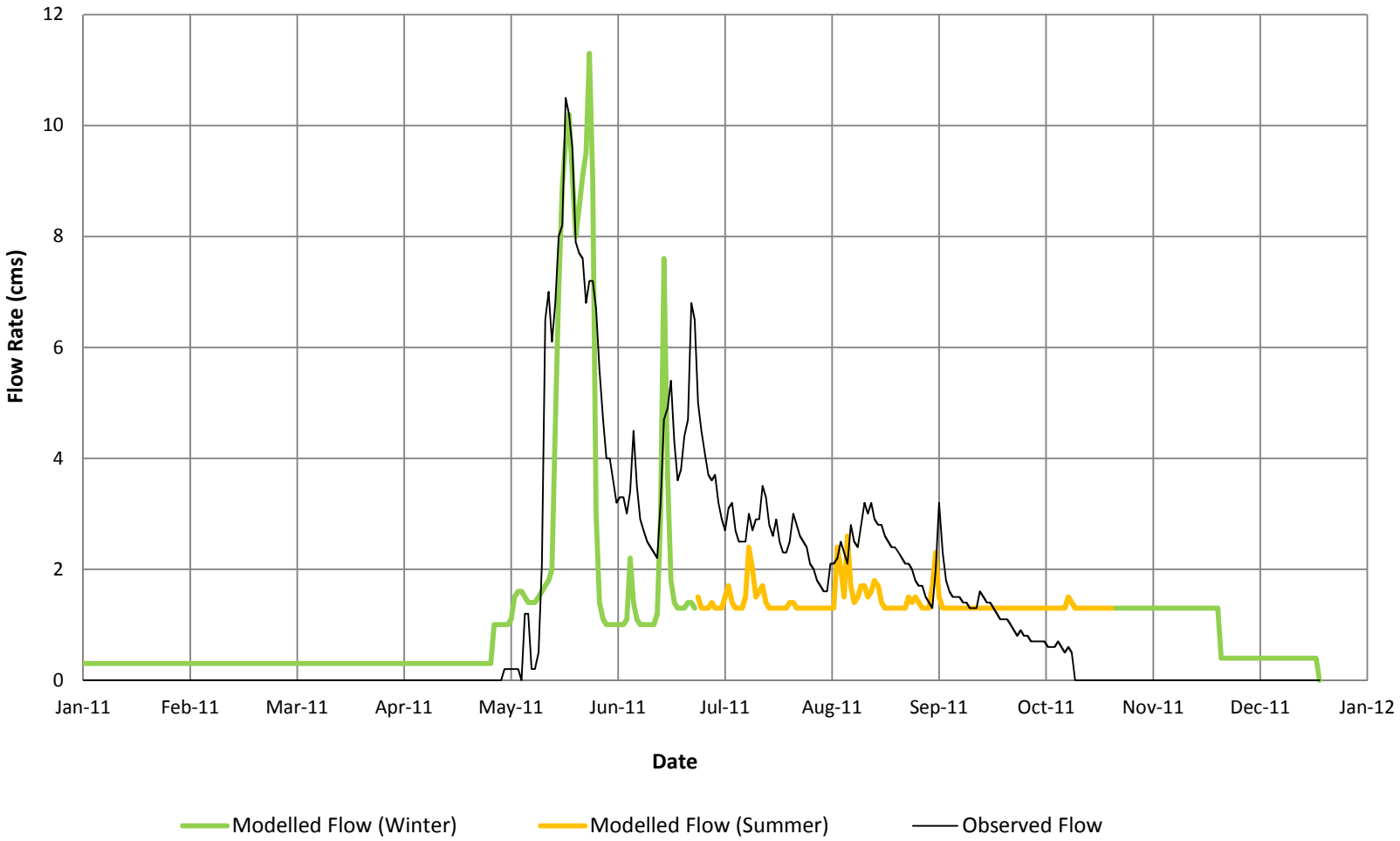

FIGURE 2-19
Modelled vs. Observed Flow at Station X2, 2011
Faro Mine Remediation Project

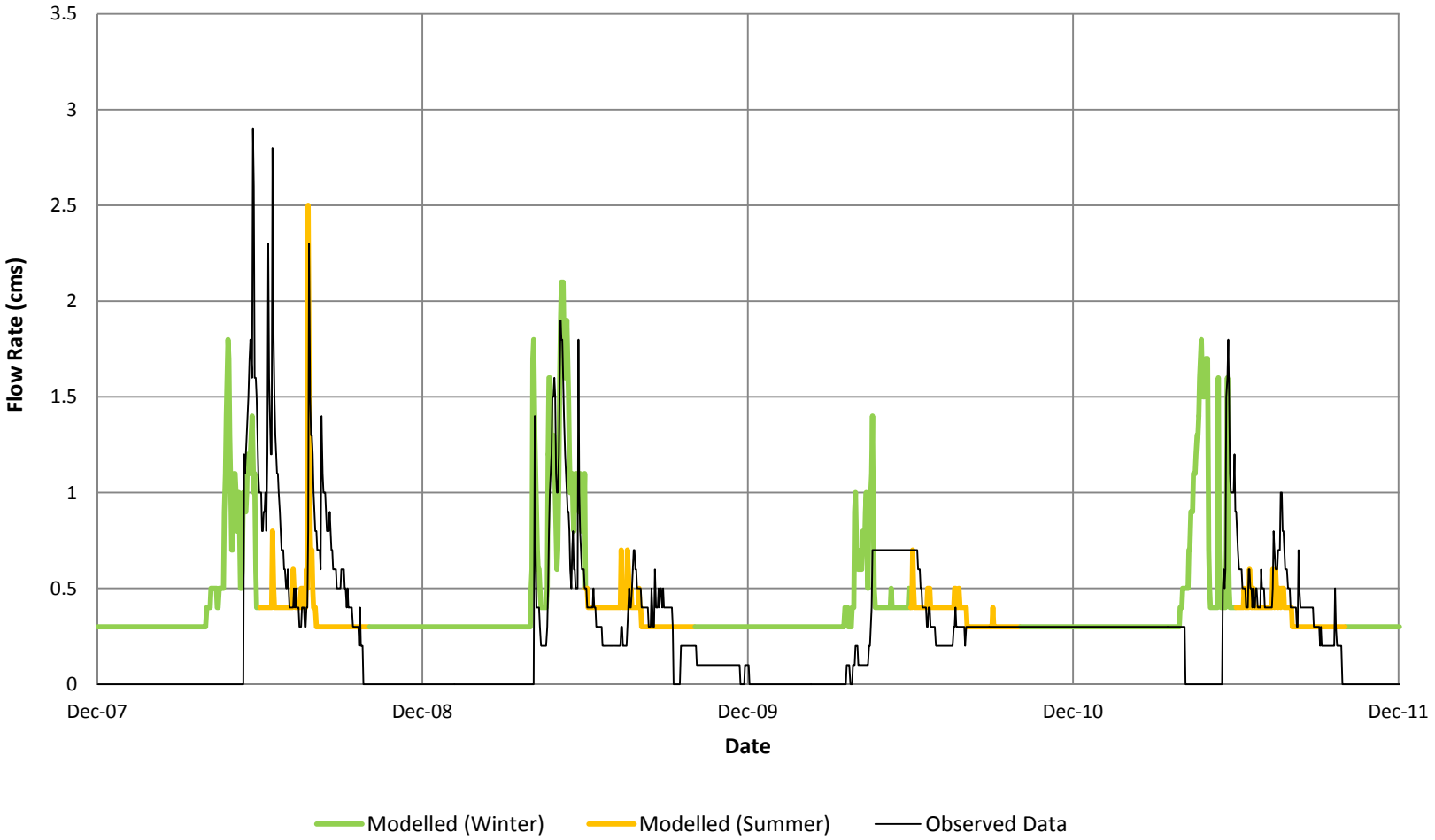

FIGURE 2-20
Modelled vs. Observed Flow at Station V1, 2008-2011
Faro Mine Remediation Project

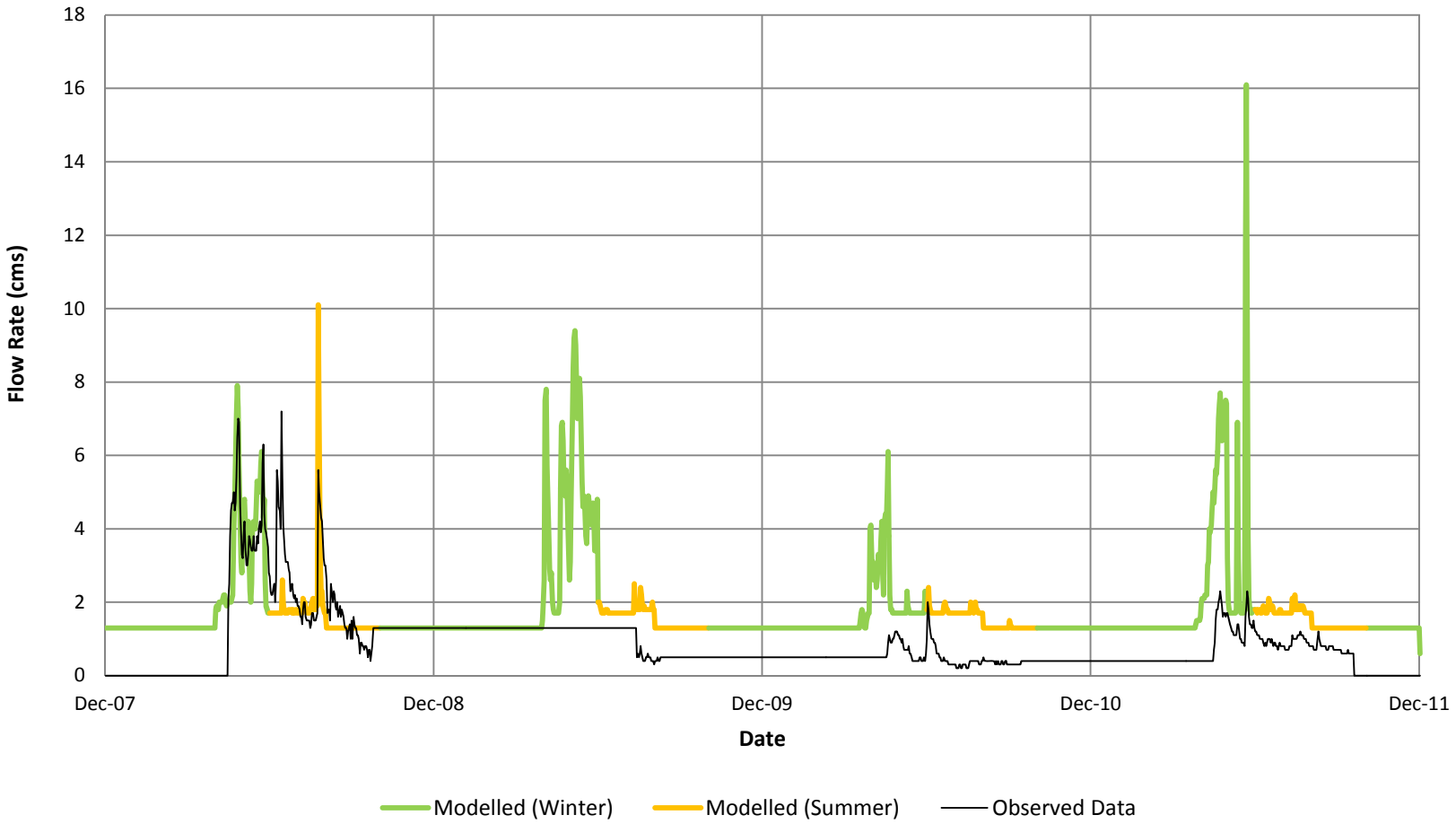

FIGURE 2-21
Modelled vs. Observed Flow at Station V8, 2008-2011
Faro Mine Remediation Project

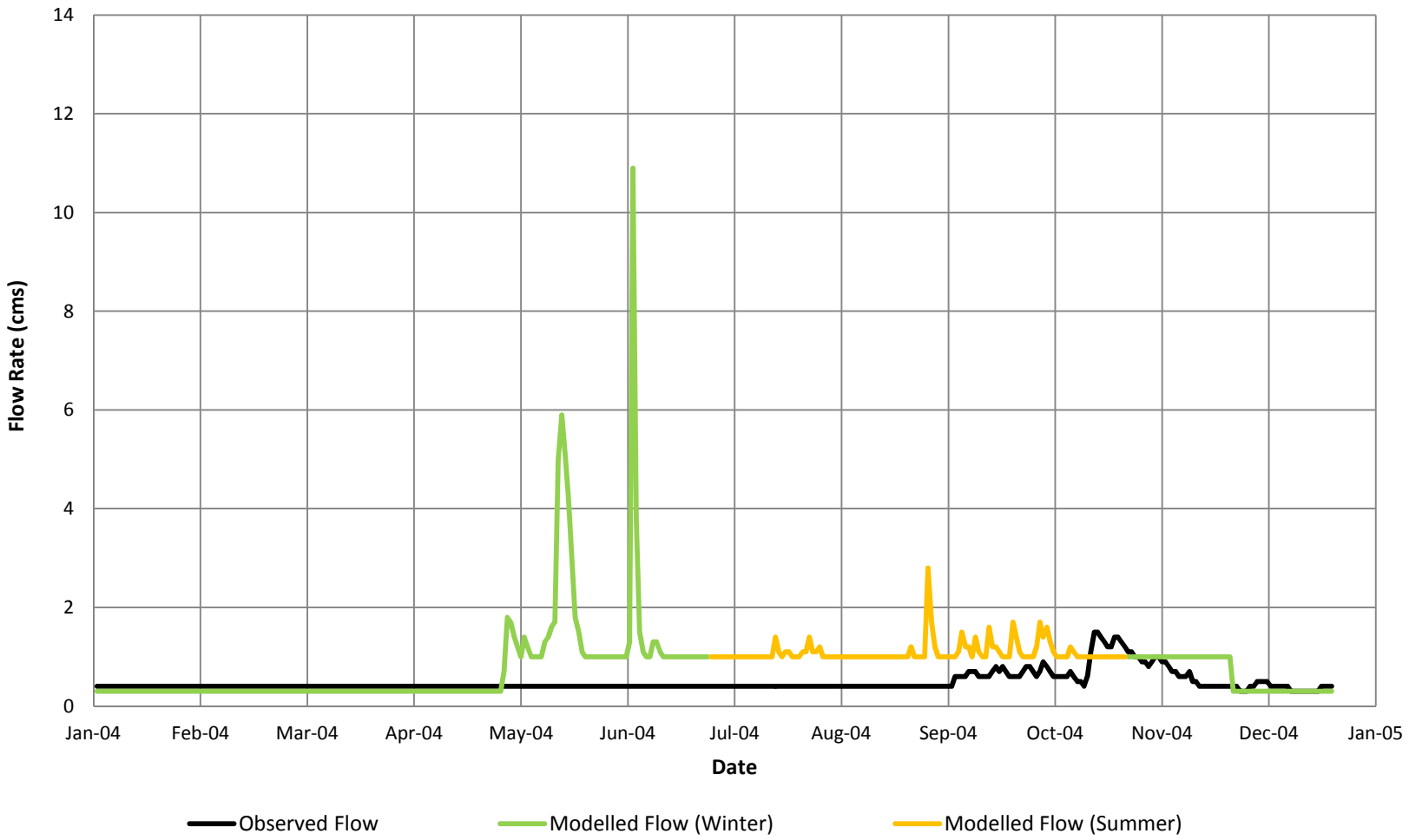

FIGURE A-1
Modelled vs. Observed Flow at Station R7, 2004
Faro Mine Remediation Project

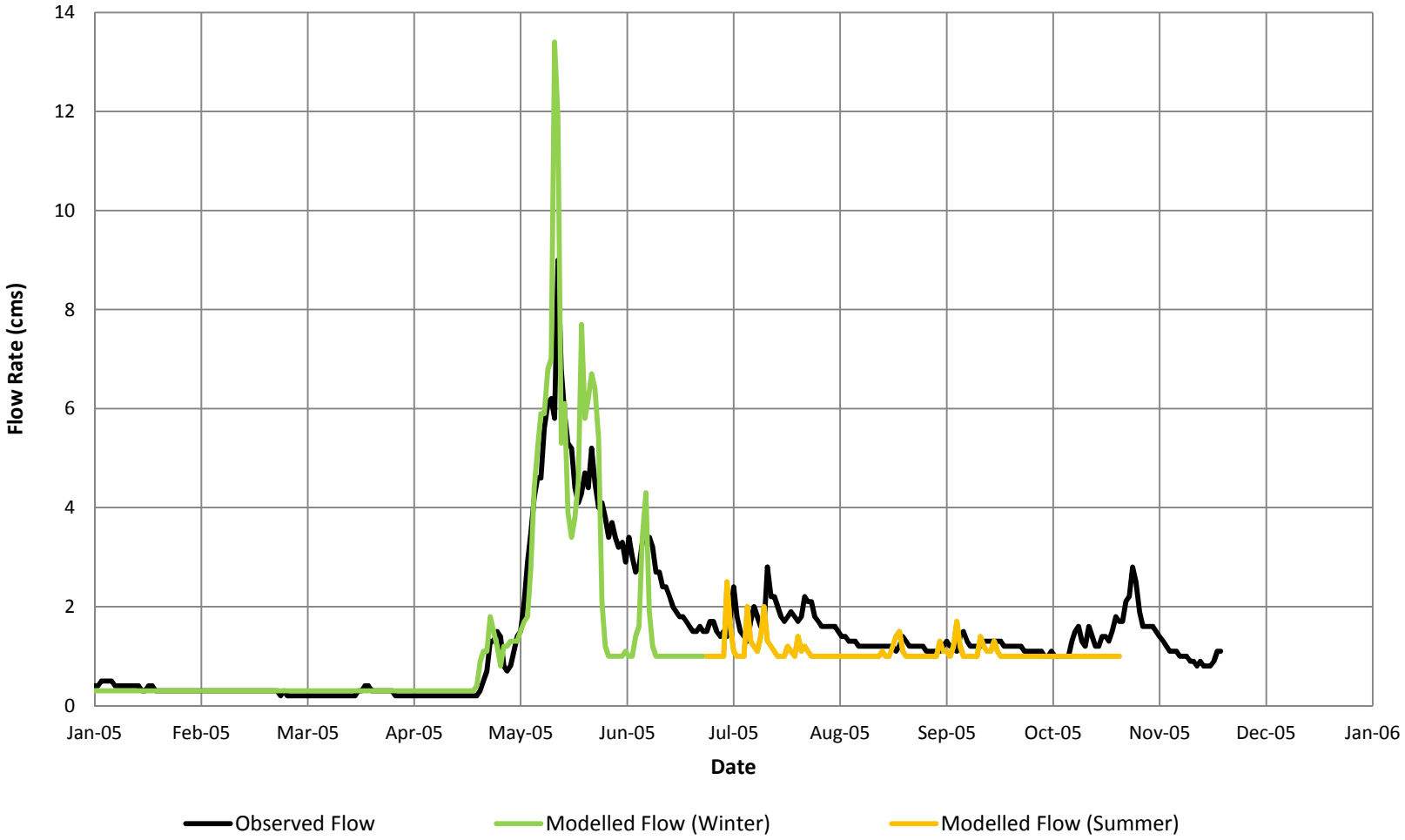

FIGURE A-2
Modelled vs. Observed Flow at Station R7, 2005
Faro Mine Remediation Project

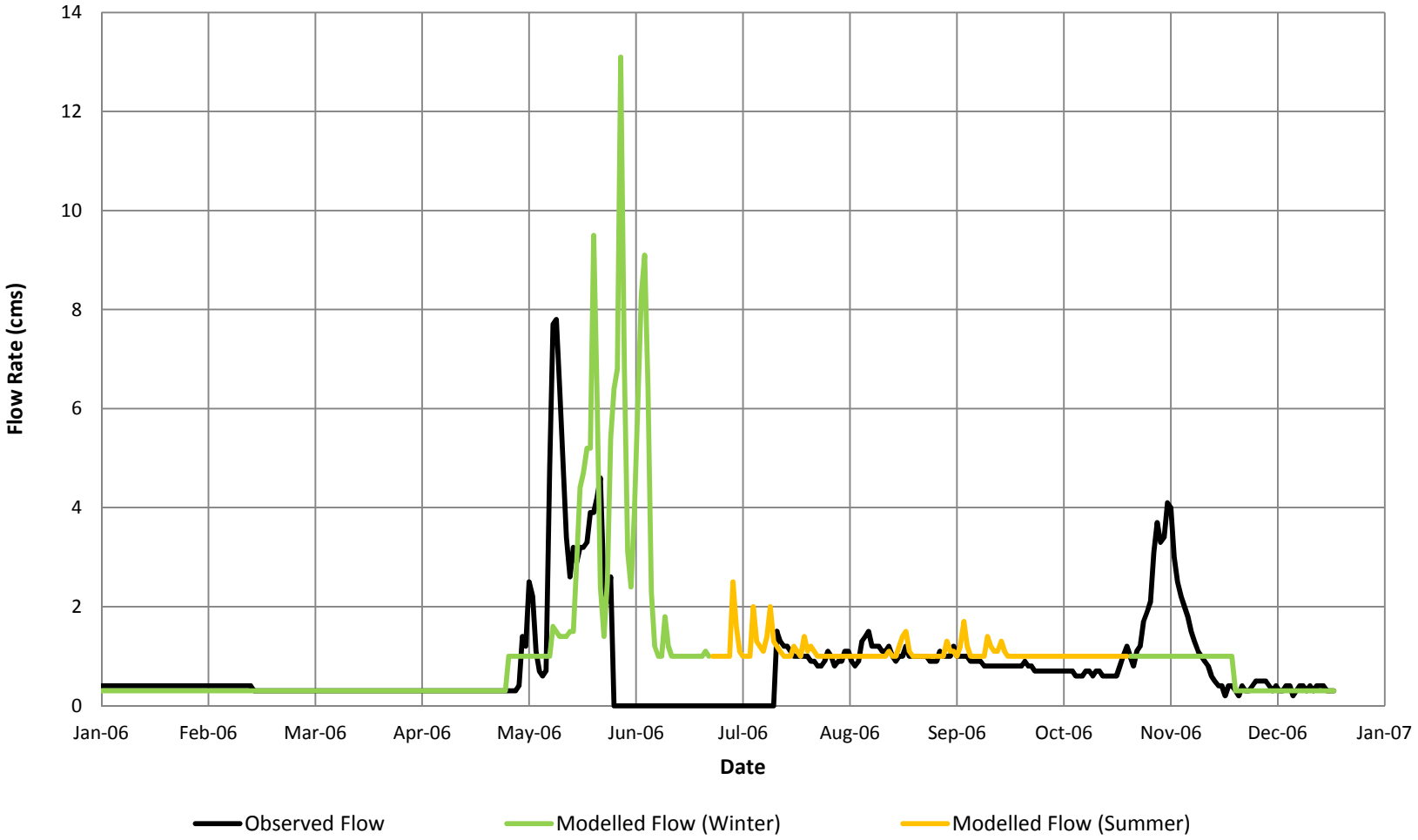

FIGURE A-3
Modelled vs. Observed Flow at Station R7, 2006
Faro Mine Remediation Project

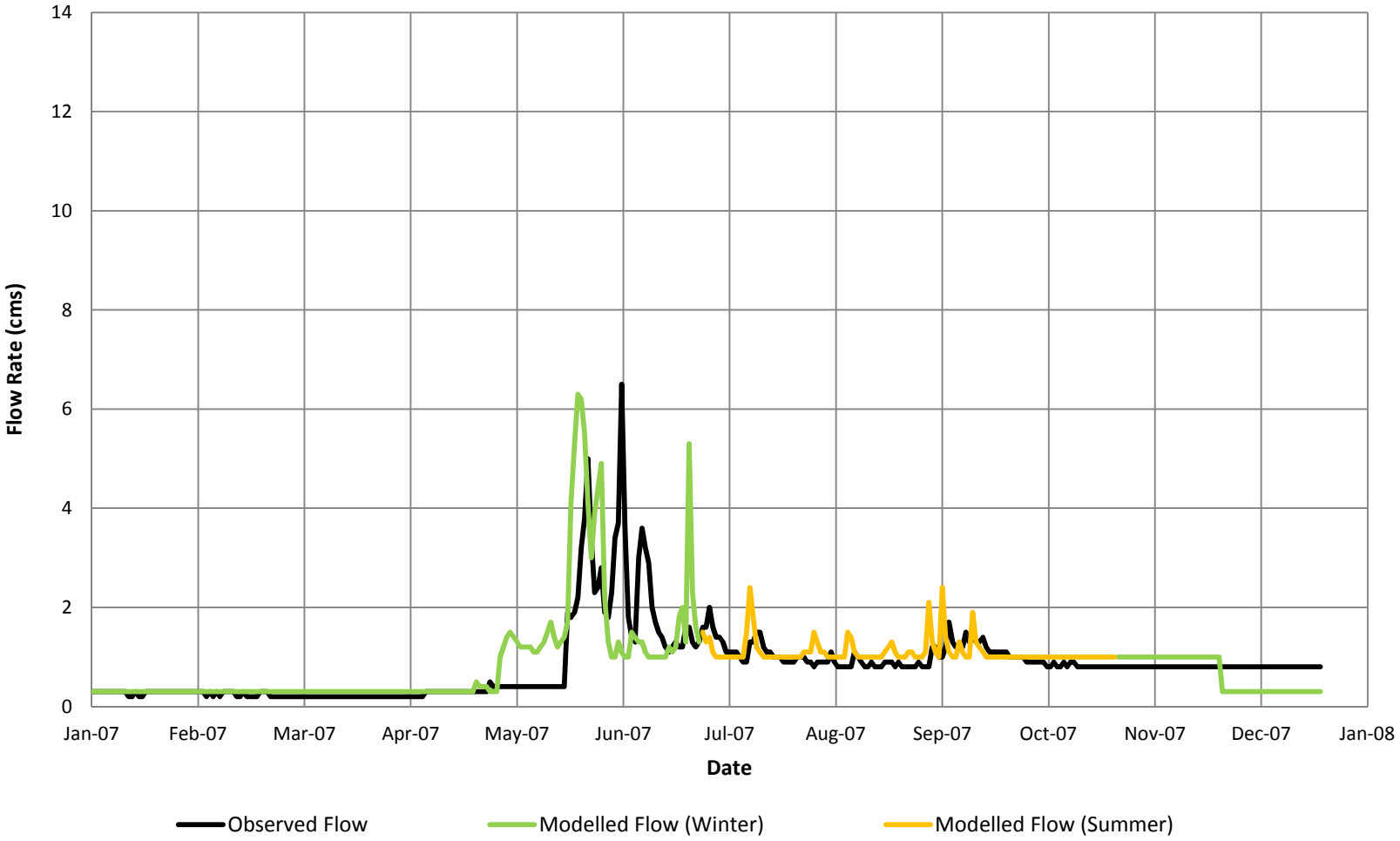

FIGURE A-4
Modelled vs. Observed Flow at Station R7, 2007
Faro Mine Remediation Project

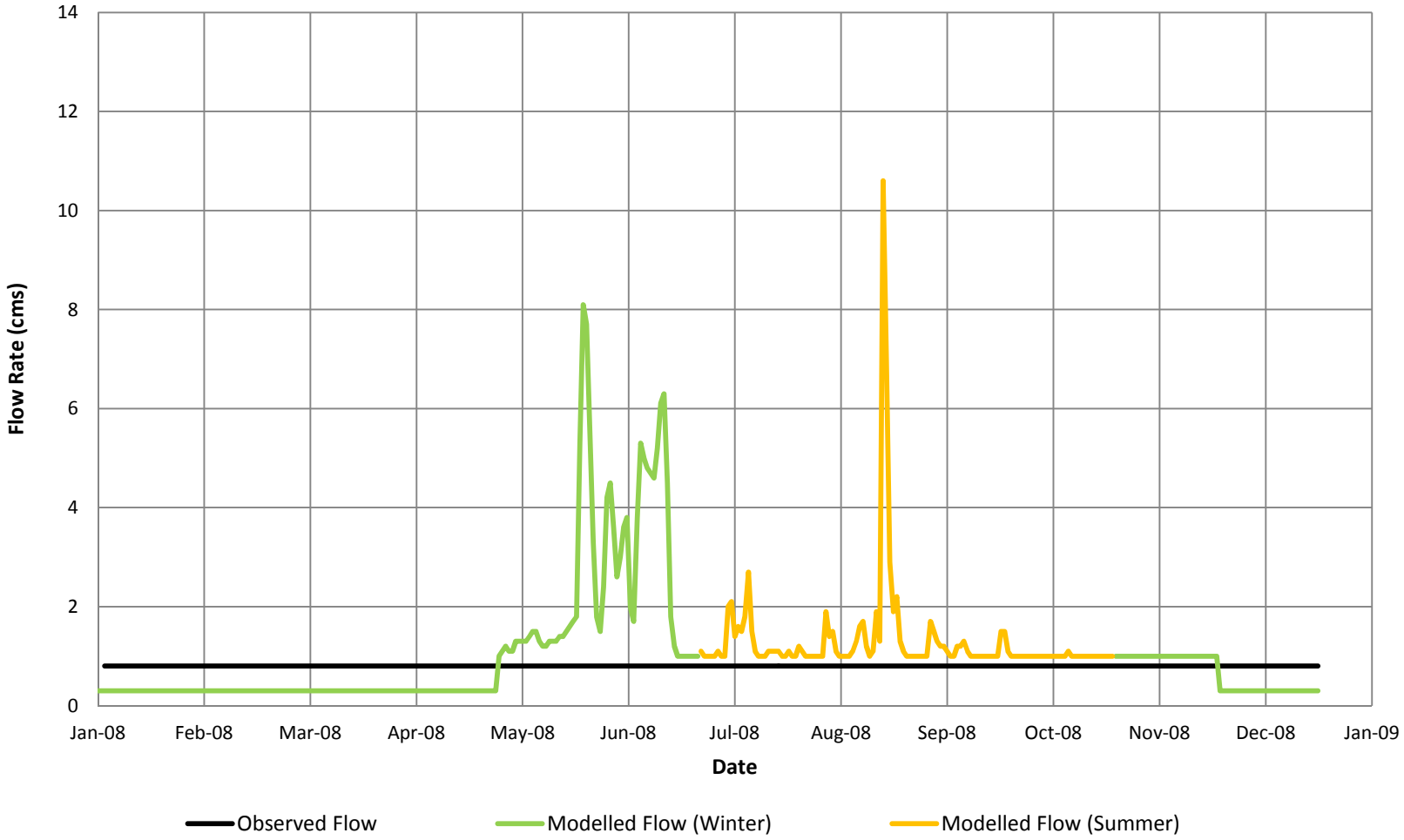

FIGURE A-5
Modelled vs. Observed Flow at Station R7, 2008
Faro Mine Remediation Project

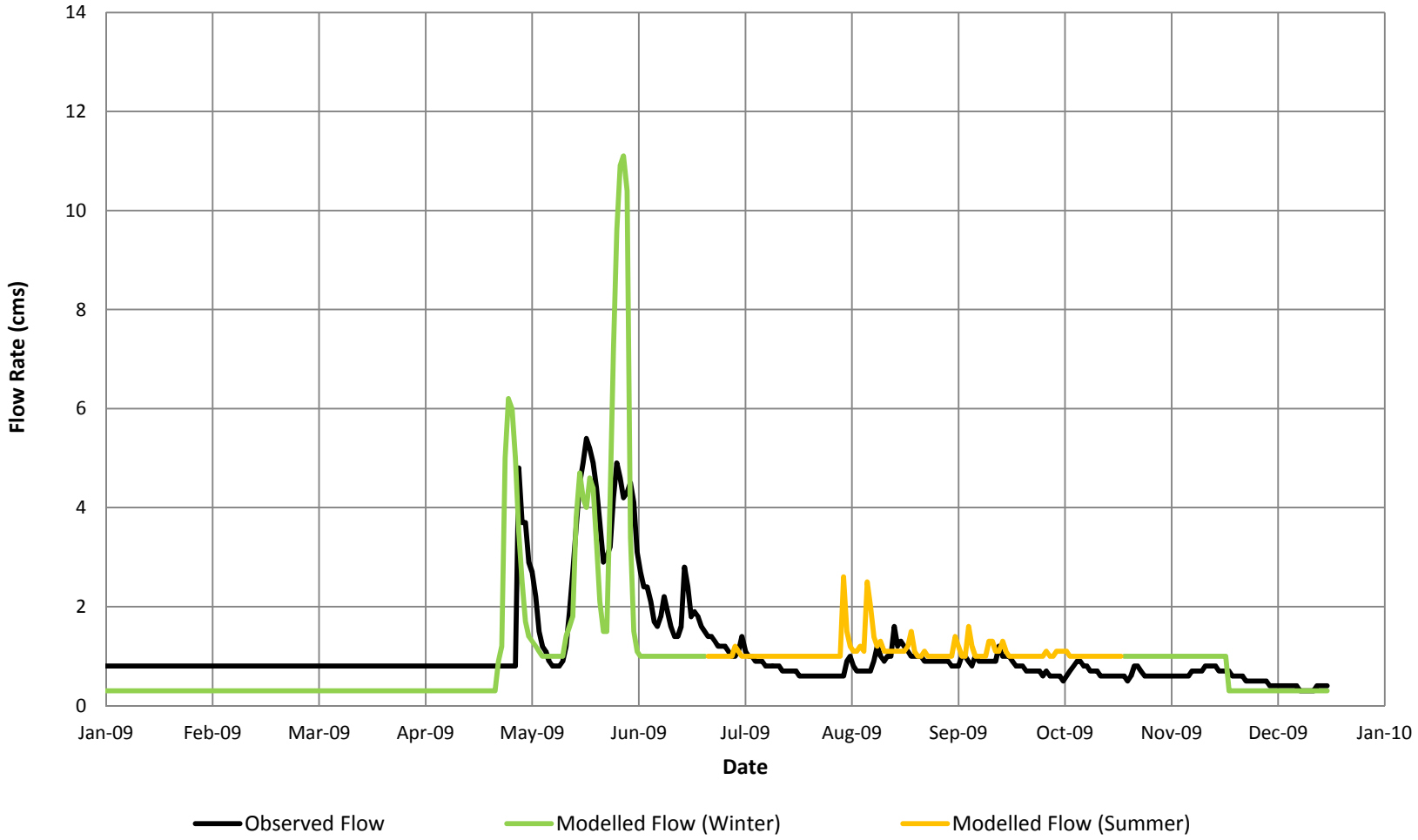

FIGURE A-6
Modelled vs. Observed Flow at Station R7, 2009
Faro Mine Remediation Project

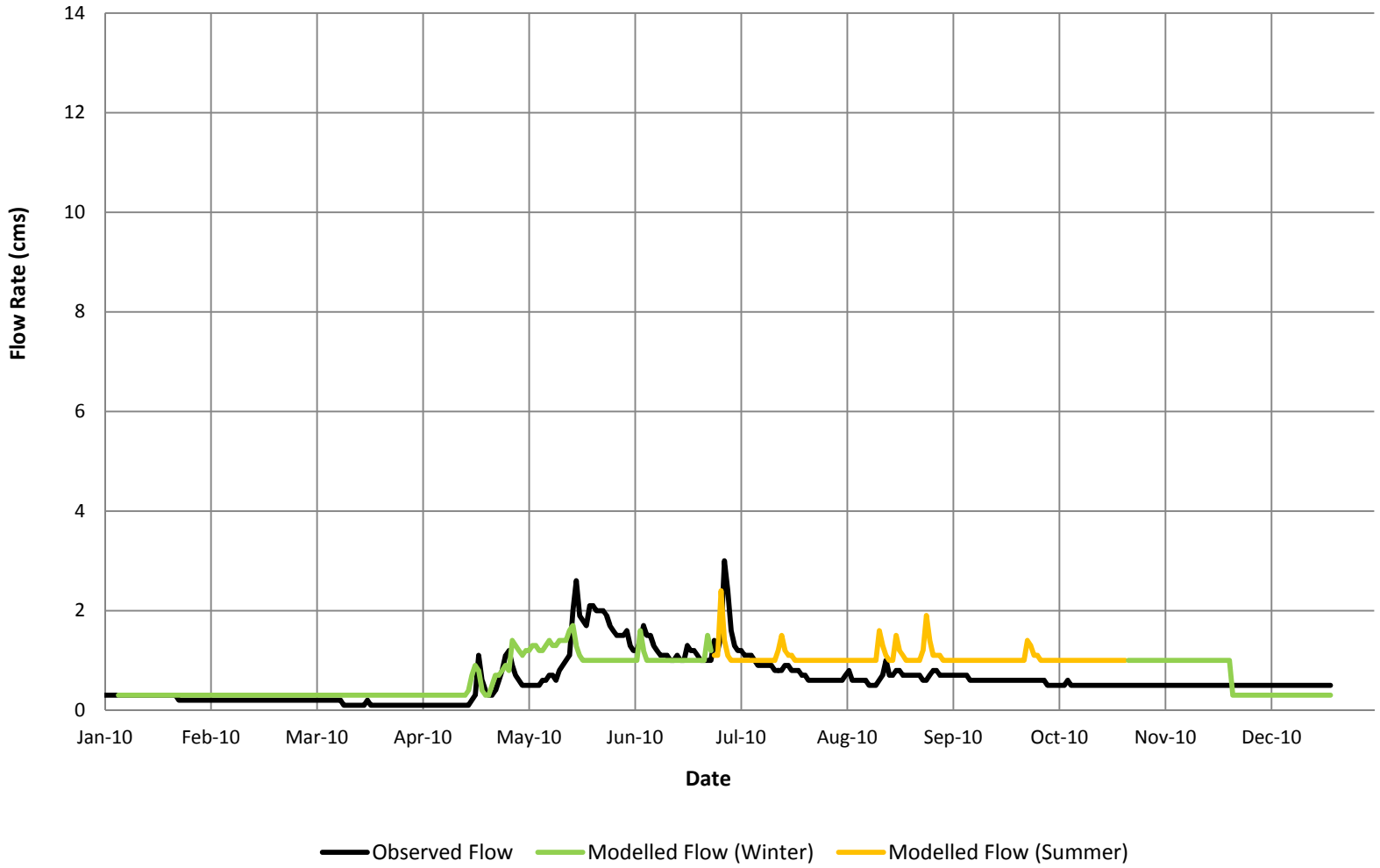

FIGURE A-7
Modelled vs. Observed Flow at Station R7, 2010
Faro Mine Remediation Project

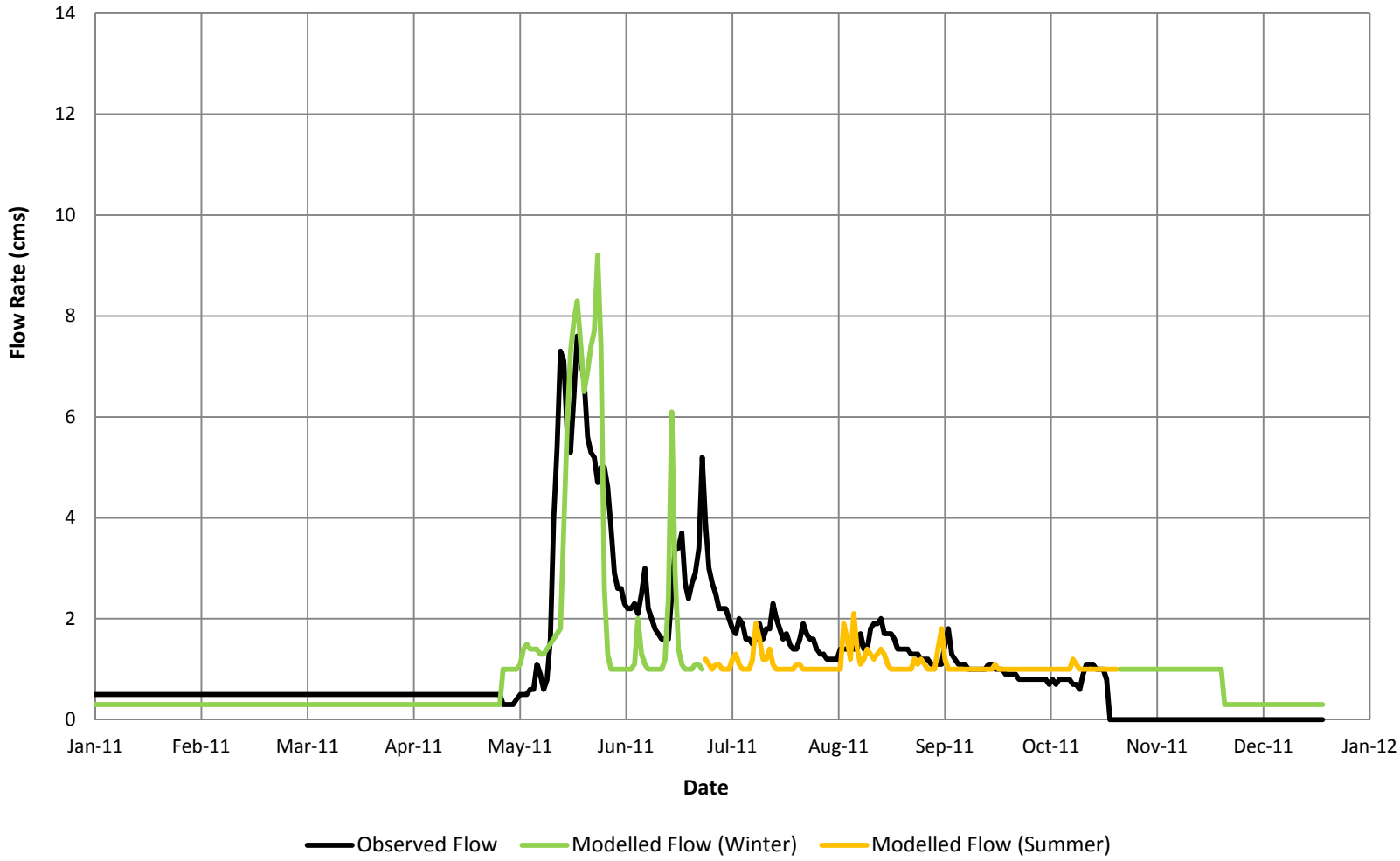

FIGURE A-8
Modelled vs. Observed Flow at Station R7, 2011
Faro Mine Remediation Project

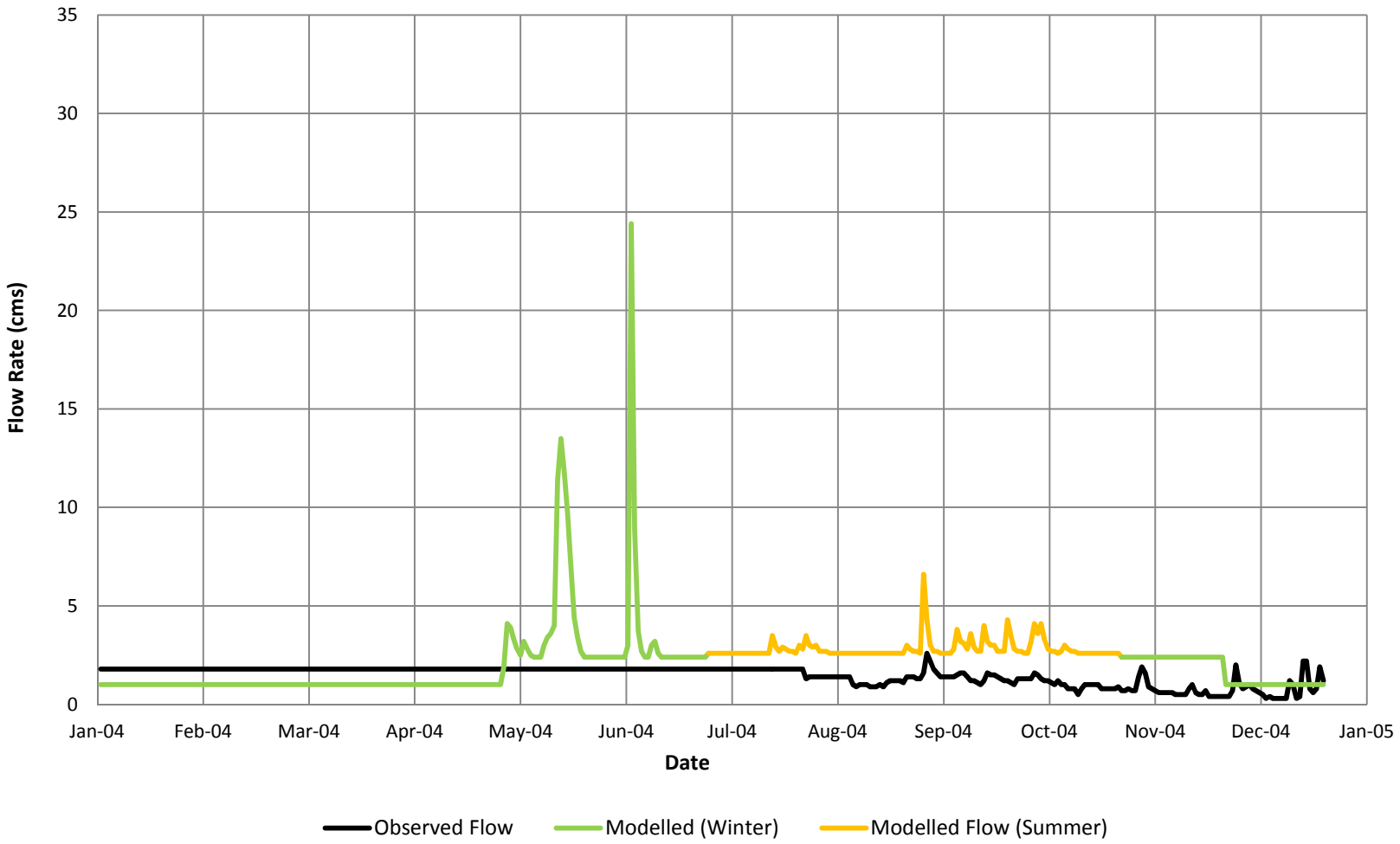

FIGURE A-9
Modelled vs. Observed Flow at Station X14, 2004
Faro Mine Remediation Project

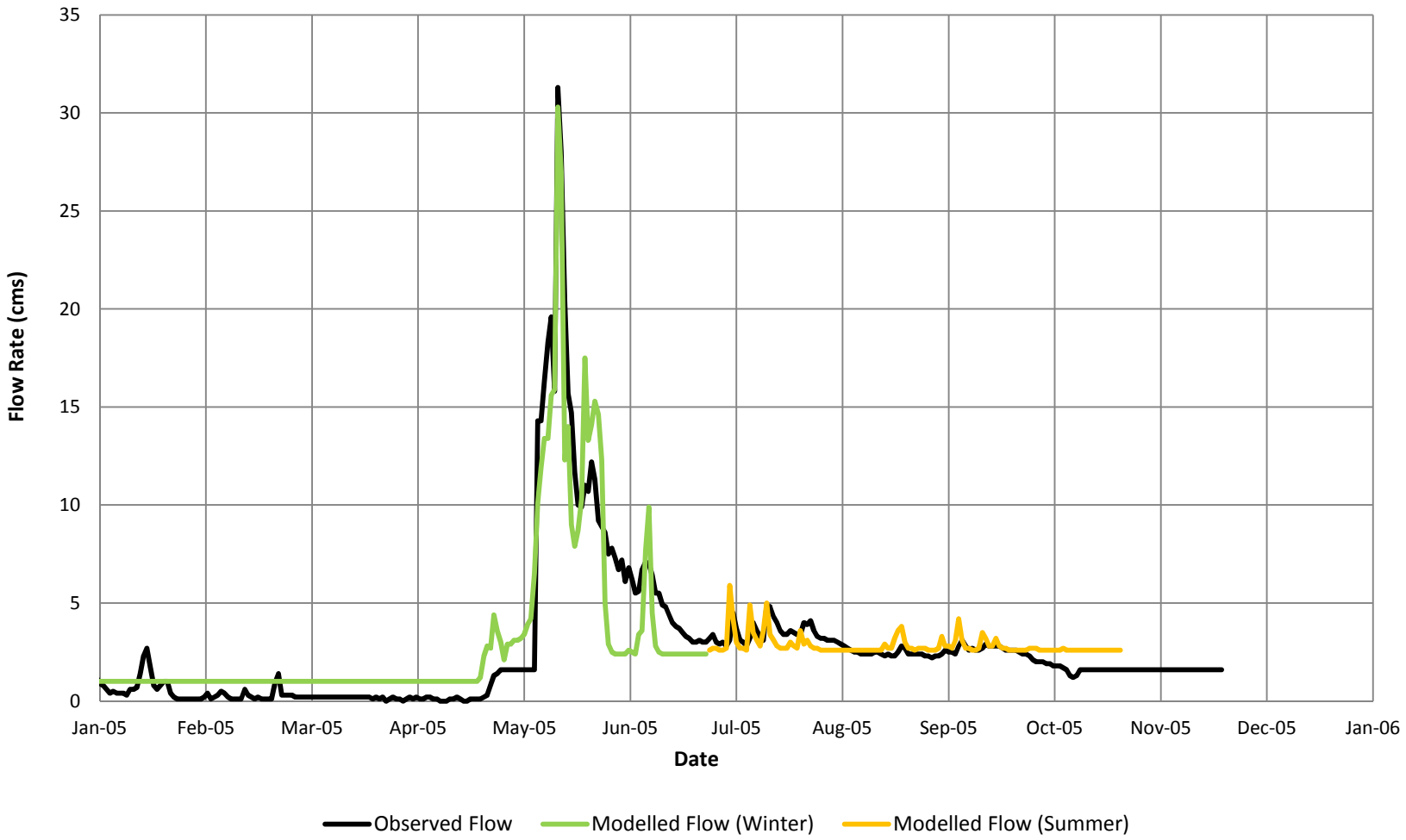

FIGURE A-10
Modelled vs. Observed Flow at Station X14, 2005
Faro Mine Remediation Project

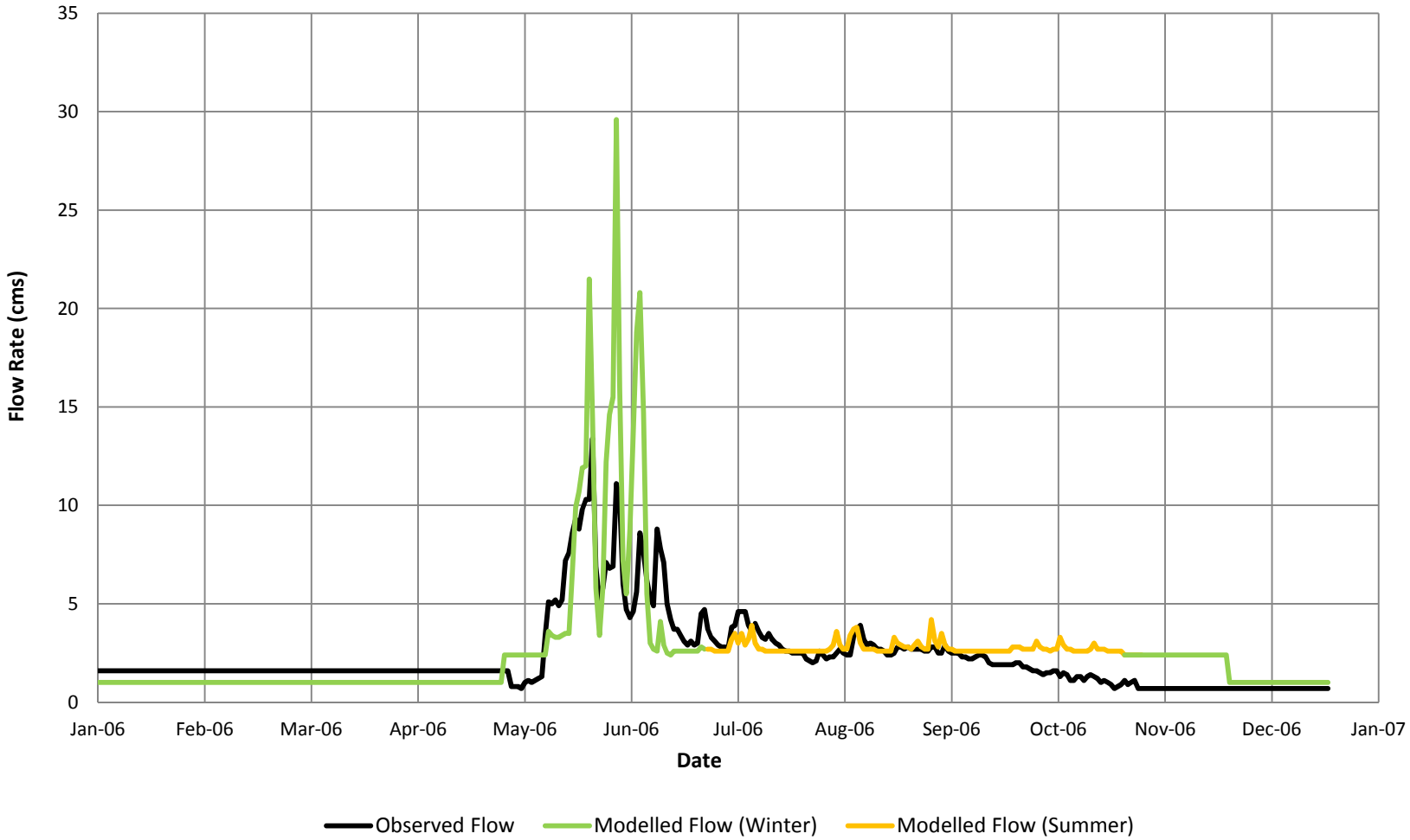

FIGURE A-11
Modelled vs. Observed Flow at Station X14, 2006
Faro Mine Remediation Project

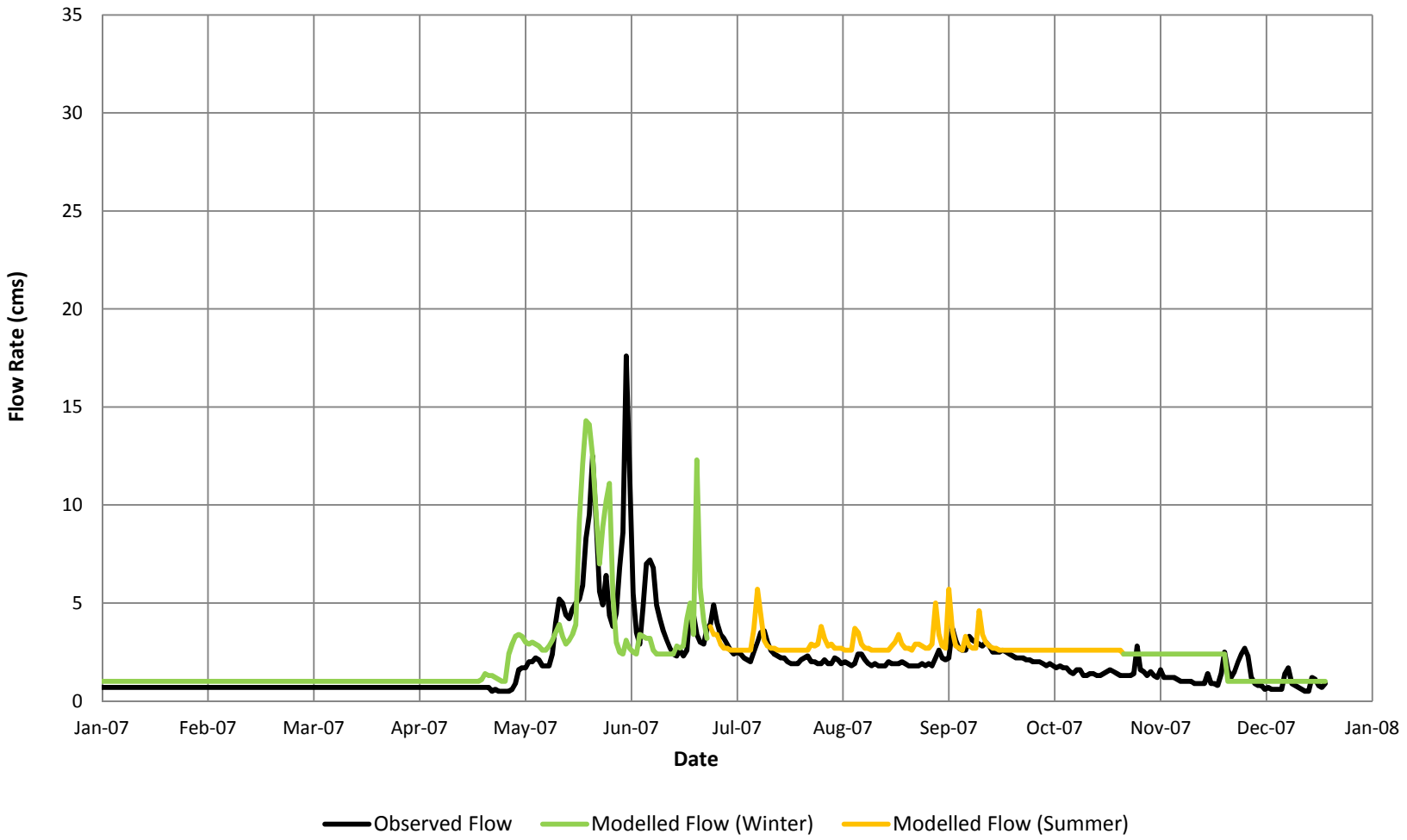

FIGURE A-12
Modelled vs. Observed Flow at Station X14, 2007
Faro Mine Remediation Project

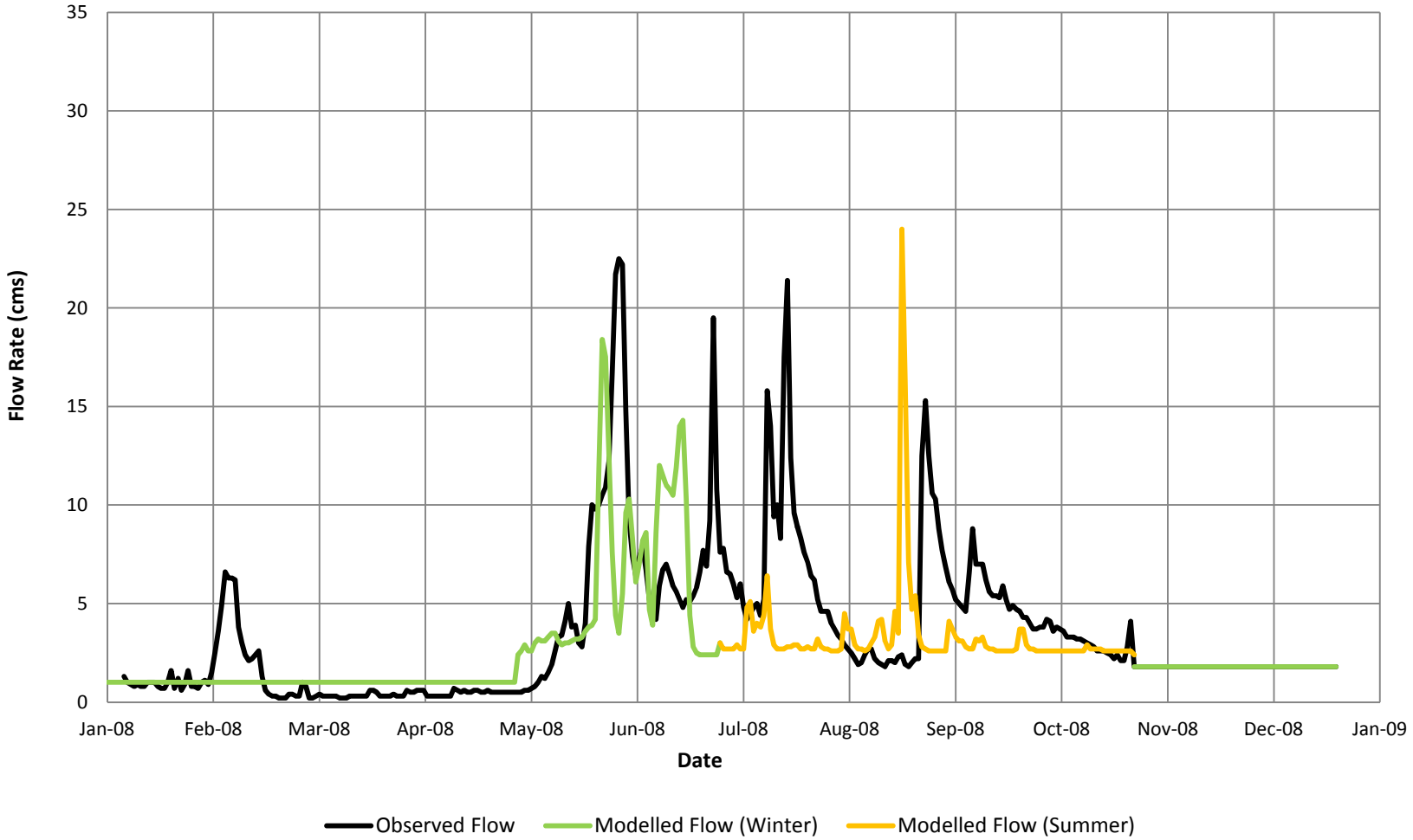

FIGURE A-13
Modelled vs. Observed Flow at Station X14, 2008
Faro Mine Remediation Project

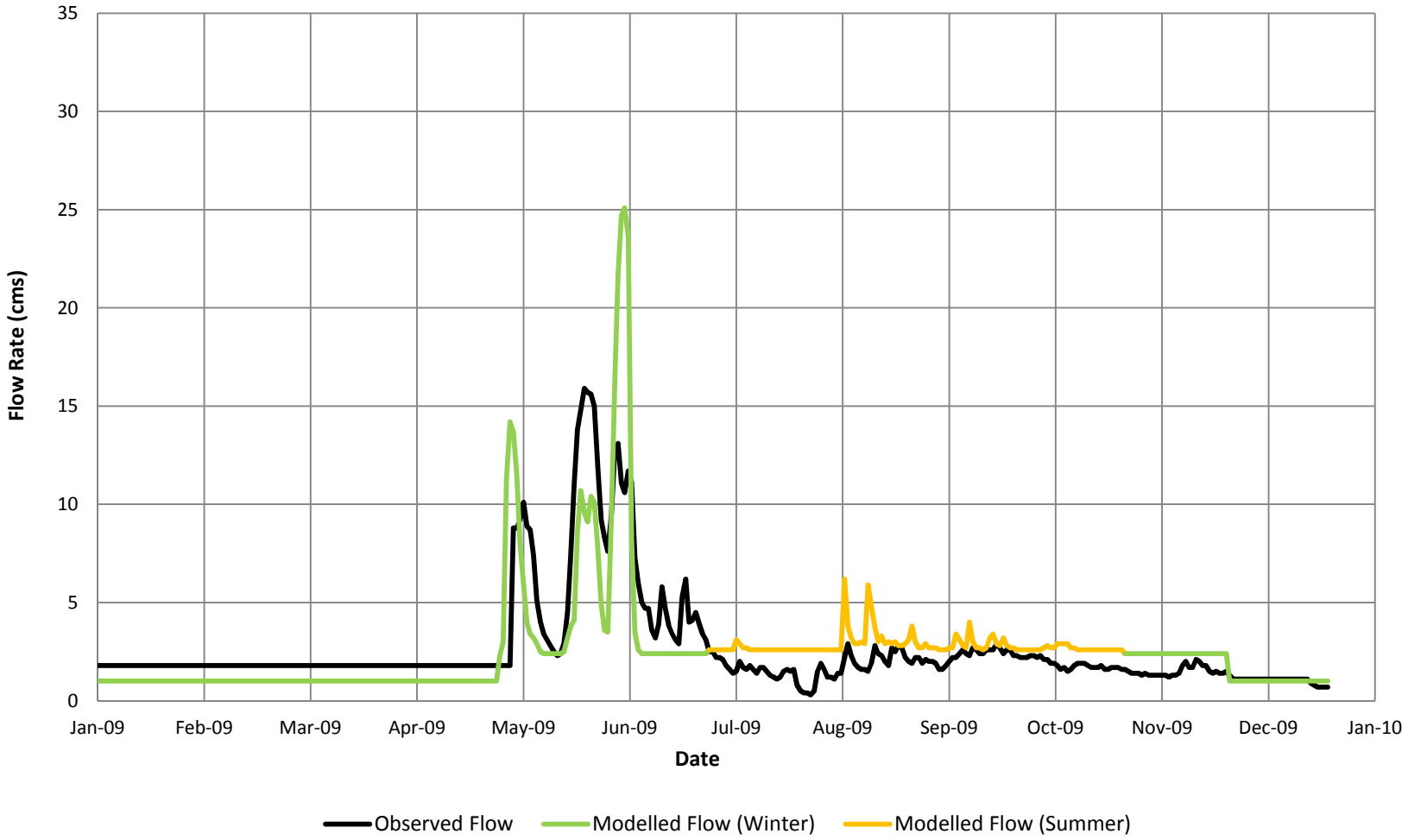

FIGURE A-14
Modelled vs. Observed Flow at Station X14, 2009
Faro Mine Remediation Project

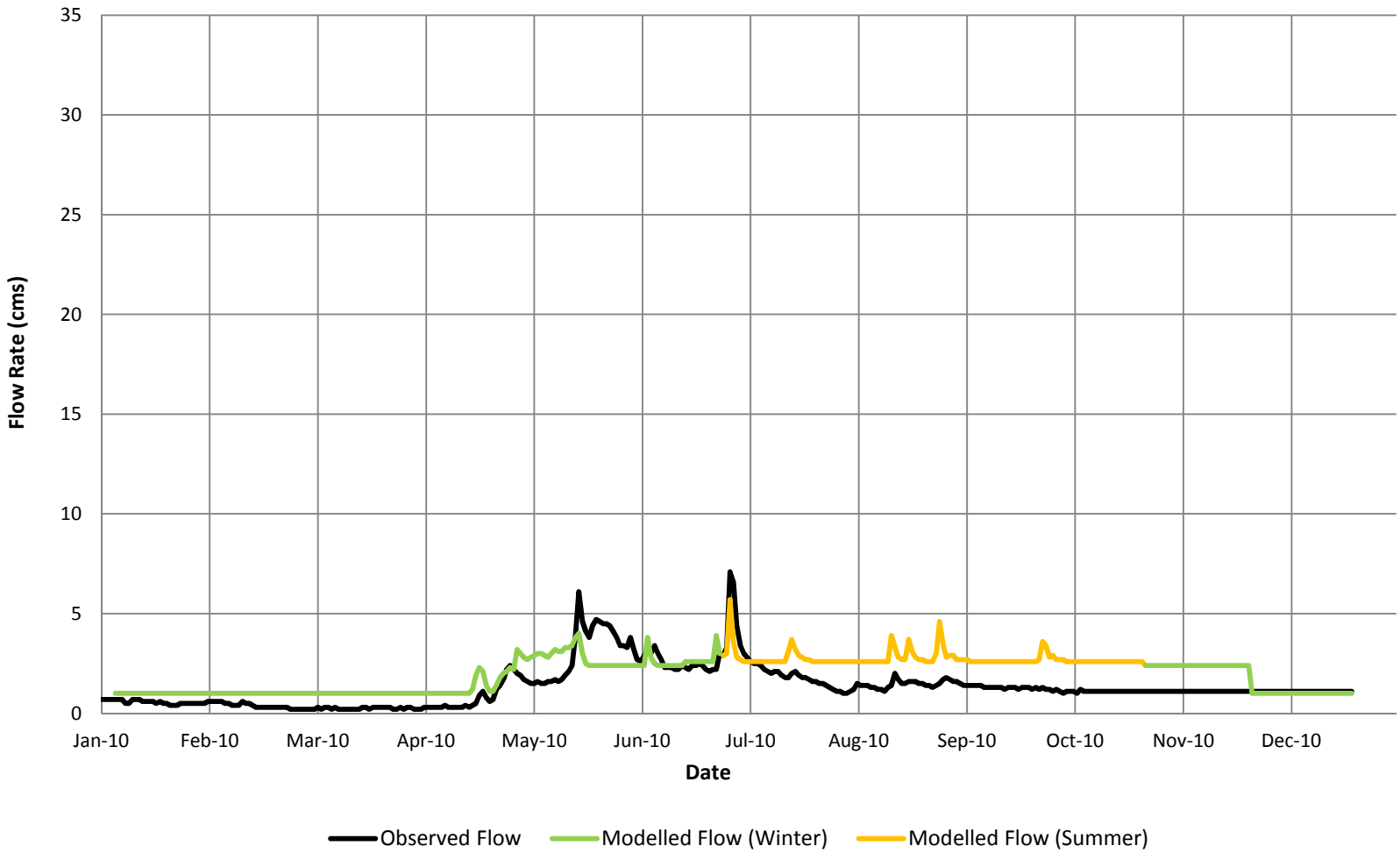

FIGURE A-15
Modelled vs. Observed Flow at Station X14, 2010
Faro Mine Remediation Project

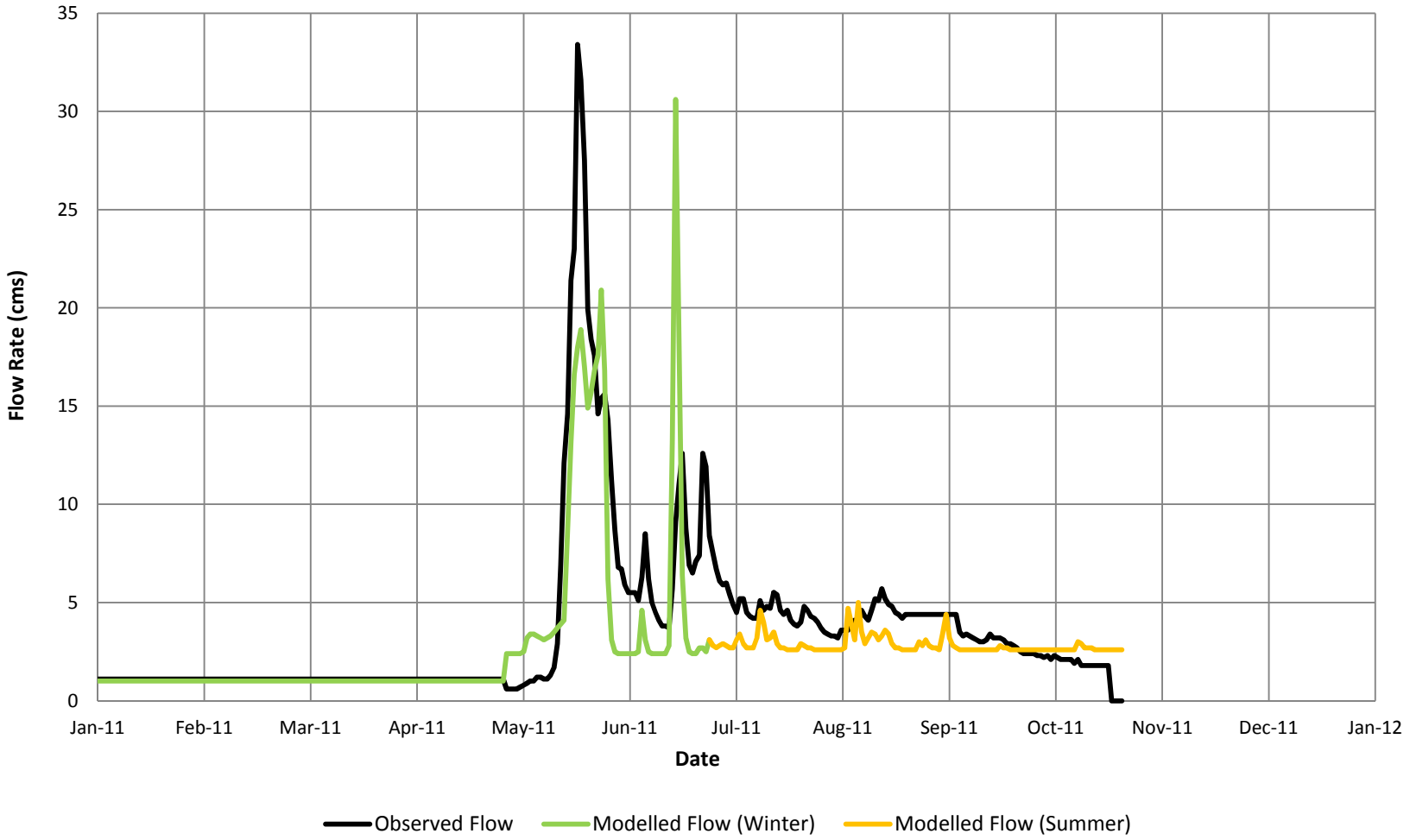

FIGURE A-16
Modelled vs. Observed Flow at Station X14, 2011
Faro Mine Remediation Project

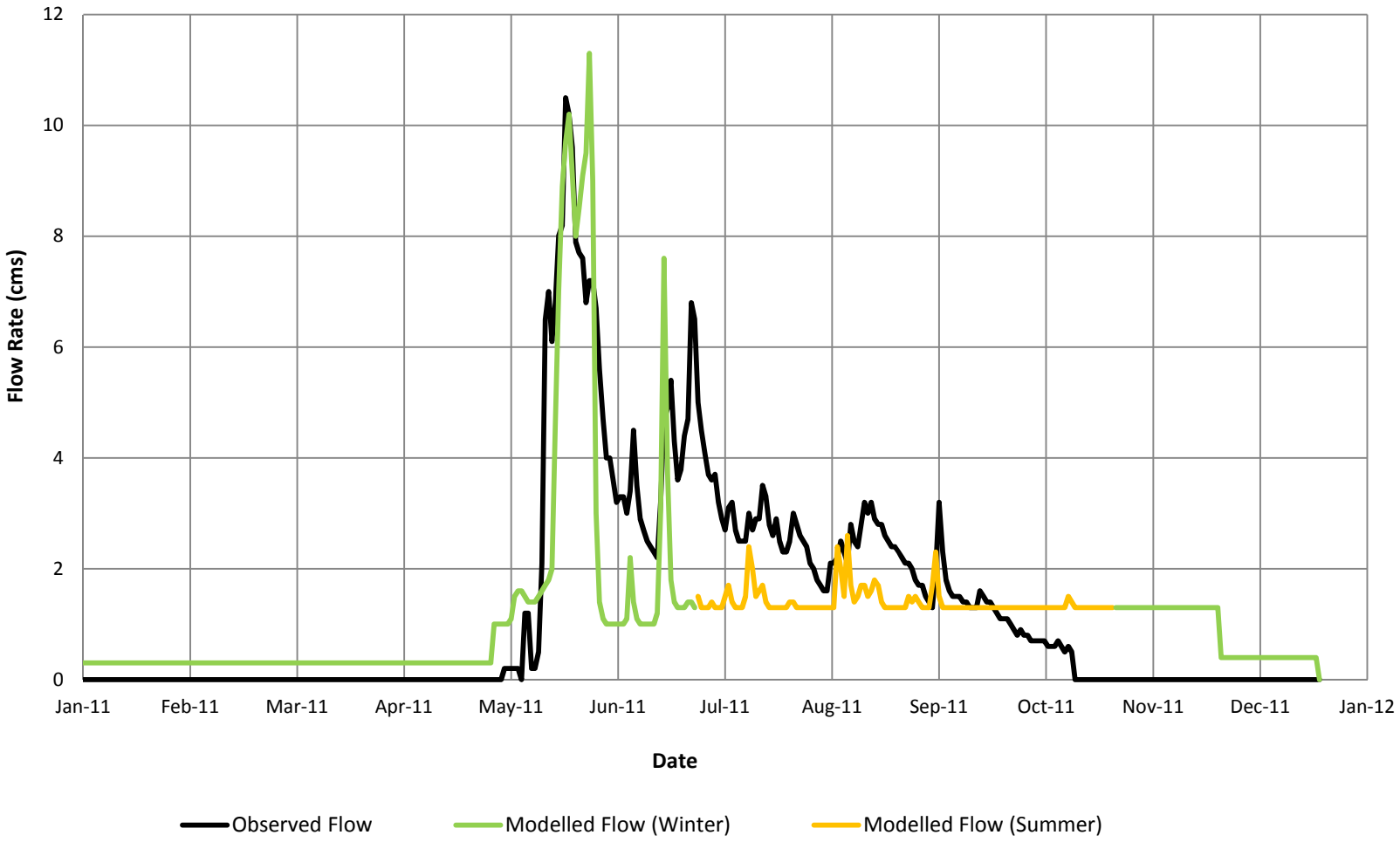

FIGURE A-17
Modelled vs. Observed Flow at Station X2, 2011
Faro Mine Remediation Project

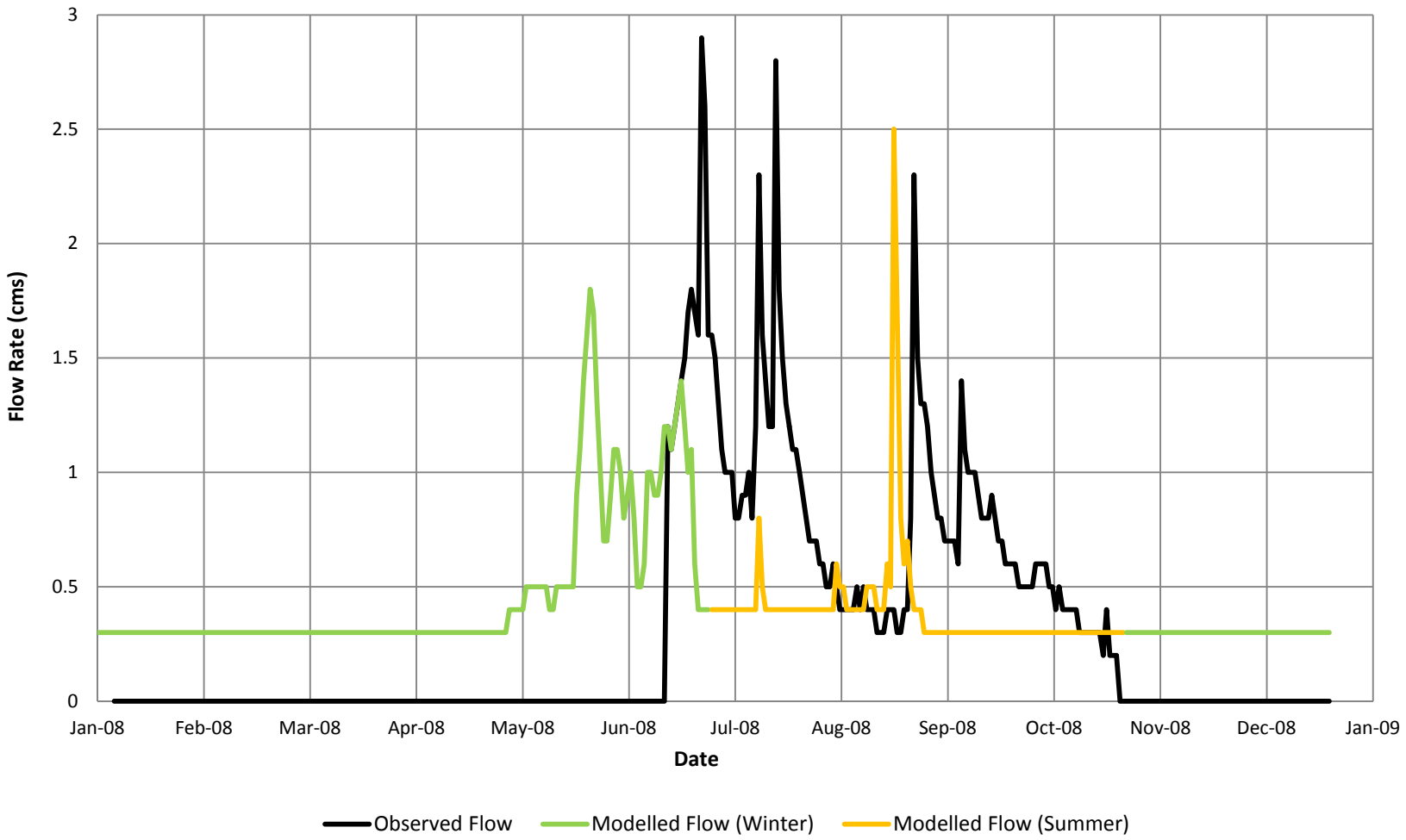

FIGURE A-18
Modelled vs. Observed Flow at Station V1, 2008
Faro Mine Remediation Project

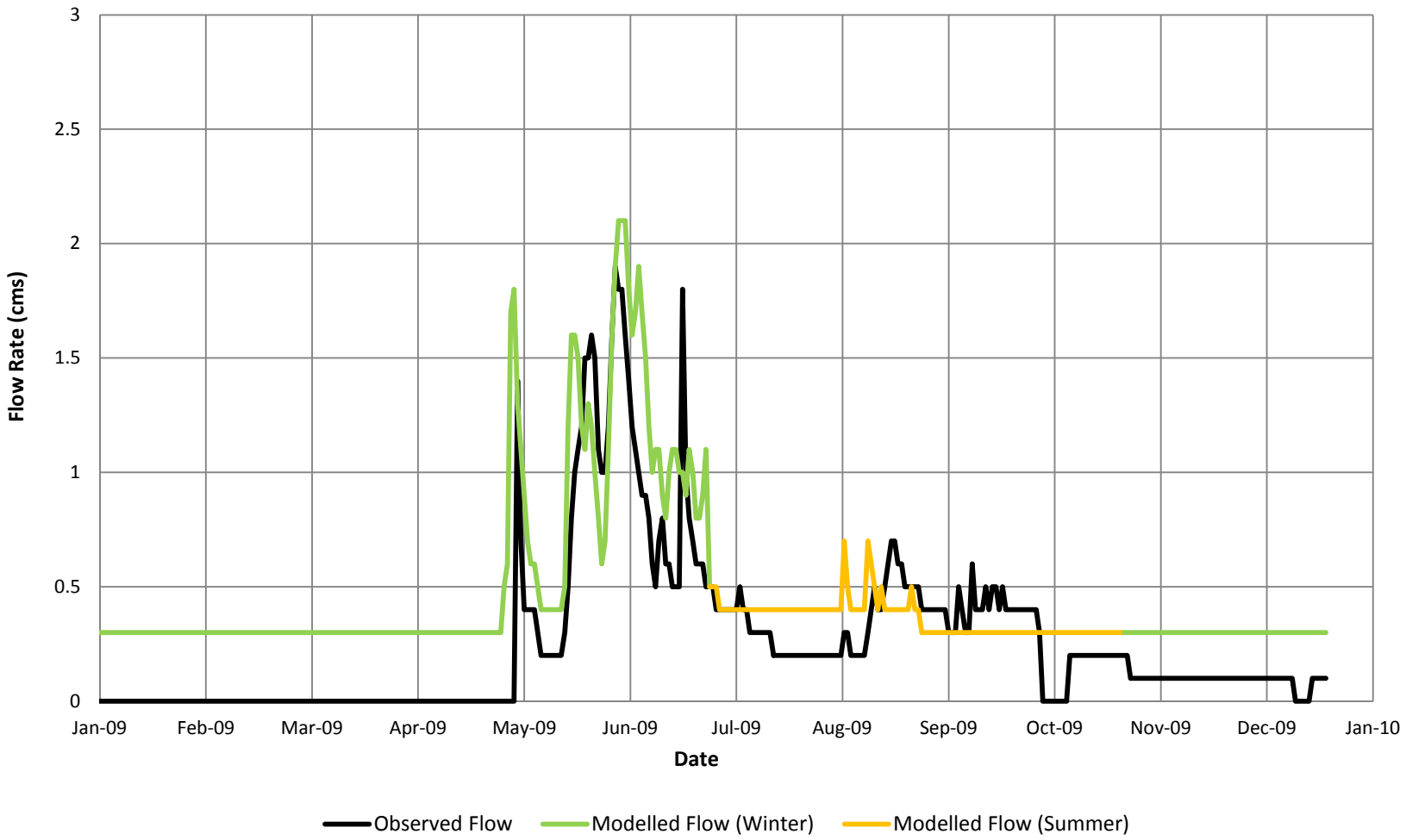

FIGURE A-19
Modelled vs. Observed Flow at Station V1, 2009
Faro Mine Remediation Project

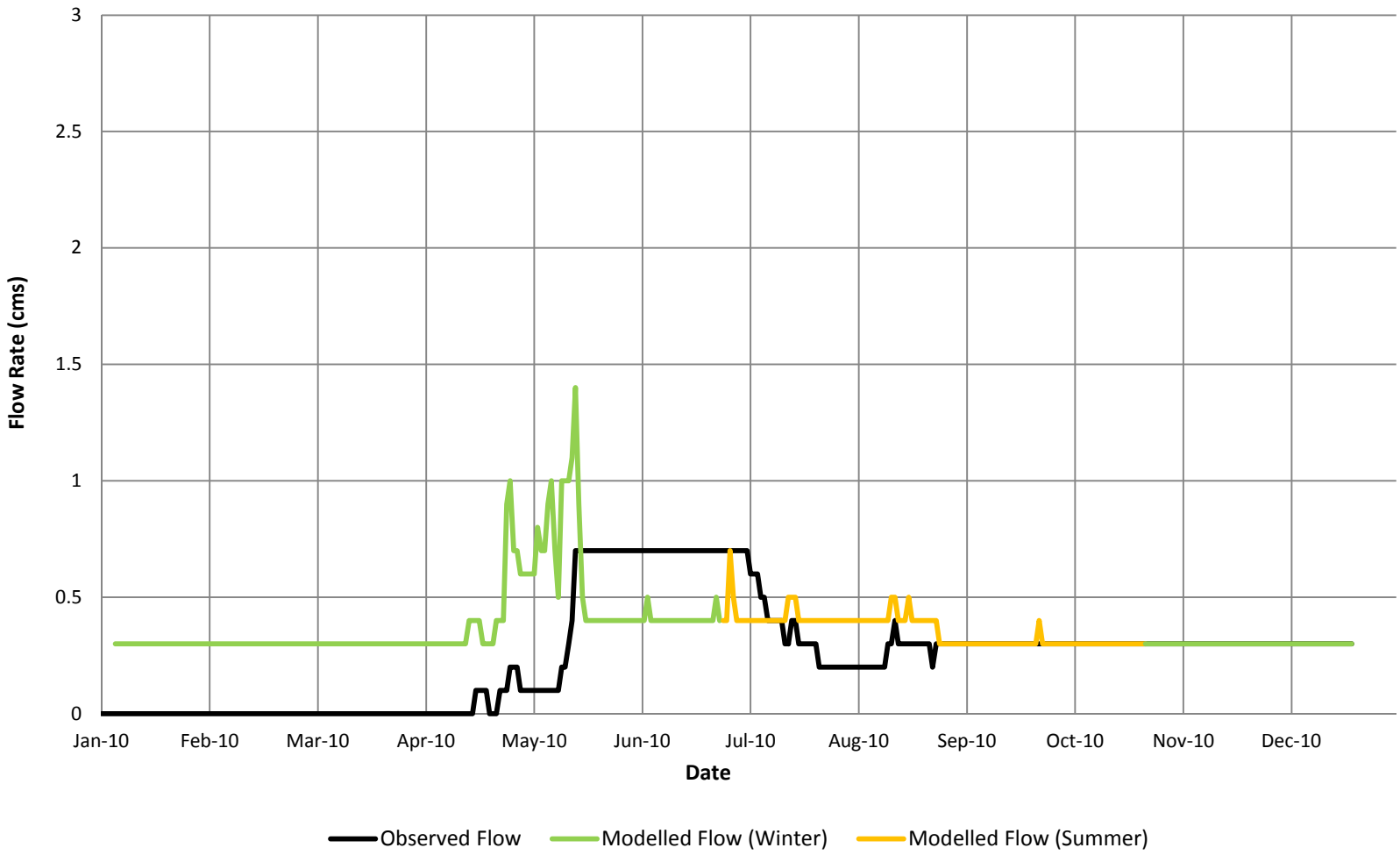

FIGURE A-20
Modelled vs. Observed Flow at Station V1, 2010
Faro Mine Remediation Project

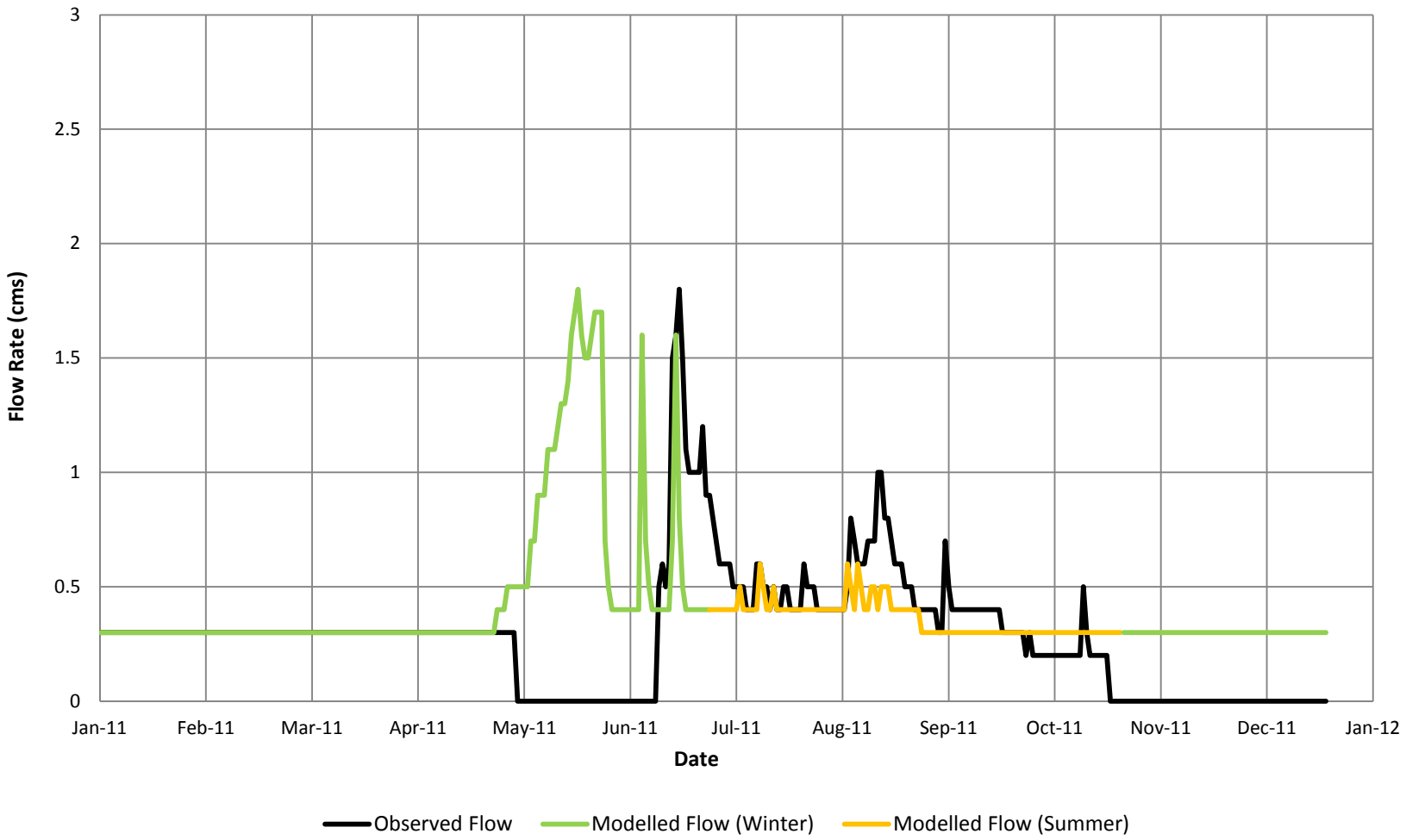

FIGURE A-21
Modelled vs. Observed Flow at Station V1, 2011
Faro Mine Remediation Project

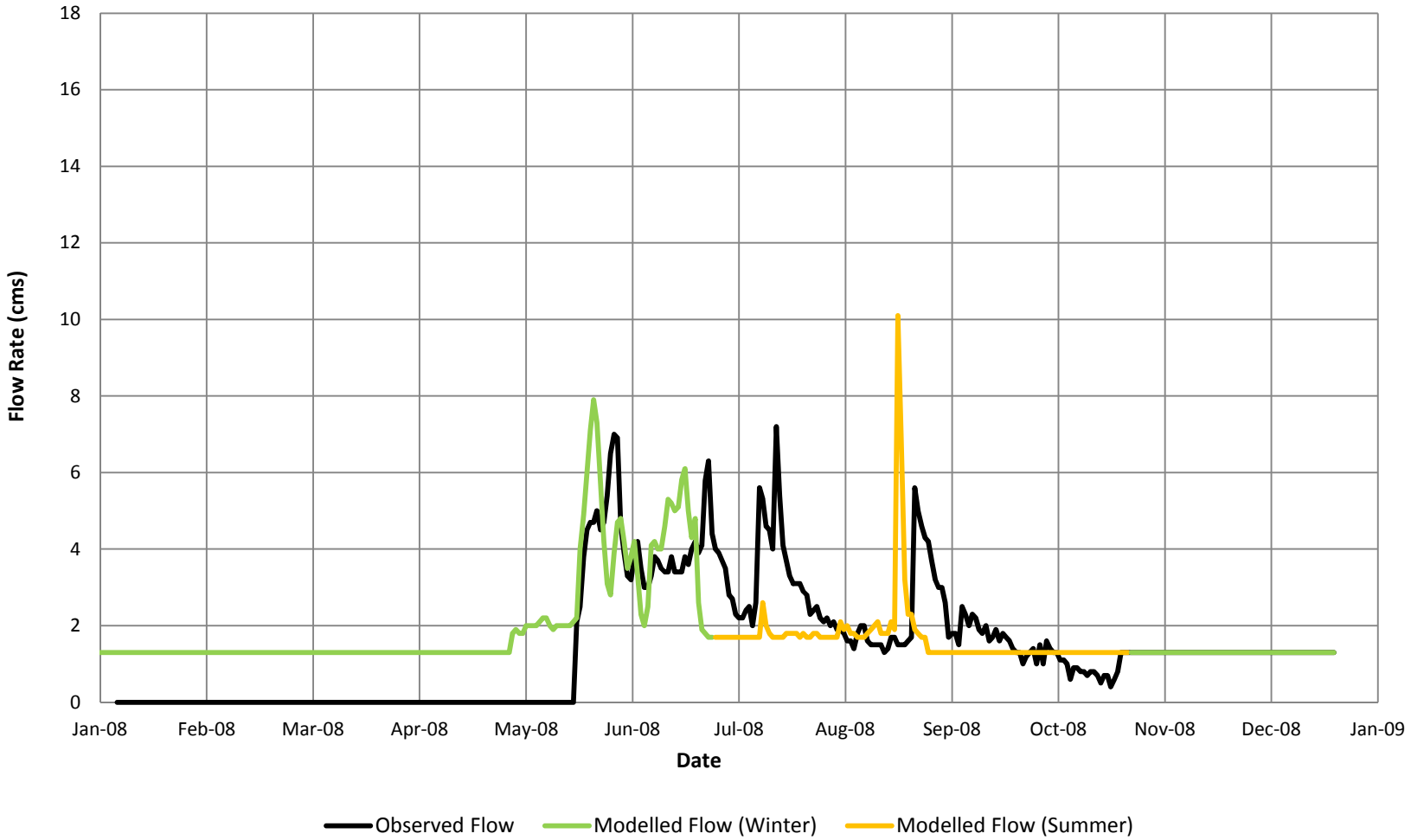

FIGURE A-22
Modelled vs. Observed Flow at Station V8, 2008
Faro Mine Remediation Project

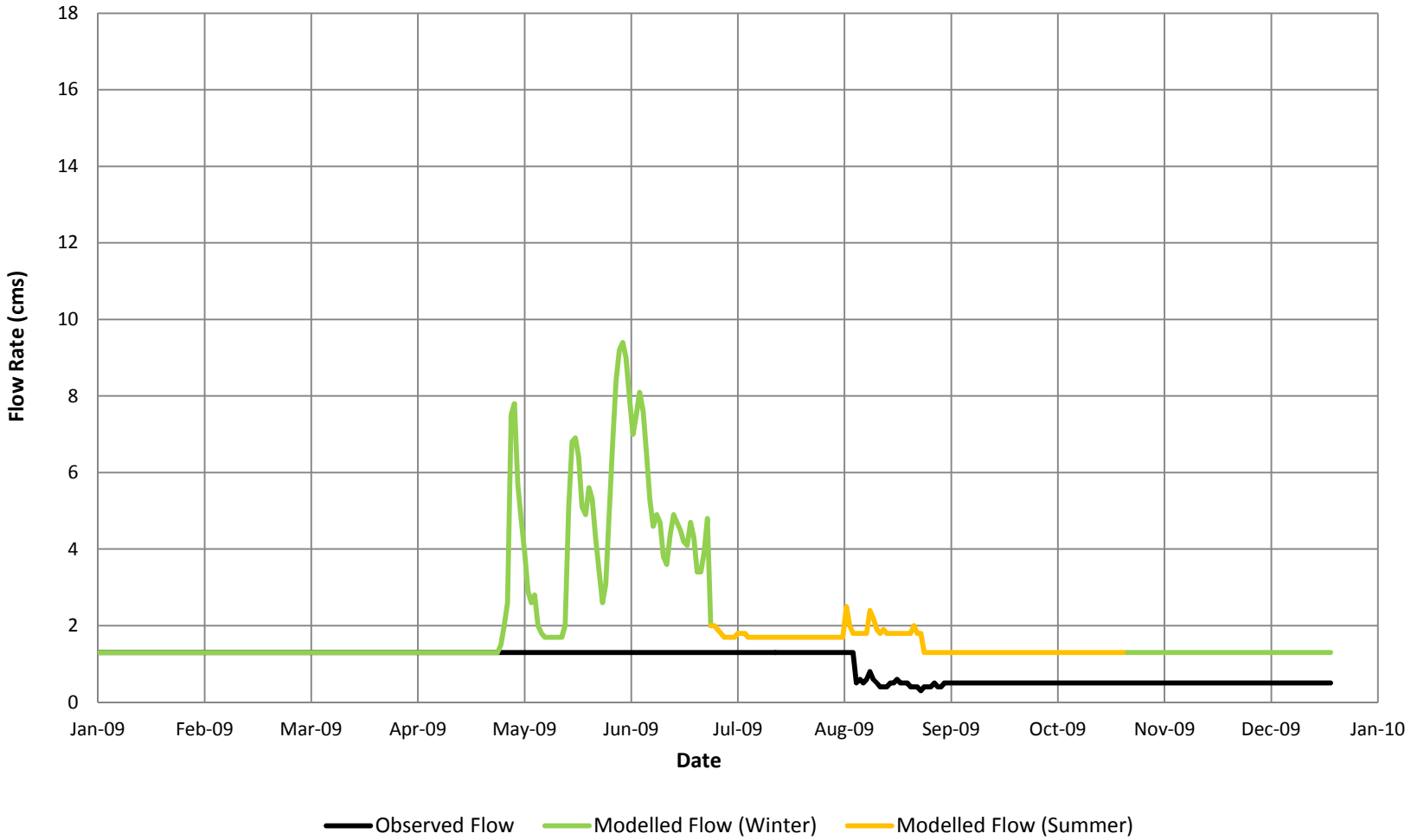

FIGURE A-23
Modelled vs. Observed Flow at Station V8, 2009
Faro Mine Remediation Project

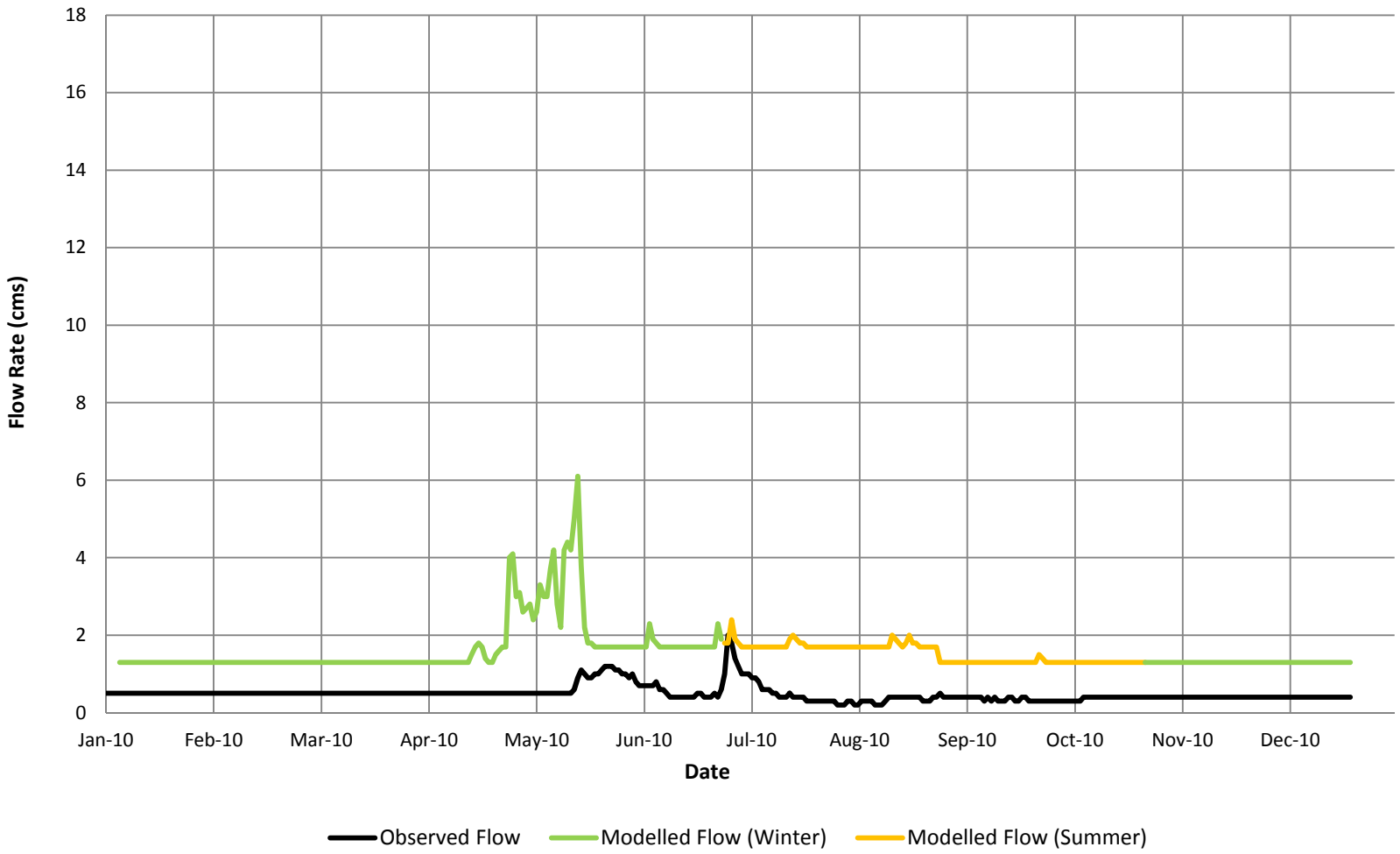

FIGURE A-24
Modelled vs. Observed Flow at Station V8, 2010
Faro Mine Remediation Project

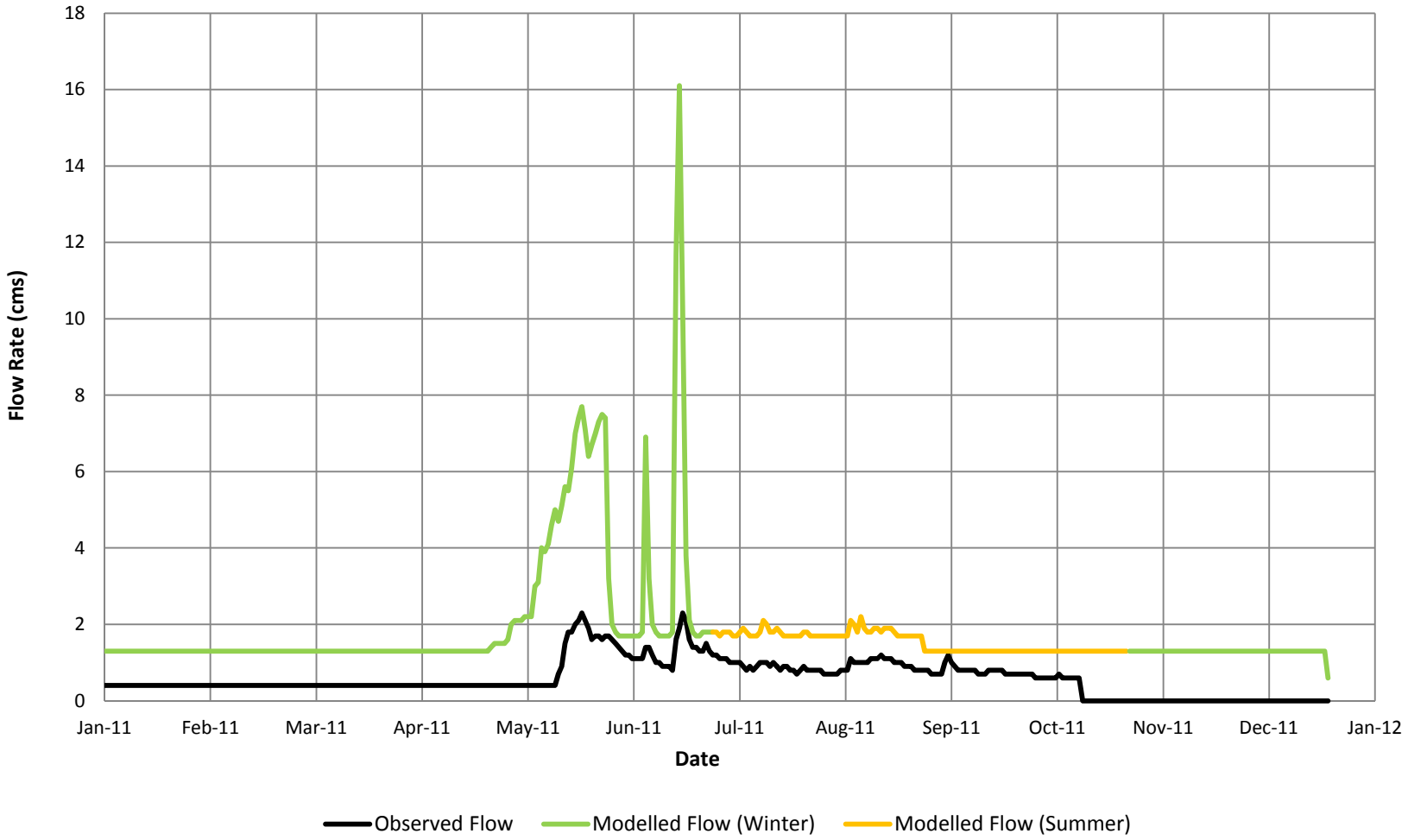

FIGURE A-25
Modelled vs. Observed Flow at Station V8, 2011
Faro Mine Remediation Project

Attachment 6F-4
Water Management Supporting Technical Memoranda

Review of Pit and Pond Water Elevations Faro Mine Remediation Project

PREPARED FOR: Government of Yukon (YG)

PREPARED BY: CH2M HILL Canada Limited (CH2M HILL)

DATE: October 11, 2013

PROJECT NUMBER: 472645.09.N1.02

Overview

This technical memorandum (TM) is in response to Task Authorization Component (TAC) 009-N, Water Elevations and Peak Flows, and addresses the following objectives of TAC 009-N:

- Review the water elevations for each onsite storage reservoir or pit (e.g., Cross Valley Pond [CVP], Intermediate Dam Pond [ID pond], Faro Pit, Zone II Pit, Vangorda Pit, Grum Pit, and Little Creek Dam Pond).
- Provide recommendations regarding revised target elevations for the end of the 2013 operating season.
- Provide an updated table of target water elevations and document recommended water management changes, including the rationale for the changes.

Current Water Management

In 2012, CH2M HILL reviewed and provided updated recommendations pertaining to the 2011 Freshet Water Management Plan (WMP) (Brodie Consulting [Brodie], 2011). These recommendations were developed with the objective to limit water of deteriorated quality from migrating offsite, and to provide storage capacity, in case of extreme environmental conditions or unexpected delays to operations (CH2M HILL, 2012a). This draft TM provides recommendations based on current site conditions and site operations in FY 2012 and 2013.

Several important operational changes to water management at the Faro Mine Complex (FMC) between 2012 and 2013, including the following:

- The Faro Mill WTP was not operated in 2013
- A temporary mobile filtration system was installed and operated at the CVP
- A conveyance system was constructed to transfer water between the ID Pond and the Faro Pit, as well as between the ETA and Faro Pit (instead of conveying ETA water to the Faro Mill WTP)
- The new Zone II Pit dewatering well (CH12-Z2-PW01) began operations
- A conveyance system was constructed to transfer water from the Grum Pit to the Vangorda Pit
- The conveyance system to transfer water between Grum-V15 and the Vangorda Pit began operating

Table 1 provides target water elevations for 2013. It also describes the water management location, including the water's source and destination, the target elevation and target objective, the recommended start and end dates, contingencies, and additional comments.

YG requested CH2M HILL provide a recommendation for 2013 end-of-season target elevations, given the following unique site conditions as of September 2013:

- The Faro WTP was not operated in 2013
- The Vangorda WTP shut down for the season
- Water elevations in the Grum Pit exceeded the target levels

These conditions preclude maintaining water levels below previously established elevations for the Grum and Vangorda Pits. On October 10, 2013, YG decided to stop seasonal water transfer from the Grum Pit to Vangorda Pit based on its evaluation of relative risk associated with the Grum and Vangorda Pits.

The next section of this TM describes the GoldSim model used to inform water management targets. The remaining sections describe each management location listed in Table 1.

GoldSim Water Management Tool

A simplified model was developed from our GoldSim model v2 (CH2M HILL, 2013). The model simulates the Faro, Vangorda, and Grum Pits, as well as the CVP and ID Pond, and existing connections between these storage reservoirs along with loading from collection systems (e.g., the Emergency Tailings Area [ETA], S-wells, Zone II, and Grum-V15). The simplified model uses total monthly inflows to the storage reservoirs, plus flows from these collection systems, as boundary conditions. Inflow values were the average of a stochastic run from the GoldSim model v2, using annual precipitation data from 1978 to 2011. The model considered stochastic variability based on the historical precipitation change from average, and its output was compared with a water balance spreadsheet model to facilitate calibration.

The GoldSim model was set to run for 1 year (from September 9, 2013 until September 9, 2014) on daily time steps, and included 250 stochastic realizations. September 9, 2013, was selected as the initial date because the most recent available water level are from September 9 to September 12 (Table 2). The 250 stochastic realizations allow a range of flows to be evaluated and therefore assess potential wet, dry, and average year conditions.

Table 2 provides initial conditions and assumptions regarding storage volumes and elevations. Table 3 provides the scenarios considered to support end-of-season target water elevations. In Table 3, blue-highlighted cells with bold text indicate value(s) that changed in the scenario.

Scenario 1 provides the base case, which assumes water from Faro Pit is not treated in 2013. Although interim water treatment is planned for 2014, the simulations did not include this treatment capacity because it is not critical to developing 2013 target elevations. It assumes discharge from the CVP occurs at 13,100 cubic metres per day (m3/day) (2,400 US gallons per minute [USgpm]) via the filtration trailers and allows 14,400 m3/day (2,600 USgpm) by-pass (siphon) release until September 30, 2013. The average historical CVP elevations are used to estimate winter pond releases.

The ID Pond is dewatered at a rate of 9,800 m3/day (1,800 USgpm), which is assumed to continue until September 30, 2013. The Vangorda WTP has ceased operations for 2013; we have assumed it will start up on May 1, 2014, at 10,900 m3/day (2,000 USgpm). The scenario also assumes Grum Pit dewatering has stopped for 2013 and that when it begins again in May 2014, it will do so at 9,300 m3/day (1,700 USgpm). Grum-V15 transfers to Vangorda Pit are also assumed to have stopped in August. This scenario is the base case because it relies on the least amount of active water management intervention.

The simulated scenarios adjust individual areas of the model, one at time, to evaluate the effect different water management scenarios would have. Scenarios 2 and 3 adjust CVP water management to evaluate the effect on CVP water levels and potential winter release volumes. Scenario 2 allows the CVP water elevation to rise to the lower spillway elevation without considering winter releases, which would need to take place before the water elevation reached the lower spillway. Scenario 3 reduces the total discharge from the CVP in September to evaluate how much more winter release will be required if the CVP does not reach the target elevation by September 30. For this scenario, the assumed discharge rate from the CVP was 6,500 m^3/day (1,200 USgpm), which would correspond to the filtration capacity if one of the two mobile filtration trailers was operational and there was no siphon release. Scenario 4 evaluates continued dewatering of the ID Pond through October. This scenario helps assess whether the target elevation can be reached, and predicts the effect this additional water will have on the Faro Pit.

Scenarios 5 and 6 assess the effect continued Grum Pit dewatering would have on Grum and Vangorda Pit water levels. Scenario 5 continues pumping the Grum Pit water to the Vangorda Pit for another 20 days beginning in mid-September and Scenario 6 continues the pumping for 25 days beginning in mid-September. Scenario 7

assesses the effect of delayed Vangorda WTP operation on Vangorda Pit water levels if WTP start-up is delayed from May to June, 2014.

Figures 1 through 8 provide the scenario results, including the minimum, mean, and maximum result from the stochastic runs.

Water Management Locations

Faro Water Treatment Plant

The Faro WTP is not operational and did not operate in 2013. During the 2013 treatment season, water from the ID Pond and ETA has instead been conveyed to the Faro Pit, raising its water level.

An interim WTP is planned for operation in 2014. Interim treatment should be implemented as soon as possible, at a high enough rate to control and reduce Faro Pit water levels and the potential for increased seepage towards the Zone II Pit, the ETA, or both.

Cross Valley Pond

The CVP is part of the active water management program at the FMC. Although the Faro WTP did not discharge treated water to the CVP in 2013, the CVP still requires active management to remove water from inputs such as rainfall and seepage. In previous years, water was released from the CVP via a siphon to Rose Creek at monitoring station X5. In 2013, turbidity exceeding the discharge limit (15 Nephelometric Turbidity Units [NTU]) made it necessary to use temporary mobile filtration units that could process up to 13,100 m^3/day (2,400 USgpm). These mobile treatment units did not arrive onsite until August.

The water elevation in the CVP has historically ranged between 1,026.3 and 1,030.3 metres (m) (Denison Environmental Services [Denison], 2012; Tlicho Engineering and Environmental Services Ltd. [TEES], 2013a). The crest of the CVD is 1,033.1 m, and the lower spillway is reported at 1,030.68 m (Domingue, 2013, personal communication).

The drawdown of water in the CVP has three constraints: (1) the water quality in Rose Creek, (2) the maximum rate of daily drawdown, and (3) the ability to maintain water cover over accumulated sludge beds. The volume of releasable flow is controlled to achieve acceptable water quality in Rose Creek (particularly at X14, the surface water quality monitoring station and compliance point). BGC Engineering (BGC) recommended a maximum drawdown of 100 millimetres (mm) per day because of concerns about the Intermediate Dam's geotechnical stability (BCG, 2008).
Operational experience at the FMC indicates the water elevation in the CVP should not be lowered below about 1,027.5 m. If it is, sludge beds could be exposed and sludge particulate suspended, which may impact water quality and the ability to discharge from the CVP (Parkin, 2013a, personal communication).

The GoldSim base case scenario indicates if additional capacity in the CVP is required to accommodate spring flows, winter discharge will be required (Figure 2). The base case uses average historical water elevations in the CVP to approximate the past site operations but does not necessarily reflect the timing or magnitude of monthly winter releases. CVP winter releases could also have been simulated by setting a winter discharge target to represent site operations, but the same conclusion would have been reached: spring storage capacity can be available if winter releases occur. Site operations will determine the timing and magnitude of releases.

Based on the historical range of precipitation, and seepage inflow estimates to the CVP, Scenarios 2 and 3 predict the following results:

- Scenario 2: If the target elevation (1,027.5 m) is reached by September 30, 2013, the water elevation could reach the lower spillway after 173 days (Figure3)
- Scenario 3: If the target elevation (1,027.5 m) is not reached by September 30, 2013, and the water is only lowered to 1,028.5 m, the water elevation could reach the lower spillway after 92 days (Figure 4)

The recommended target water-level elevation in the CVP is 1,027.5 m, which provides the maximum storage capacity considering the elevation of the sludge beds: approximately 670,000 m^3 (3.18 m) of freeboard between the target elevation and the lower spillway elevation. Winter release is recommended when conditions allow.

Intermediate Dam Pond

Water and tailings are retained behind the Intermediate Dam, which is approximately 650 m long, 7 m wide, and 32 m high, with a crest elevation at 1,049.2 m (Klohn Crippen Berger Ltd. [KCB], 2012) and has a spillway elevation of 1,047.7 m (Denison, 2012). The water level in the ID Pond has historically ranged between 1,043.0 and 1,047.6 m (Denison, 2012; TEES, 2013a). In 2013, ID Pond water was pumped to the Faro Pit.

There are two constraints on the drawdown of water in the ID Pond: (1) a maximum drawdown per day of 40 mm; (2) the operations regime prescribed by KCB (2012) because of concerns about the ID's geotechnical stability (CH2M HILL, 2012b). No changes are recommended for the ID Pond target water levels.

The GoldSim base case scenario indicates that, considering accumulated winter inflows, ID Pond water levels may reach the spillway elevation if dewatering ceases on, or before, September 30. Scenario 4 suggests continued dewatering of the ID Pond at a rate of 9,800 m^3/day through October will bring the water elevation towards its target, although the target will not be reached by the end of October. Considering predicted accumulated winter inputs to the ID Pond, the water elevation is not expected to reach the spillway elevation before dewatering begins again in May 2014 (Figure 5), although the water will rise above the recommended upper elevation of 1,045.2 m, the top of the lower riprap. The Faro Pit water elevation is predicted to rise by 0.4 m, because of water being transferred from the ID Pond in October (Figure 1).

Maintaining the ID Pond's elevation at between 1,045.2 m (the top of the lower riprap) and 1,044.2 m (the bottom of the lower riprap) will limit the potential for the upstream face of the Intermediate Dam to erode. Operation outside this range could take place as a contingency measure, to prevent uncontrolled releases of ID Pond water. If the ID Pond elevation is maintained below the bottom of the lower riprap (1,044.2 m), the dam face should be monitored for erosion and will likely require maintenance in the future (i.e., erosion repair and riprap replacement). CH2M HILL (2012a) provides more discussion about this situation. CH2M HILL recommends pumping from the ID Pond while site conditions allow, to draw the ID Pond level down towards 1,044.2 m.

Faro Pit

The Faro Pit receives groundwater seepage, direct precipitation, runoff, Faro Creek Diversion seepage, and water from managed sources such as the ID Pond, the ETA, S-Wells, and Zone II Pit. From 2004 until 2012, the water-level elevation in Faro Pit was maintained between approximately 1,140 m and 1,143 m (Denison, 2012; TEES, 2013a). During the 2013 treatment season, source areas that used to go to the Faro WTP (which did not operate in 2013) went to the Faro Pit, which raised its water elevation above this range. On September 9, 2013, the Faro Pit water elevation was 1,146.1 m.

The end-of-season target elevation (between 1,140 and 1,141 m) and the maximum recommended elevation (1,144.3 m) (Denison, 2012) have been exceeded. CH2M HILL recommends dewatering activities begin at Faro Pit as early as possible in 2014, at a high enough rate to control and reduce the Faro Pit water level and the potential for seepage increases towards Zone II Pit or towards the ETA.

Emergency Tailings Area

The ETA is an area of historical tailings deposition between the Mill Building and RCTA. In previous years, water from the ETA was collected at a cut-off trench and dual sump and then pumped to the Faro WTP. In 2013, water was not initially collected at the ETA; however, as the season progressed, water was collected and pumped from the ETA to the Faro Pit via the old tailings box and a booster pump located east of the former Mill Building. There is no target elevation for the ETA, but the objective is to collect as much water as practical based on the system capacity. This will limit water of deteriorated quality from seeping downgradient to the ID Pond and the underlying Rose Creek Aquifer, and will reduce the volume of water in the ID Pond.

S-Wells and S-Wells Bypass

The S-Wells are located between the Intermediate Waste Rock Dump (WRD) and the North Fork of Rose Creek (NFRC) and consist of two parts: the S-Wells and the S-Wells Bypass (or Shallow Interception Trench). There were no changes to water management for the S-Wells in 2013. CH2M HILL (2012a) provides additional details about this system.

Zone II Pit

The Zone II Pit is located directly southeast of the Faro Pit and northwest of the NFRC. The Pit was mined in the late 1970s and early 1980s and subsequently filled with about 40 million tonnes of unclassified waste rock from mining operations at other areas at the FMC (Robertson Geoconsultants Inc. [RGC], 1996). The Zone II Pit base is at an elevation of about 1,094.5 m (RGC, 1996) and the current surface topography is at an elevation of about 1,166 m. If water rose above 1,128 m, it would spill over the buried rim and seep toward the NFRC. Between the base of the Zone II Pit and an elevation of 1,128 m, the backfilled Pit has about 480,000 m^3 of storage capacity, assuming 30 percent porosity of the backfilled waste rock (SRK, 2007). In 1991, a pumping well was installed to manage the water level and limit water from migrating towards the NRFC. In 2012, a replacement pumping well (CH12-Z2-PW01) was added. The water-level elevation at Zone II Pit has been managed at approximately 1,107 m and has ranged between about 1,103 and 1,111 m since October 2010 (Denison, 2012). However, this elevation leaves a hydraulic gradient between the groundwater elevation in the Pit and the stage elevation of the NFRC (about 1,096 m). The expired water licence (QZ03-059) required the groundwater elevation in Zone II Pit to be maintained lower than 50 metres below ground (mbg), or 1,116 m.

X26 (Zone II – Old Well)

X26 was not used to dewater the Zone II Pit in 2013. The well is still used to monitor the water elevation in the Zone II Pit. CH2M HILL (2012a) provides additional details about this pumping well. Table 1 does not provide a target elevation for this location.

CH12-Z2-PW01 (Zone II – New Well)

During the summer of 2012, CH2M HILL oversaw the drilling and installation of CH12-Z2-PW01. This well extends to a total depth of 77.4 mbg, with a screened interval between 1,091.7 and 1,114.0 m and a sump extending below 1,091.7 m to the end of the hole at 1,088.6 m (CH2M, 2012c). The lithology consisted of waste rock to a depth of approximately 69.45 mbg (1,096.5 m) (i.e., within 2 m of the reported base of the Pit). The purpose of this well was to replace X26 and allow the groundwater levels within the Pit to be managed so they are lower than those previously achievable. The objective of this deeper well was to lower the groundwater elevation below the stage elevation of the NFRC, to reverse the hydraulic gradient. CH2M HILL understands the water conveyance system installed at this location consists of an insulated high-density polyethylene (HDPE) pipeline, heat-traced for year-round operation. According to the 2011 WMP (Brodie, 2011), the pipeline is positioned to discharge water at 30 m below the surface of the Faro Pit lake. The recommended target elevation for the water level in Zone II Pit is at or below 1,096 m. Groundwater collection should continue from Zone II Pit year-round.

Faro Valley Dumps

The Faro Valley Dumps refers to an area of ponded water along the alignment of the original Faro Creek Channel, upstream from the Faro Valley WRD on the north–northeast side of the Faro Pit. There were no changes to water management for the Faro Valley Dumps in 2013. CH2M HILL (2012a) provides additional details about the system.

Grum Pit

The Grum Pit receives groundwater seepage, direct precipitation, runoff, and Grum Northeast Interceptor Ditch seepage. The Adaptive Management Plan (AMP) threshold level to trigger a response to rising water levels (1,210.8 m) was surpassed in October 2011. The trigger and maximum water elevation was set under AMP Event 6 (Gartner Lee Limited [GLL], 2005) to manage water level increases in the Grum Pit, which was a requirement of the expired water licence (QZ03-059).

This is the first year water elevations in the Grum Pit have been actively managed. The objective is to prevent water of deteriorated quality from reaching downstream receptors and to provide additional storage capacity to

retain water received in the Grum Pit. In August 2013, water transfer from Grum Pit to Vangorda Pit began (TEES, 2013b).

SRK (2009) indicated the overflow elevation to be 1,232.3 m, which is the lowest elevation of the Pit walls in the Grum Slot, located at the southern end of Grum Pit. The maximum recommended elevation, 1,213.4 m, allows storage capacity for a 1-week probable maximum flood before the water reaches the contact elevation of the overburden and bedrock (at 1,216 m) near the Grum Slot (Denison, 2011a). The permeability of the overburden above the bedrock contact was estimated to be about $5x10^{-4}$ metres per second (SRK, 2009). The 2011 Annual Review, AMP Report (Denison, 2012) suggests a revised maximum pit water elevation between 1,214.3 and 1,216.1 m, considering potential hydraulic containment south of the Pit (CH2M HILL, 2012a provides additional discussion). This suggested elevation range is based on the storage capacity between this range of elevations and the elevation of the potential hydraulic containment, as well as the estimated volume of water that could drain to Grum Pit during an extreme precipitation event or breach of the Grum Northeast Interception Ditch.

Observed groundwater elevations in the monitoring wells installed in the Grum Slot are higher than the water elevation in Grum Pit. This condition could contain the water within Grum Pit. However, groundwater elevations in the Grum Slot monitoring wells fluctuate seasonally and there are limited monitoring locations. As a result, there is uncertainty about the effective level of hydraulic containment provided by groundwater under the Grum Slot. Continued dewatering of the Grum Pit would slow the steadily rising water levels, so the water level could be managed to remain below the overburden/bedrock contact. Maintaining the water level below an elevation of about 1,213.4 m will limit potential seepage and provide storage capacity during an estimated 1-week probable maximum flood (Denison, 2011a). Given the water elevation in Grum Pit in mid-September, the water elevation cannot be lowered below 1,213.4 m during this operating season.

The base case scenario (Figure 6) indicates if no additional water is transferred from the Grum Pit to the Vangorda Pit, the Grum Pit water elevations will stay above the overburden/bedrock contact until about a month after transfers begin in 2014. Scenarios 5 and 6 estimate the Grum Pit water level if additional pumping takes place starting in mid-September2013 for 20 and 25 days, respectively (Figure 6). These scenarios consider winter accumulations and suggest that pumping down Grum Pit water levels for another 20 days in 2013 at a rate 9,300 m^3/day (to an elevation of about 1,215 m) will maintain the water elevation below the overburden/bedrock contact until May 2014 (Figure 6). Pit water above the documented overburden/bedrock contact could allow seepage, and less storage capacity would be available in case of an extreme rainfall event or if the interceptor ditch was breached.

On October 10, 2013, YG decided to stop seasonal water transfer from the Grum Pit to Vangorda Pit based on its evaluation of relative risk associated with the Grum and Vangorda Pits. Hence, the decision on the end-of-season water elevation has been made for the Grum Pit.

Grum Sulphide Cell Sediment Control

In 2010, an engineered cover was placed over the Grum Sulphide Cell (GSC) to limit infiltration, and in 2011, a series of surface water management upgrades were completed to improve this remedial measure. Before 2010, runoff from the GSC discharged to Moose Pond, along with runoff from areas upgradient of the Pond. Moose Pond discharges to Vangorda Creek (Denison, 2012). CH2M HILL (2012a) provides additional details about the system.

In 2013, a ditch along the north and east perimeters of the GSC was constructed to intercept and redirect runoff generated in the catchment upstream of the GSC. These two ditches direct the collected water to Vangorda Pit.

Grum V15 Seep and Grum Creek Seeps

Seepage from the Grum WRD surfaces at V15 and Grum Creek, downgradient from the waste rock pile on the southeastern side. If such seepage is not otherwise collected, it discharges to Moose Pond, west of Vangorda Creek, after V15 and the Grum Creek intersect at the Grum weir. After the high runoff conditions in 2011, a seepage collection system was constructed to manage peak spring runoff conditions and constituents of concern in seepage from the Grum WRD. The pumping system at V15, located east of the Grum WRD, consists of

an insulated and heat-traced, 76-mm HDPE pipeline, a power supply, and pumps (Denison, 2011b). The system can redirect seepage from the Grum WRD (V15, Grum Creek, or both) to the Vangorda Pit all year.

In 2013, the V15 conveyance system was operated to transfer water collected from V15 and Grum Creek to Vangorda Pit. However, the conveyance system is not operated year-round. When it is not operated, discharge flows to Moose Pond (Parkin, 2013b, personal communication). The V15 and Grum Creek have no target elevation; however, the target objective is to limit water of deteriorated quality from seeping to downstream receptors (i.e., Vangorda Creek).

Vangorda Pit

Vangorda Pit receives groundwater seepage, direct precipitation, runoff, and Vangorda Creek Diversion seepage, along with water from managed sources such as the Little Creek Pond and the GSC Pond. In 2013, additional sources were placed in Vangorda Pit, including Grum Pit water, discharge collected from V15 and the Grum Creek, and discharge collected in the ditch around the northeast perimeter of the GSC and from dewatering the sludge ponds. There is uncertainty around the timing and magnitude of transfers to Vangorda Pit for these new sources, which are not fully accounted for in the GoldSim model. The water-level elevation in Vangorda Pit has averaged near 1,085 m since 2004, and has ranged between 1,074.6 and 1,094.1 m (Denison, 2012, TEES 2013a). Based on water levels from 2010 to 2012 (Denison, 2012), water elevations in the Vangorda Pit appear to have been lowered to 1,083 m or lower at the conclusion of dewatering activities. They were then allowed to rise throughout the fall and winter, reaching about 1,088 m in the spring.

In 2012, TEES lowered the Pit water elevation to 1,076.8 m at the end of August and stopped dewatering activities (TEES, 2013a). The water elevation was at 1,081.6 m on October 1 and reached 1.084.4 m by early May. The water elevation peaked around mid-June at 1,088.8 m. The water level exceeded the maximum recommended water elevation of 1,091.8 m once in 2008 and once in 2009. Since then, as a result of annual pumping, the water level appears to have been maintained below the maximum recommended level (Denison, 2012). At the maximum recommended water level in the Vangorda Pit (1,091.8 m), which was the limit in the now expired water licence QZ03-059, there is about 3 Mm^3 of storage capacity in case of diversion failure or an extreme storm event.

The base case scenario (Figure 7) suggests water elevations will be below the maximum recommended level, until the Vangorda WTP starts up in May 2014. This considers winter water accumulation and assumes no additional water is actively transferred to the Vangorda Pit in 2013. The base case scenario predicts the May 1, 2014 Pit water elevation will reach between 1,084 and 1,086 m.

Scenarios 5 and 6 evaluate the Grum Pit transfers assuming the Vangorda WTP will not operate for the remainder of 2013. The scenarios estimate the Vangorda Pit water levels considering additional pumping in 2013 for 20 and 25 days beginning in mid-September, respectively (Figure 7).These scenarios suggest the Vangorda Pit water elevation in spring 2014 will be below the maximum recommended level if the end-of-season elevation is below 1,086 m. If Vangorda Pit receives water from Grum Pit until mid-October, its elevations on May 1, 2014 will range from approximately 1,087 m and 1,089 m. However, Vangorda Pit water levels will continue to rise with spring inflows (natural and transfers).

Scenarios 5 and 6 suggest a 2013 end-of-season elevation in Vangorda Pit of 1,086 m or lower accommodates inflows below the 1,091.8 maximum recommended water level, if dewatering of the Vangorda Pit begins on May 1, 2014. The final water elevation will depend on the timing and magnitude of inflows (natural and transfers), as well as the start-up date of the Vangorda WTP in 2014.

Scenario 7 suggests even if no additional water is transferred from the Grum Pit to the Vangorda Pit in 2013, the maximum recommended water level may be exceeded if the Vangorda WTP does not start until June 1, 2014 (Figure 8).

As discussed previously, on October 10, 2013, YG decided to stop seasonal water transfer from the Grum Pit to Vangorda Pit based on its evaluation of risk. This decision effectively determines the end-of-season water elevation for the Vangorda Pit. Dewatering activities should begin at the Vangorda Pit in 2014, as soon as practical, and should continue until the storage capacity is restored.

Little Creek Pond

The Little Creek Pond collects runoff and seepage from the Vangorda WRD via a seepage collection ditch. There were no changes to water management for Little Creek Pond in 2013. CH2M HILL (2012a) provides additional details about the system.

Sheep Pad Ponds

The Sheep Pad Ponds are located south of the Grum Overburden Pile. They collect runoff from upslope areas, and discharge to the lower portion of the Vangorda Creek Diversion (KCB, 2012). There were no changes to water management for Sheep Pad Ponds in 2013. CH2M HILL (2012a) provides additional details about the system.

Vangorda Watering Hole

The Vangorda Watering Hole is understood to be located in the original Vangorda Creek Channel, upstream from the Vangorda Creek Diversion. Since 2002, a sump at this location has collected runoff from the local catchment and pumped it to the Vangorda Creek Diversion (Denison, 2011C). There were no changes to water management for Vangorda Watering Hole in 2013. CH2M HILL (2012a) provides additional details about the system.

Vangorda Waste Rock Dump

A seepage collection ditch along the southern and western basal perimeter of the Vangorda WRD collects and redirects seepage toward Little Creek Pond. There were no changes to water management for Vangorda WRD in 2013. CH2M HILL (2012a) provides additional details about the system.

Summary and Recommendation

The 2013 water elevation targets (see Table 1) were established to limit water of deteriorated quality from migrating offsite, and to provide potential storage capacity in case of extreme environmental conditions or unexpected delays to operations. Changed site conditions and facility operations were also considered when providing recommendation on target elevations.

The target water elevations should be reviewed annually to address changing site conditions and varying environmental factors.

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Tables

TABLE 1

Faro 2013 Water Management Targets

Faro Mine Remediation Project

Management Location		Target Elevation (m)	Target Objective	Start	End	Contingency	Comments
Source	Destination						
Cross Valley Pond	Release at X5 or via mobile treatment system to Rose Creek	1,027.5 m	Maximum achievable drawdown of water level until 1,027.5 m Transition to inflow equals outflow once water elevation at target *Limitations* *+ WQ criteria at X14* *+ Max drawdown of 100 mm/day* *+ Lowering below 1,027.5 m exposes sludge beds*	As early as practical per seasonal site constraints	Cease as required based on seasonal constraints	See site emergency response plan	1,027.5 m provides 3.18 m of freeboard (~670,000 m^3 of storage) between the target elevation and the lower spillway elevation (1,030.68 m). This provides an estimated average of 173 days of water accumulation based on the historical range of precipitation and seepage inflow estimates to the CVP, before the water elevation reaches the spillway elevation (i.e., from October 2013 until the end of March 2014). Winter release, as conducted in previous years, should be performed when conditions allow.
Intermediate Dam Pond	Faro Pit (pump to)	Between 1,044.2 and 1,045.2 m	This range is recommended to prevent erosion of the dam face. [a] *Maximum drawdown 40 mm/day*	As early as practical per seasonal site constraints	When target level reached	See site emergency response plan	It is recommended that the water level elevation be maintained as practical between elevations 1,045.2 m, which is the top of the lower riprap, and elevation 1,044.2 m, which is the bottom of the lower riprap, as per the 1991 as-built drawings. Operation outside this range could be performed as a contingency measure to prevent uncontrolled releases of IP water; however erosion monitoring should occur and future maintenance on the dam face will likely be required.
Faro Pit	None currently available	1,141 m	Target end of season water level elevation is 1,141 m, however it is not possible to achieve this elevation in 2013.	As early as practical per commissioning of interim water treatment plant.	Cease as required based on seasonal constraints	None currently available	Faro WTP not currently operational. During the 2013 treatment season IP and ETA water have been placed in Faro Pit raising the water level. Recommended that interim treatment be implemented as soon as possible in 2014 at a rate high enough to control and begin to reduce Faro Pit water level and therefore potential increases of seepage towards Zone II Pit and/or towards the ETA.
Emergency Tailings Area (ETA)	Faro Pit (pump to)	N/A	Collect as much water as practical based on system capacity.	Commence collection as early as practical per seasonal site constraints	Cease collection as required based on seasonal constraints	If problem is encountered, repair system as soon as practical.	
S Wells	Faro Pit (pump to)	N/A	Target objective is to limit bypass of water of deteriorated quality from reaching the receiving environment. Pump to sump to be conveyed to Faro Pit.	Year-round operation		If problem is encountered, repair system as soon as practical.	Capacity of pumping system should be evaluated
S Wells bypass (Shallow Aquifer Interception Trench)	Faro Pit (pump to)	N/A	Target objective is to limit seepage bypass from reaching receiving environment. Pump to main sump to be conveyed to Faro Pit.	As needed to prevent seepage into NFRC		If problem is encountered, repair system as soon as practical.	Capacity of pumping system should be evaluated
X26 (Zone II - Old Well)	Faro Pit (pump to, surface)	-	-	-	-	-	Replaced by CH12-Z2-PW01
CH12-Z2-PW01 (Zone II - New Well)	Faro Pit (pump to, depth)	1,096 m	Target objective is to limit the hydraulic gradient and thus seepage of water of deteriorated quality from the Zone II Pit from reaching the NFRC and underlying alluvial aquifer.	Year-round operation		If problem is encountered, repair system as soon as practical.	Target elevation lowered from 1,103 m to 1,096 (approximate stage elevation of NFRC to the east) to utilize new well screened depth.
Faro Valley Dumps	Faro Creek Diversion Channel	-	-	-	-	-	[b]Water quality does not meet criteria to enable active water management from this location
Grum Pit	Vangorda Pit (pump to)	-	Target end of season water level elevation is not possible to achieve in 2013. [c]AMP trigger: 1,210.8 m; [c]AMP maximum elevation: 1,213.4 m [b]2011 AMP review suggests increasing maximum level to between 1,214.3 and 1,216.1 m.	As early as practical given site constraints	When target level reached	See site emergency response plan	Pit water elevation above the documented overburden/bedrock contact at 1,216 m allows possible seepage and there is a decrease in storage capacity in the case of an extreme rainfall event or breach of interceptor ditch. On October 10, 2013, YG decided to stop seasonal water transfer from the Grum Pit to Vangorda Pit based on its evaluation of relative risk associated with the Grum and Vangorda Pits. Hence, the decision on the end-of-season water elevation has been made for the Grum Pit.

TABLE 1

Faro 2013 Water Management Targets

Faro Mine Remediation Project

Management Location		Target Elevation (m)	Target Objective	Start	End	Contingency	Comments
Source	Destination						
GSC sediment control	Vangorda Pit (pump to)	N/A	Prevent unacceptable water from entering the receiving environment.	When water starts flowing into lined storage pond at toe of GSC	As allowed by pond inflows	Unlined 9,000 m^3 storage pond located to southwest of lined storage pond	-
Grum V15 Seep and Grum Creek Seep	Vangorda Pit (pump to)	N/A	Collect as much water as practical based on system capacity.	Year-round operation		-	[d]TEES reports that the system was shutdown in August. "Normal" flow volumes currently report to Moose Pond. High spring flows will be pumped to Vangorda Pit.
Vangorda Pit	Vangorda/Grum WTP	-	Based on operational experience, the target end of season water level elevation is 1,083 m, or lower, however, it is not possible to achieve this elevation in 2013. Recommended maximum water level is 1,091.8 m, which is consistent with the limit in the expired water licence (QZ03-059) and provides about 3 Mm^3 of storage capacity in the event of diversion failure or an extreme storm event.	As soon as practical per seasonal site constraints	When target level reached	See site emergency response plan	Additional 2013 inputs to Vangorda Pit include Grum Pit, Grum-V15 transfers and runoff collected by the perimeter ditch around the northeast portion of the GSC. On October 10, 2013, YG decided to stop seasonal water transfer from the Grum Pit to Vangorda Pit based on its evaluation of risk. This decision effectively determines the end-of-season water elevation for the Vangorda Pit. Vangorda WTP operation should begin as soon as practical per seasonal site constraints in 2014 to restore storage capacity.
Little Creek Pond	Vangorda Pit (pump to)	1,108 m	Target elevation is 1,108 m; however, the operational management level since 2010 has been 1,106.5 m. Maintain minimum 3 m freeboard; Licence limit is 1,111.8 m	When water starts flowing in Vangorda rock pile collection ditch	When target level reached; historically, fall freeze-up	See site emergency response plan	[e]September 19, 2013 TEES reports that operations shut down for season. Elevation reached 1,107.9 m.
Sheep Pad Pond	Vangorda Creek (siphon)	N/A	Produce water of sufficient quality for discharge to Vangorda Creek.	When water starts flowing in Grum overburden ditch	As allowed by pond inflows	See site emergency response plan	-
Vangorda - Watering Hole	Vangorda Creek Diversion	N/A	Intercept run-off and reduce the volume of water entering Vangorda Pit by pumping into the Vangorda Creek Diversion.	As early as practical given site constraints	As required by inflow volumes	See site emergency response plan	-
Vangorda Waste Rock Dump	Little Creek Pond (via seepage collection ditch)	N/A	-	-	-	-	-

Notes:

°C - degrees Celsius

AMP - adaptive management plan

GLL - Gartner Lee Limited

GSC - Grum Sulphide Cell

KCB - Klohn Crippen Berger

m - metre(s)

mm - millimetre(s)

m^3 - cubic metres

Mm^3 - million cubic metres

masl - metres above sea level

max - maximum

N/A - not applicable

NFRC - North Fork Rose Creek

TDS - total dissolved solids

TEES - Tlicho Engineering and Environmental Services Ltd

WQ - water quality

WTP - Water Treatment Plant

[a]Klohn Crippen Berger (KCB). 2012. *Faro Mine Remediation Project, Drawdown Rate of Intermediate Pond*. June 15.

[b]Denison Environmental Services (Denison). 2012. *2011 Annual Environmental Monitoring and Activities Report*. *Faro Mine Complex* . *Faro Mine Complex – Faro, YT.* Prepared for Government of Yukon. February 29.

[c]Gartner Lee Limited (GLL). 2005. Anvil *Range Mine Complex 2004 Annual Environmental Report Water Licence QZ03-059*. Prepared for Deloitte & Touche. February 28.

[d]Parkin, Tracey/Tlicho Engineering and Environmental Services Ltd. (TEES) Environmental Coordinator. 2013b. Personal communication with Steve Momeyer/CH2M HILL. September 19.

[e]Tlicho Engineering and Environmental Services Ltd. (TEES). 2013b. Appendix K - 2013 Water Moved.xls. 2013 Annual Environmental Monitoring and Activities Report. Faro Mine Complex (in progress). Prepared for Government of Yukon. September.

TABLE 2

Pit and Pond Elevations

Faro Mine Remediation Project

Location	Water Elevation[a] (m)	Date of Water Elevation Measurement (m)	Pit Crest or Spillway Elevation (m)	Overburden/ Bedrock Contact (m)
Faro Pit	1,146.1	9-Sep-13	1,158[b]	1,147 to 1,157[c]
Grum Pit	1,216.0	9-Sep-13	1,232	1,216[d]
Vangorda Pit	1,082.2	9-Sep-13	1,130	1,122[e]
Intermediate Dam Pond	1,045.8	12-Sep-13	1,047.7	N/A
Cross Valley Pond	1,029.0	12-Sep-13	1,030.68	N/A

Notes:

N/A - not applicable

[a]Tlicho Engineering and Environmental Services Ltd. (TEES). *Elevations data to September 12, 2013.xls. 2013 Annual Environmental Monitoring and Activities Report. Faro Mine Complex* (in progress). Prepared for Government of Yukon. September.

[b]An elevation of 1,158 m for the Faro Pit represents the elevation of the southeast access road where it intersects the Zone II Pit.

[c]BGC Engineering (BGC). 2006. *Task 20B. Plug Dam Conceptual Design.* Prepared for Deloitte & Touche Inc. on behalf of Faro Mine Closure Planning Office. November 9.

[d]SRK Consulting Engineers and Scientists (SRK). 2009. *Faro Mine Complex. 2009 Groundwater Investigations. Draft.* Prepared for Government of Yukon. January.

[e]Denison Environmental Services (Denison). 2012. *2011 Annual Environmental Monitoring and Activities Report. Faro Mine Complex. Faro Mine Complex – Faro, YT.* Prepared for Government of Yukon. February 29.

TABLE 3

GoldSim Model Scenarios

Faro Mine Remediation Project

		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
	Starting Date	9/9/2013	9/9/2013	9/9/2013	9/9/2013	9/9/2013	**09/18/2013**	9/9/2013
	End Date	9/9/2014	9/9/2014	9/9/2014	9/9/2014	9/9/2014	**09/18/2014**	9/9/2014
Faro Treatment	Start	no Start	no Start	no Start	no Start	no Start	no Start	no Start
	Faro Storage	No pumping out of Faro Storage	No pumping out of Faro Storage	No pumping out of Faro Storage	No pumping out of Faro Storage	No pumping out of Faro Storage	No pumping out of Faro Storage	No pumping out of Faro Storage
	Capacity(USgpm)	0	0	0	0	0	0	0
ID Pond pumping to Faro	Max pumping (USgpm)	1800	1800	1800	1800	1800	1800	1800
	Pumping Season	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	**May1st-Oct30th**	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th
	ID Pond Target Elev (min during Treatment Season)	1044.5	1044.5	1044.5	1044.5	1044.5	1044.5	1044.5
CVP	CVP X5 capacity (USgpm)	5000	5000	**1200**	5000	5000	5000	5000
	CVP Operation	To Keep pit Elevation at target - rule curve 1	**Allow pond to rise to emergency spillway elevation 1030.68 over winter**	**Allow pond to rise to emergency spillway elevation 1030.68 over winter**	To Keep pit Elevation at target - rule curve 1	To Keep pit Elevation at target - rule curve 1	To Keep pit Elevation at target - rule curve 1	To Keep pit Elevation at target - rule curve 1
	CVP Target Elev (min during Treatment Season)	1027.5	1027.5	1027.5	1027.5	1027.5	1027.5	1027.5
Vangorda Treatment	Start	Start in May 2014	Start in May 2014	Start in May 2014	Start in May 2014	Start in May 2014	Start in May 2014	**Start in June 2014**
	Treatment capacity(USgpm)	2000	2000	2000	2000	2000	2000	2000
	Vangorda Treatment window	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th
	Vangorda Pit Target Elevation(m)	1083	1083	1083	1083	1083	1083	1083
Grum to Vangorda Pumpir	Start	Start in May 2014	Start in May 2014	Start in May 2014	Start in May 2014	**Operate until end of Sept 2013 (effective 20 days)**	**Operate from Sept 18 to Oct 15 2013 (effective 25 days)**	Start in May 2014
	Max Capacity (USgpm)	1700	1700	1700	1700	1700	1700	1700
	Window	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	May1st-Sep30th	na	May1st-Sep30th
	Grum Pit Target Elevation	1213.4	1213.4	1213.4	1213.4	1213.4	1213.4	1213.4

Notes:

Cells with blue highlight and bold text indicate the value(s) changed in the scenario

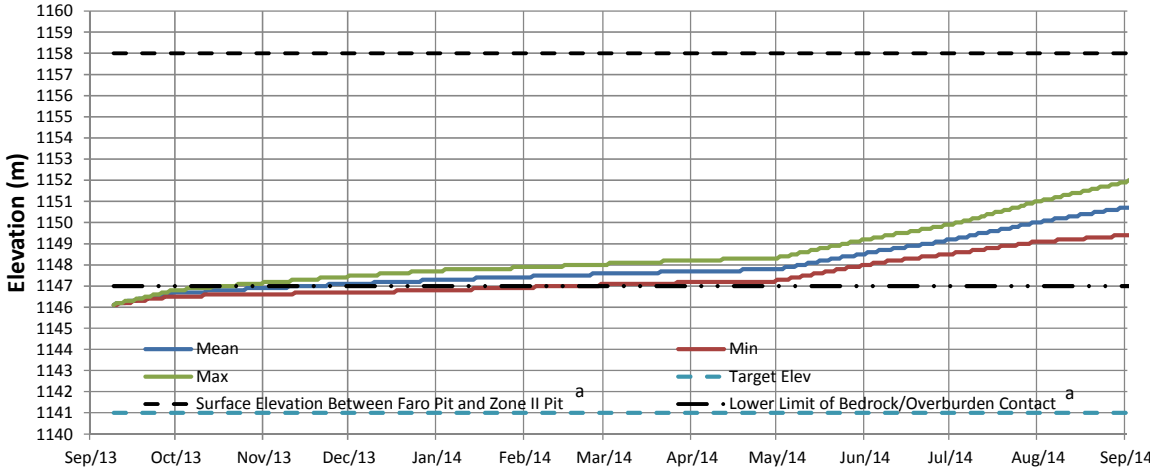
CVP - Cross Valley Pond

ID Pond - Intermediate Dam Pond

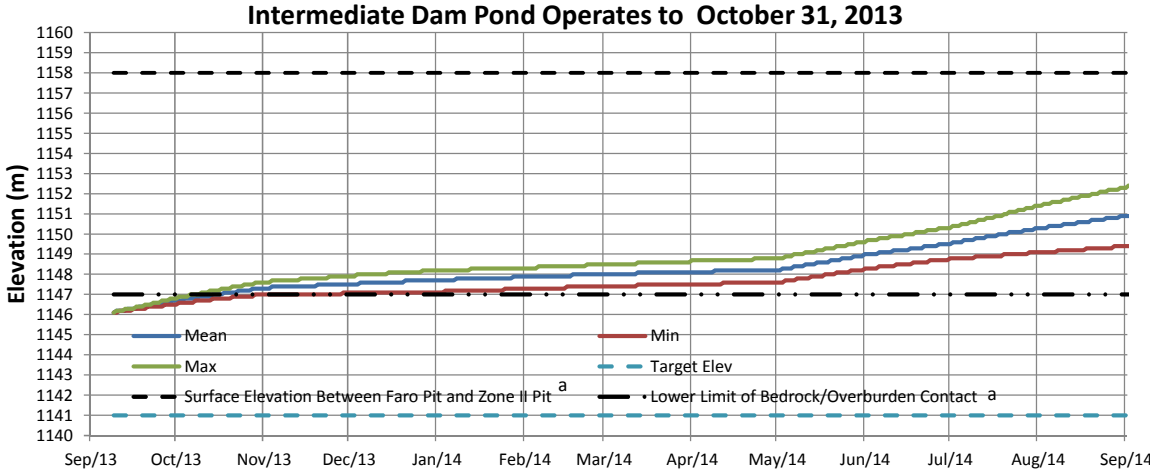
USgpm - US gallons per minute

Figures

Faro Pit Elevation - Scenario 1 - Base Case



Faro Pit Elevation - Scenario 3 - Intermediate Dam Pond Operates to October 31, 2013

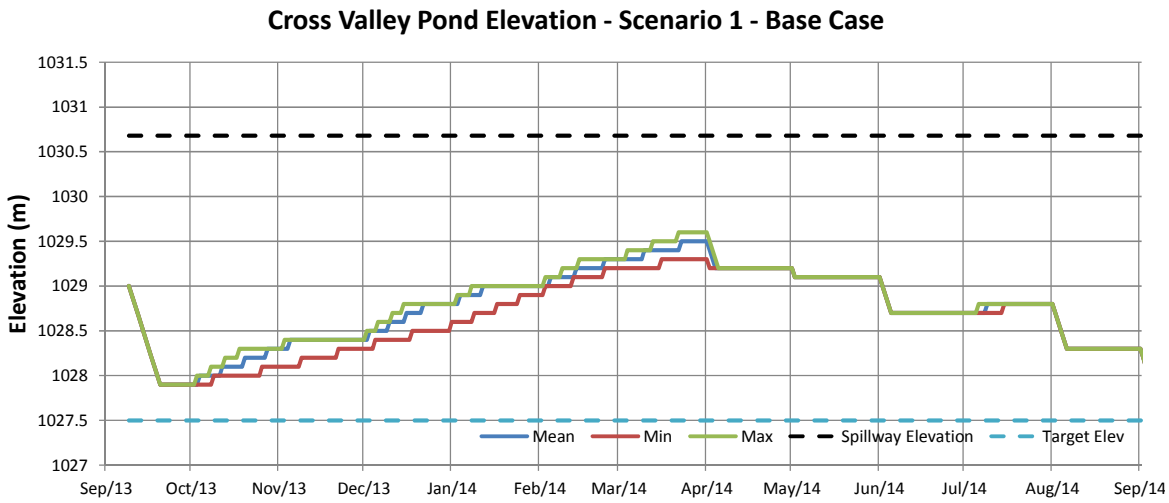


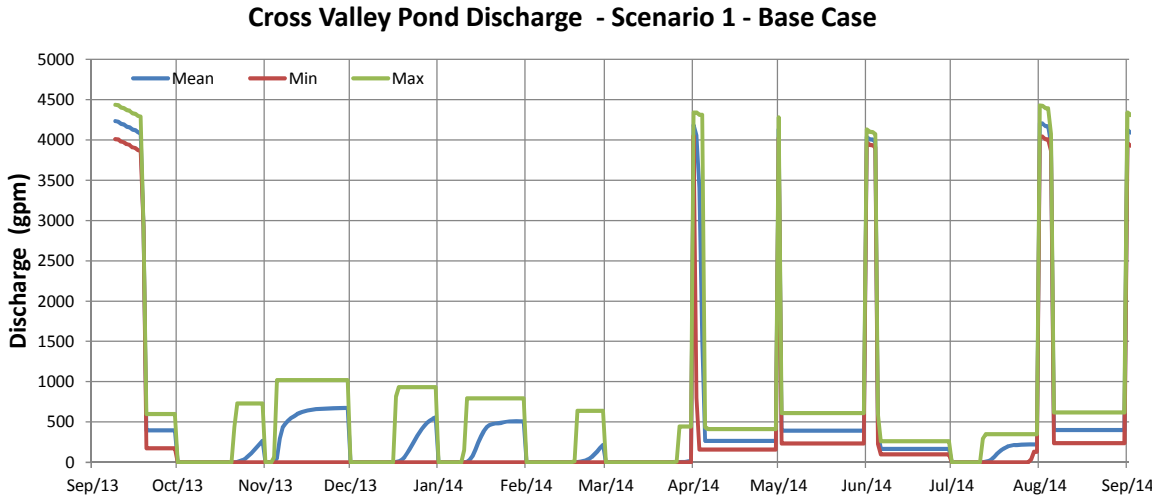
[a]The range of elevations presented reflect the surface elevation of the southeast access road where it intersects the Zone II Pit (1,158 m) and the lower identified bedrock/overburden contact (1,147 m) between the Faro Pit and Zone II Pit (BGC, 2006).

Scenario 1: Base Case

Scenario 3: Intermediate Dam Pond pumped to Faro Pit until October 31, 2013

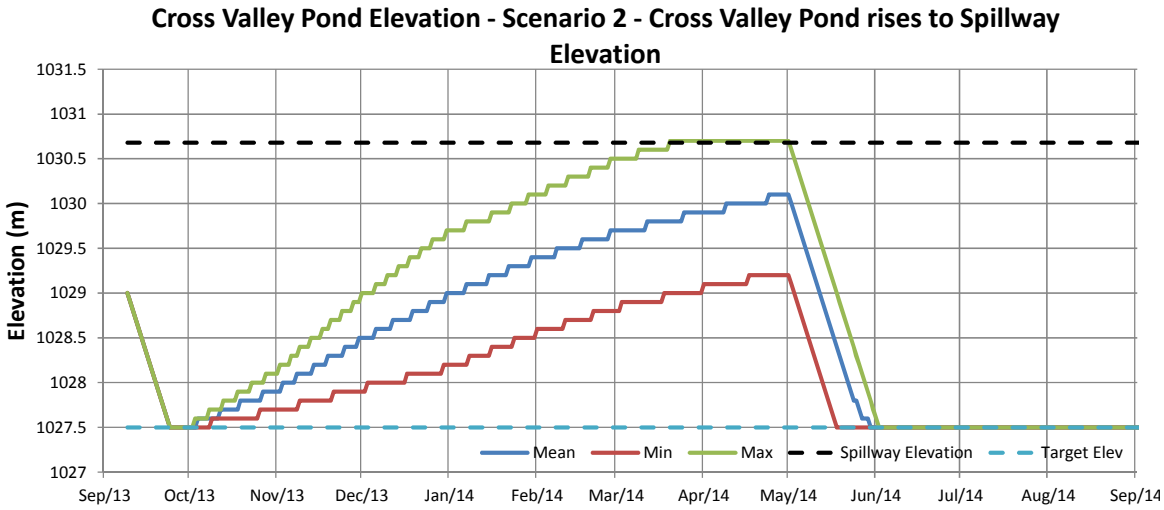
Figure 1
Faro Pit Elevations
Faro Mine Remediation Project

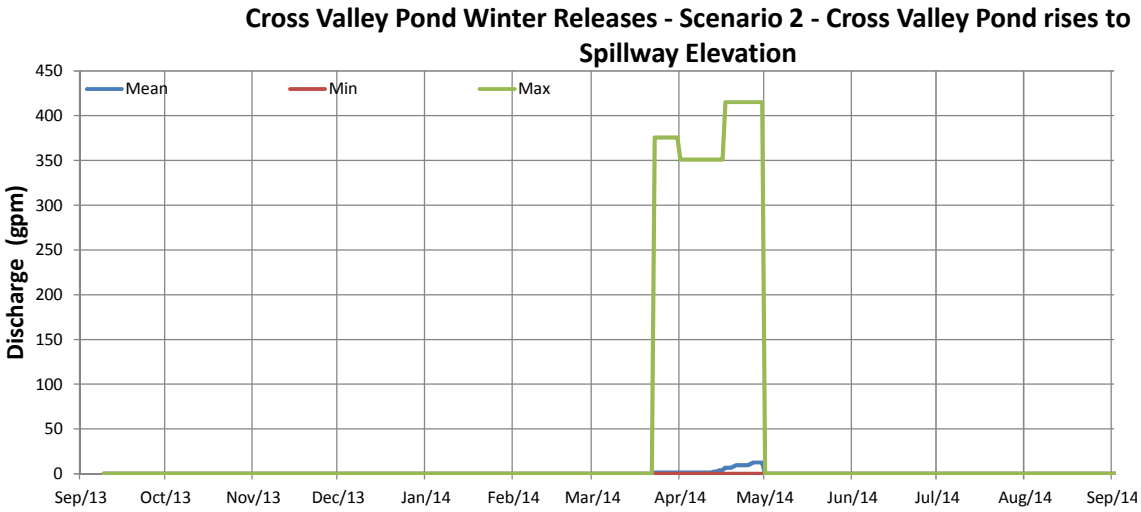




Scenario 1: Base Case

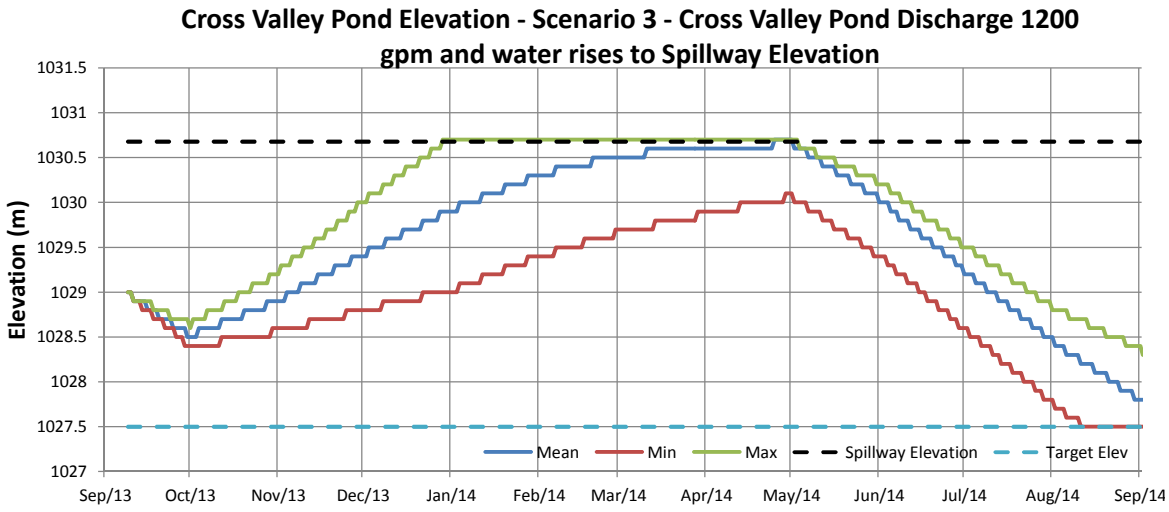
Figure 2
Cross Valley Pond Elevations
Faro Mine Remediation Project

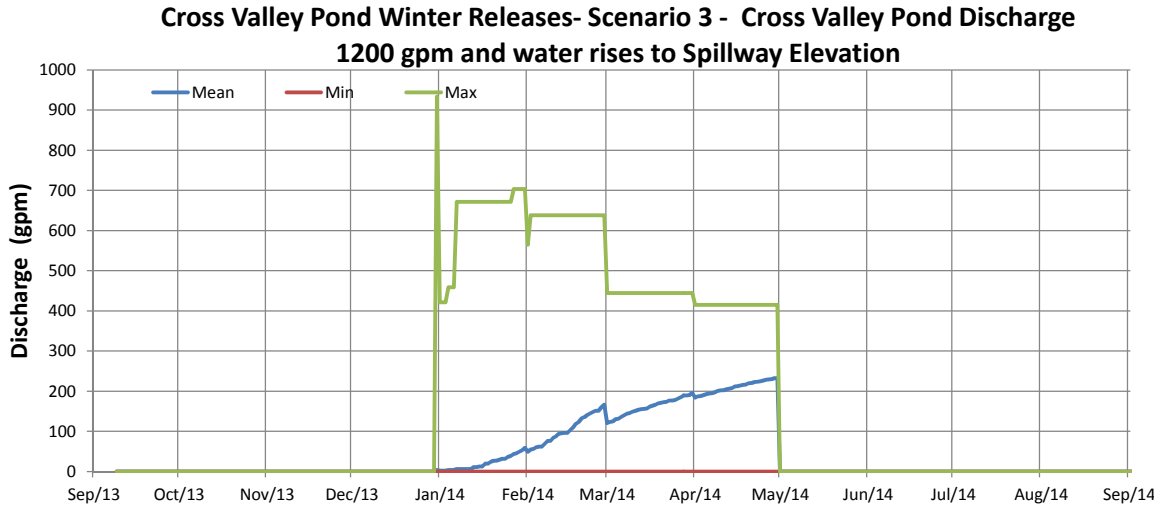




Scenario 2: Cross Valley Pond rises to spillway elevation over winter

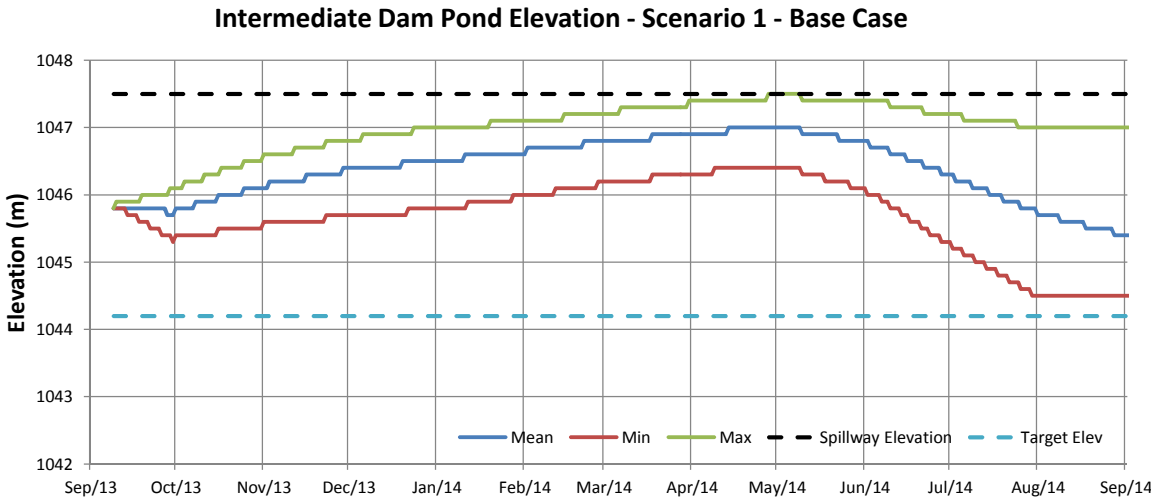
Figure 3
Cross Valley Pond Elevations
Faro Mine Remediation Project





Scenario 3: Cross Valley Pond discharge capacity limited to 1200 gpm

Figure 4
Cross Valley Pond Elevations
Faro Mine Remediation Project



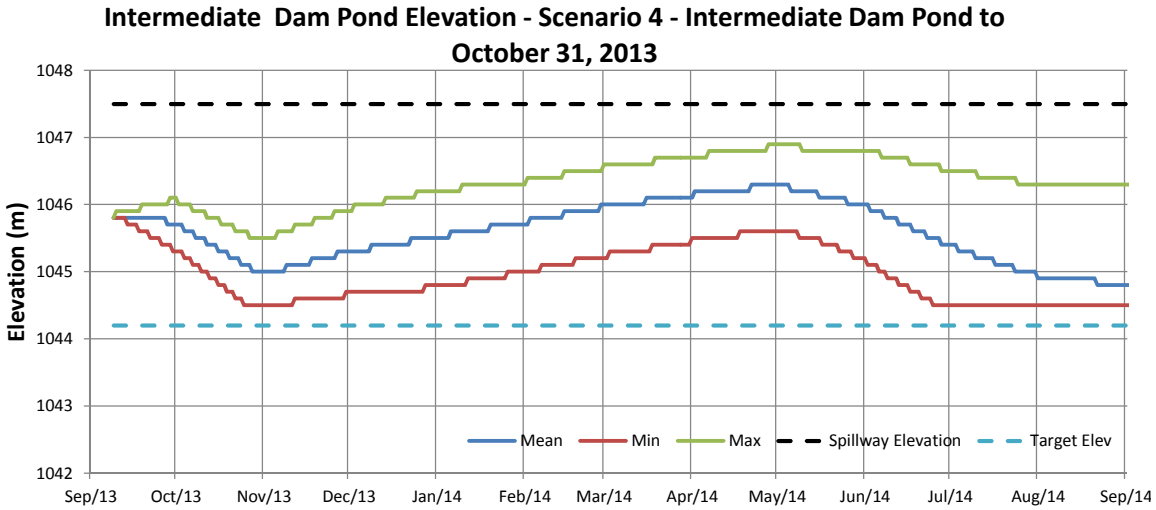
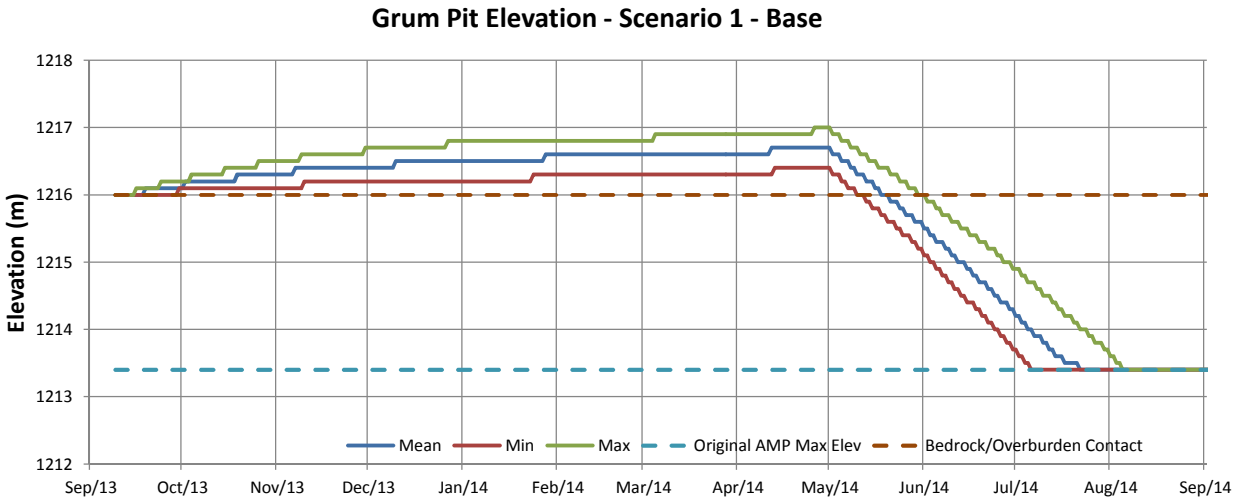
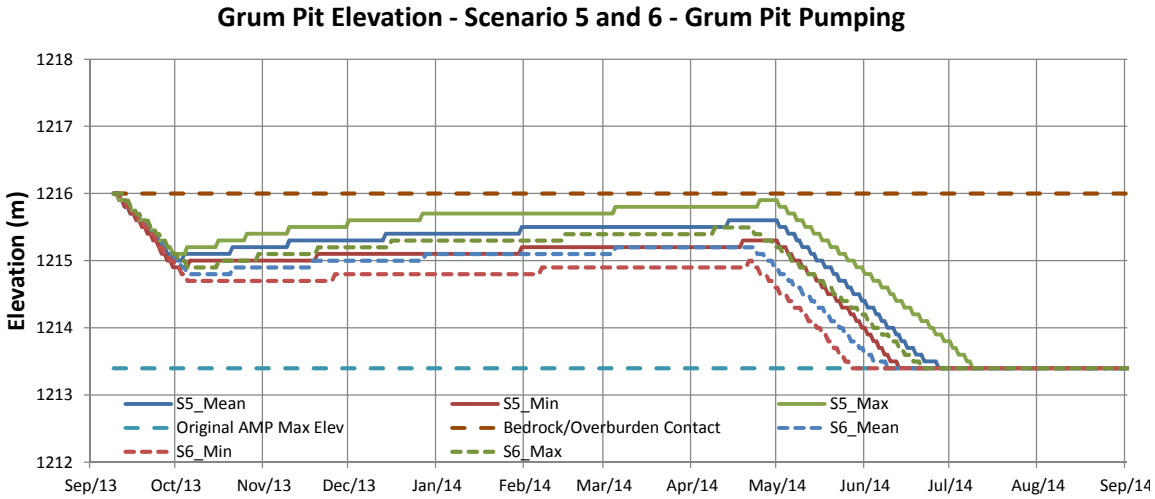


Figure 5
Intermediate Dam Pond Elevations
Faro Mine Remediation Project

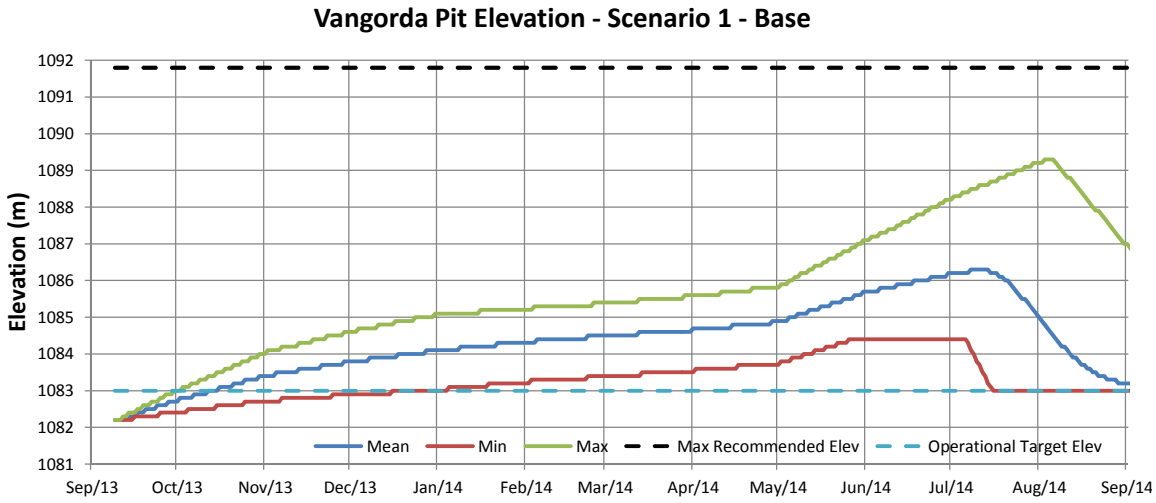
Scenario 1: Base Case
Scenario 4: Intermediate Dam Pond pumped to Faro Pit until October 31, 2013

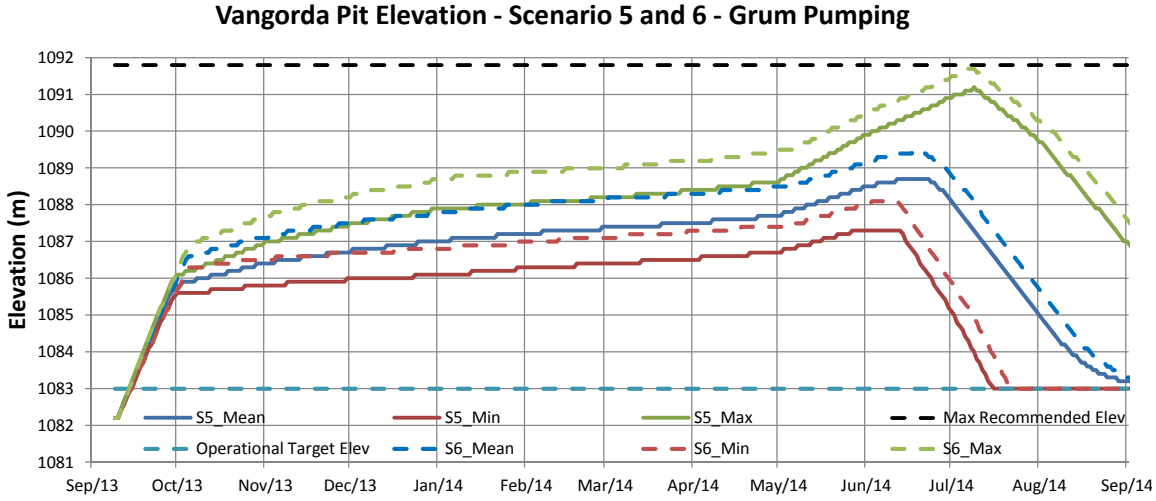




Scenario 1: Base Case
Scenario 5: Grum Pit pumping continues additional 20 days in 2013
Scenario 6: Grum Pit pumping continues additional 25 days in 2013

Figure 6
Grum Pit Elevations
Faro Mine Remediation Project





Scenario 1: Base Case
Scenario 5: Grum Pit pumping continues additional 20 days in 2013
Scenario 6: Grum Pit pumping continues additional 25 days in 2013

Figure 7
Vangorda Pit Elevations
Faro Mine Remediation Project

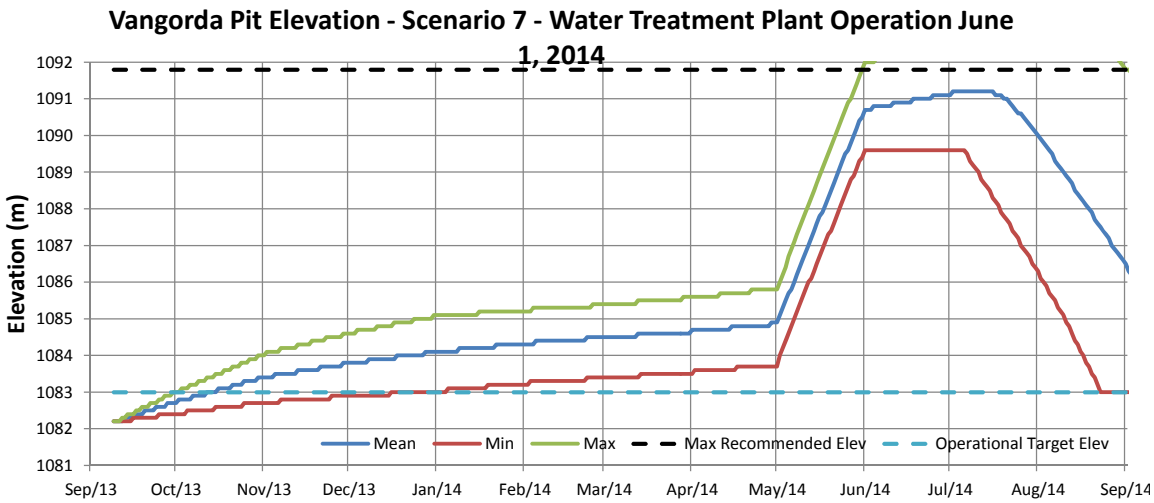


Figure 8
Vangorda Pit Elevations
Faro Mine Remediation Project

Scenario 7: Vangorda Water Treatment Plant does not start until June 1, 2014

Response to Objective 5 of Task Authorization Component 009-D Water Management Support, Faro Mine Remediation Project

PREPARED FOR: Kaori Torigai/Government of Yukon (YG)

PREPARED BY: CH2M HILL Canada Limited (CH2M HILL)

DATE: September 4, 2012

PROJECT NUMBER: 436662.09.D4.OA

Overview

This technical memorandum (TM) is submitted in response to Task Authorization Component (TAC) 009-D, Water Management Support. This TM addresses the following objective of TAC 009-D:

- Review rates of infilling/storage capacity for Vangorda Pit.

This TM provides a review of existing data and work previously completed regarding Vangorda Creek Diversion (VCD) flow regimes. The calculations and conclusions contained herein are based on elevations reported by Denison, and these assumptions need to be confirmed by field surveys, scheduled for completion in early September 2012. This review of existing information included a discussion with Pat Bryan (independent consultant) to clarify previous work he completed for YG. The estimated time required for Vangorda Pit to fill under average conditions (base case), during the June 2012 high flow event, and under extreme flow events is provided.

This evaluation was completed through the review of existing historical data and reports pertaining to pit water level fluctuations; runoff arising from a range of hydrological conditions, including extreme rainfall events; and accounting for the VCD failure and water treatment plant (WTP) failure. Failure of the WTP is included in this scenario since dewatering of the pit would be suspended. Under large storm events, this volume of water would be relatively minor compared to discharge from a diversion breach. Calculations on time required to fill the Vangorda Pit in the event of a failure of the VCD is provided based on work performed by Pat Bryan (date unknown).

On June 8, 2012, CH2M HILL was notified that water flow in the VCD exceeded the design capacity and water was pooling above the drop structure (Figure 1). At that time, YG requested CH2M HILL provide an estimate of the time required for the Vangorda Pit to fill in the event of a breach of the diversion channel. An email summary produced by CH2M HILL was provided to YG on June 8, 2012, which concluded that Vangorda Pit would be expected to fill with water within days in the event of a failure of the FCD during an event with peak flows sustained at 10 cubic metres per second (m^3/s) (the design flow of the diversion).

Vangorda Pit

Vangorda Pit is approximately 1,150-metres (m) long by 350-m wide and 150-m deep from the crest of the pit walls to the deepest point of the pit (SRK, 2010a). The lowest elevation of the surrounding pit walls where water would first overflow from the pit during an uncontrolled rise in water level is indicated to be at an elevation of 1,130 metres above sea level (masl) at the original Vangorda Creek channel on the northwest side of the pit (SRK, 2006). However, in the *2011 Annual Environmental Monitoring and Activities Report* (Denison, 2012), the maximum water level elevation before overflow from the pit would occur is indicated to be about 1,122 masl. This elevation was also used in the work by Pat Bryan and will be considered the maximum water level elevation throughout this TM to be conservative. Vangorda Pit receives groundwater seepage, direct precipitation, runoff, and VCD seepage, along with water from managed sources, such as the Little Creek Pond, the GSC Pond, and V15/Grum Creek (the V15 system has yet to be operated). Average annual inflows to Vangorda Pit have been

reported as 500,800 m^3 between 2005 and 2009 (Denison, 2010), 350,000 m^3 in 2010 (Denison, 2011), and 384,000 m^3 in 2011 (Denison, 2012). The average annual flow to Vangorda Pit between 2005 and 2011 is estimated as 462,600 m^3 (14.7 litres per second [L/s]).

Water level elevations in the Vangorda Pit between 2005 and 2012 recorded by Denison are shown in Figure 2. The water level elevation in Vangorda Pit has averaged near 1,085 masl and has ranged between 1,074.6 and 1,094.1 masl since 2005 (Denison, 2012). Based on 2010 and 2011 groundwater levels reported by Denison (2012), water surface elevations in Vangorda Pit appear to be lowered to 1,083 masl at the initiation of dewatering activities, and are then managed below approximately 1,088 masl throughout the summer (Denison, 2012). At the maximum recommended water level in Vangorda Pit (1,091.8 masl), which was the license limit in the expired water licence QZ03-059, there is about 1.6 million cubic metres (Mm^3) of water contained in the pit (SRK, 2006). About 4.6 Mm^3 of storage capacity is available at the final overflow elevation at about 1,122 masl, which is about 1.2 Mm^3 less storage than is indicated to be available at 1,130 masl (SRK, 2006). At the average water level elevation in Vangorda Pit (about 1,085.8 masl) (Denison, 2012), Vangorda Pit contains about 1.5 Mm^3 (SRK, 2006). For the current analysis, the approximate available storage capacity is calculated by subtracting the volume associated with the maximum recommended water surface elevation of 1,091.8 masl (1.6 Mm^3) from the volume available at the approximate capacity of pit (4.6 Mm^3) according to Denison.

Vangorda Creek Diversion Channel

To limit runoff from entering Vangorda Pit, the approximately 1,200-m-long VCD was constructed in 1991 around the northern perimeter of the pit (SRK, 2010b). Since that time, upgrades and maintenance to the VCD have occurred, but the design and alignment has not changed (SRK, 2010a). The alignment of the VCD is shown in Figure 3 (Figure 5.11 in RGC, 1996).

In June 2004, a storm event occurred with a magnitude equivalent to the estimated 100-year return period event that resulted in damage to the conveyance system and nearly overtopped the VCD dam at the head of the diversion (SRK, 2010b). An overflow spillway was installed in the VCD dam in 2005 to redirect water into Vangorda Pit if this water level is reached again.

As indicated by SRK (2010b), the VCD consists of the following components:

- Headworks comprising an 8-m-high earth dam and a 1.5-m-diameter culvert within the dam which directs the water into an 800-m-long, 2,400-millimetre (mm)-diameter, half-round, corrugated steel pipe (CSP) culvert section
- A plunge pool or stilling basin located at the end of the culvert sections
- A 3,000-mm-diameter drop-box structure, a 2,000-mm CSP culvert, and a 1-600-mm outfall culvert conveying the discharge from the plunge pool beneath the Haul Road and back into Vangorda Creek
- Two 1,000-mm-diameter culverts at the headworks provide an emergency spillway to the Vangorda Pit for events that exceed the 100-year event

The flume structure (2,400-mm-diameter CSP) was designed to accommodate the 1:100-year storm event, with a peak instantaneous flow of 10 m^3/s (SRK, 2010b). The water level in the flume is expected to rise to a maximum depth of 0.73 m during this peak discharge (SRK, 2010b). The water level in the flume in June 2012 (Figure 1) appears to reach the top of the half-round CSP culvert in places; therefore, it is assumed that the June 2012 event was greater than a 1:100-year event; however, the flow in the diversion is not known.

Infilling of Vangorda Pit

The report titled *Candidate Method for Selecting Design Flood Events for Faro Creek and Vangorda Creek Closure Diversions* by Pat Bryan (date unknown) was reviewed to understand how quickly the Vangorda Pit is expected to fill under extreme flood events. Note that CH2M HILL has not reproduced the work performed by Pat Bryan; we are only reporting his results.

In this work, an average discharge in litres per second per square kilometre (L/s/km^2) for a number of consecutive days based on five return periods is presented from a regional analysis (Table 1). This work generated estimates of average flow for a range of consecutive days and for a range of return-period storm events. Based on regional analyses performed on 15 stations in Yukon and Alaska, Pat Bryan determined that unit flow values (that is, L/s/km^2) were independent of the catchment area. Therefore, the Salcha River near Fairbanks, Alaska with a watershed area of approximately 5,618 km^2 was selected to represent the 20.9-km^2 VCD and pit lake catchment. At the time of the analyses, the data available for the Salcha River covered a 56-year period of record. Table 1 from Bryan (date unknown) provides average discharge rates normalized to the catchment area for various return periods and flow periods generated from the Salcha River dataset by multiple hydrological frequency analyses.

TABLE 1
Average Discharge over Consecutive Days
Faro Mine Remediation Project

Return Period (years)	Average Discharge in L/s/km^2 for the Following Number of Consecutive Days											
	1	**2**	**3**	**5**	**7**	**10**	**15**	**30**	**60**	**90**	**183**	**365**
2	68	61	57	49	45	41	35	27	22	19	13	8
100	285	239	217	179	152	131	107	77	52	44	29	15
200	336	278	252	208	174	148	121	86	57	48	32	17
500	408	335	303	247	204	172	140	99	63	53	35	18
1,000	469	381	345	280	228	192	155	109	69	57	38	19

(Bryan, date unknown)

The values presented in Table 1 are average discharge rates normalized to the catchment area for the indicated number of consecutive days and for various return periods. Based on correspondence with Pat Bryan (2012), it is understood that for the 1-day average discharge (Column 2), the maximum average daily flow for each year in the period of record from the Salcha River is used as input to the frequency analyses. For consecutive-day periods, the average daily flows from each consecutive-day period in a year (for example, using the 7-day period, Day 1 to 7, 2 to 8, 3 to 10…359 to 365) were first produced; then, the maximum of these average daily flows over the number of consecutive days was selected for each year within the period of record, which were used as the input for the frequency analyses. The procedure was similar for other consecutive-day periods. The 365-consecutive-day period used the annual average daily flow for each year in the period of record from the Salcha River as input to the frequency analyses to predict the average discharge normalized to the catchment for various return periods.

The volume of water that would be generated for each return period from discharge over the indicated number of consecutive days was calculated for the Vangorda Pit catchment at approximately 20.9 km^2 (Table 2).

TABLE 2
Calculated Volume of Flood-Generated Water
Faro Mine Remediation Project

Return Period (years)	Calculated Volume of Water Generated by Flood - Mm^3 Following Number of Consecutive Days											
	1	**2**	**3**	**5**	**7**	**10**	**15**	**30**	**60**	**90**	**183**	**365**
2	0.1	0.2	0.3	0.4	0.6	0.7	1.0	1.5	**2.4**	**3.0**	4.4	5.1
100	0.5	0.9	1.2	1.6	1.9	2.4	**2.9**	4.2	5.7	7.1	9.7	10.2
200	0.6	1.0	1.4	1.9	2.2	**2.7**	**3.3**	4.7	6.2	7.8	10.5	11.0
500	0.7	1.2	1.6	2.2	2.6	**3.1**	3.8	5.4	6.9	8.7	11.7	12.0
1000	0.8	1.4	1.9	2.5	**2.9**	**3.5**	4.2	5.9	7.4	9.3	12.6	12.8

Notes: Bold values indicate, for each return period, the closest volume approaching the available capacity in the pit.

The flood volumes reported in Table 2 were used to estimate the time required to fill the approximate 3 Mm^3 capacity of Vangorda Pit in the event that all water was directed from the diversion to the open pit. For each return period, the closest volume approaching the available capacity in the pit is highlighted in bold in Table 2.

Base Case

The estimated time required for Vangorda Pit to fill with water under the base case scenario is presented in this section. The base case scenario considers average flow conditions and failure of the diversion (or drop box) which results in all flow from VCD being directed to Vangorda Pit.

Based on the 2-year return period event for annual flow, 8 $L/s/km^2$ (Table 1), the annual flow in the VCD is approximately 5 Mm^3. Therefore, assuming a storage capacity in Vangorda Pit of 3 Mm^3 (4.6 Mm^3 at 1,122 masl minus 1.5 Mm^3 at 1,085 masl), in the event of a breach of the diversion channel that was left unrepaired, the pit would fill within approximately 220 days.

June 2012 Event

The estimated time required for Vangorda Pit to fill with water under the estimated flow conditions experienced during the spring freshet in June 2012 is discussed in this section. Flow data is not available for the VCD; therefore, the peak instantaneous flow rate and the duration or overall volume of runoff arising from this runoff event is unknown. Rob Wren (TEES, 2012) indicates flows in the diversion were elevated beginning early in the morning on Friday, June 8, 212, and receded by about Sunday, June 10, 2012. Because insufficient flow records are available, it is not possible to accurately estimate how much of the pit would have filled if the diversion had failed at the beginning of this event.

As noted, following a rain-on-snow event in 2004 which resulted in an estimated 1:100-year event, an overflow spillway was installed behind the headworks dam, which directs flow to Vangorda Pit. Therefore, even without breaching the diversion channel under flow conditions greater than the 1:100-year event, discharge should still be directed to Vangorda Pit. However, based on discussion with TEES (2012), the water elevation behind the headworks dam did not reach a level to initiate flow through the overflow spillway during the June 2012 event. It is uncertain whether this has to do with an issue with the design or construction of the overflow spillway, or is a reflection on the size of the event.

Extreme Event

Bryan reports that the estimated time to fill the 3-Mm^3 capacity in the Vangorda Pit is about 1 week (7 days) for an extreme 1,000-year flood event scenario (Table 3). Based on flood volumes estimated by Bryan for a flood event with a recurrence interval of 100 years, it would require about 16 consecutive days of sustained flows to generate this volume. Additional time would be required for lower-magnitude and shorter-duration flood events.

TABLE 3
Estimated Time Required to Fill Buffer Storage after Breach of Diversion
Faro Mine Remediation Project

Pit Name	Number of Days Required to Fill Pit during Peak of Flood with Return Period of:				
	2 years	**100 years**	**200 years**	**500 years**	**1,000 years**
Vangorda Pit	90	16	12	9	7

(Bryan, date unknown)

The following assumptions were stated in the Pat Bryan report (italicized text):

> *The time estimates presented in Table 4 [*Table 3*] are associated with a number of assumptions. Some of these assumptions would result in an underestimation of the actual amount of time available to repair a breach. The following two assumptions have that effect.*
>
> - *The breach is assumed to occur in the early stages of the flood event. In reality, a large proportion of the flood waters would likely have been successfully conveyed around the open pit before the breach actually developed.*
> - *Upon development of the breach, the full flow of the stream is assumed to report to the open pit. However, the diversion may still be partially functional and continue to convey a portion of the flood waters around the open pit.*
> - *The following two assumptions could potentially result in an overestimation of the time available to repair the diversions.*
> - *The sample of floods provided by the Salcha River streamflow record were assumed to be a good representation of the overall population of floods that could potentially occur in the region of the mine. However, it is possible that the true population is more skewed than suggested by the 56 years of data collected at the USGS station. This would result in true flood volumes that are greater than estimated in Table 2 [Table 1], particularly for the return periods of 500 and 1000 years.*
> - *The flood volumes were assumed to be relatively insensitive to a stream's long term mean annual runoff (MAR). This is probably a good assumption for the shorter durations (say up to 7 days). However, for the longer durations the flood volumes probably show some relationship with MAR. The Salcha River catchment is somewhat drier than the catchments controlled by the diversions (261 mm vs. approx. 350 mm). Thus, the flood volumes presented in Table 2 [Table 1] for the longer durations may underestimate the true amount of water that would be generated by the diversion catchments. This effect is expected to be relatively small.*

The following assumptions have been applied to the current calculations prepared by CH2M HILL:

- The maximum available storage volume of 3.0 Mm^3 is based on the assumption that the pit is already at its maximum recommended water surface elevation of 1,091.8 masl.
- The maximum water surface elevation (overflow elevation) is assumed to be 1,122 masl according to Denison (2012), which results in approximately 1.2 Mm^3 less available storage as compared to the maximum water surface elevation of 1,130 masl reported by SRK (2006).

Water Treatment Plant Failure

In the event of a failure of the WTP, dewatering activities to maintain the water level to the desired elevation would cease, and the volume of water that would normally be processed by the WTP would accumulate in Vangorda Pit. The estimated volume of water which would be pumped from the pit to the WTP over four durations of WTP downtime at an assumed rate of 10,900 m^3/day (that is, the approximate operating capacity of the Vangorda/Grum WTP [Denison, 2011]) is presented in Table 4. If the WTP was inoperable for 30 days, there would be about 327,000 m^3 of water which would accumulate in Vangorda Pit; this is approximately equal to 11 percent of the pit storage capacity (Table 4).

TABLE 4
Estimated Volume which could not be removed from Vangorda Pit in the Event of WTP Failure
Faro Mine Remediation Project

Duration of WTP Failure (days)	Volume which would Not be Processed during this period (m^3)	Percent of Available Vangorda Pit Storage (%)
5	54,500	0.02
10	109,000	0.04
15	163,500	0.05
30	327,000	0.11

In consideration of an event which resulted in additional water being stored in Vangorda Pit, the time required to process the accumulated water was estimated (Table 5). The following steps were taken. A volume of accumulated water as a percentage of the total storage volume in Vangorda Pit was used to estimate a duration required to complete treatment. The portion of annual average inflow to the pit over this duration was then estimated based on annual average inflow of 462,600 m^3 (1,267 m^3/day). The estimated time required to treat the revised total volume (i.e., accumulated volume and portion of annual average inflow over the treatment duration) was then calculated. Approximately 31 days would be required to remove and treat 300,000 m^3 of accumulated water in the event that 10 percent of the current storage capacity was filled. Approximately 307 days would be required to remove and treat 3 Mm^3 of accumulated water. It is clear that very long durations would be needed to treat large volumes of water spilled into the pit, requiring treatment over the winter or over multiple summer seasons.

TABLE 5
Estimated Time Required to Treat Accumulated Volumes
Faro Mine Remediation Project

Volume of Accumulated Water as percent of Total Storage Volume (%)	Volume of Accumulated Water (m^3)	Initial Estimated Time required to Treat (days)	Estimated Annual Inflow during this Period (m^3)	Revised Total Volume to Treat (accumulated and portion of annual average inflow) (m^3)	Estimated Time Required to Treat Total Volume (days)
10	300,000	28	34,880	334,880	31
20	600,000	55	69,759	669,759	61
30	900,000	83	104,639	1,004,639	92
40	1,200,000	110	139,518	1,339,518	123
50	1,500,000	138	174,398	1,674,398	154
60	1,800,000	165	209,277	2,009,277	184
70	2,100,000	193	244,157	2,344,157	215
80	2,400,000	220	279,037	2,679,037	246
90	2,700,000	248	313,916	3,013,916	276
100	3,000,000	275	348,796	3,348,796	307
Assumed WTP capacity		10,900	m^3/day		

Vangorda Pit Summary and Recommendations

In summary, if the VCD were to breach at the initiation of sustained peak flows equal to the design capacity of the VCD (i.e., 10 m^3/s), there appears to be a danger of the Vangorda Pit reaching the water level elevation at which overflow would occur in a short time span (days to weeks) if all the water is directed towards the pit. In the event of a breach of the VCD while the water elevation in Vangorda Pit is at or below 1,085 masl, the pit has the capacity to store approximately 3 Mm^3 of runoff before reaching an elevation from which discharge would occur (1,122 masl). Based on flood volumes generated for an estimated flood event with a recurrence interval of 100 years, it would require several days (about 16 consecutive days) of sustained flows to generate this volume. For an estimated flood event with a recurrence interval of 1,000 years, it would require about 1 week of sustained flows to generate this volume. Remedial measures would need to be implemented rapidly to prevent uncontrolled discharge from the pit. It is uncertain if repairs could be made in this time frame.

Based on this information, CH2M HILL recommends that in the short-term, the VCD be monitored closely, including implementation of a continuous flow monitoring program on this channel. Also, diversion failure modes should be identified and an emergency response plan be developed and ready to implement. In the event of a breach, the diversion should be re-established as soon as practicable, and before the water elevation approaches an elevation of 1,122 masl. The specific design return-period event or peak flow rate that is to be used for ultimate diversion design (level of service) is to be defined, and in the longer-term, the VCD should be upgraded to accommodate these defined events.

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Figures









FIGURE 1
Photographs of Vangorda Creek Diversion on June 8, 2012 (TEES, 2012)
Faro Mine Remediation Project

Vangorda Pit Water Elevations

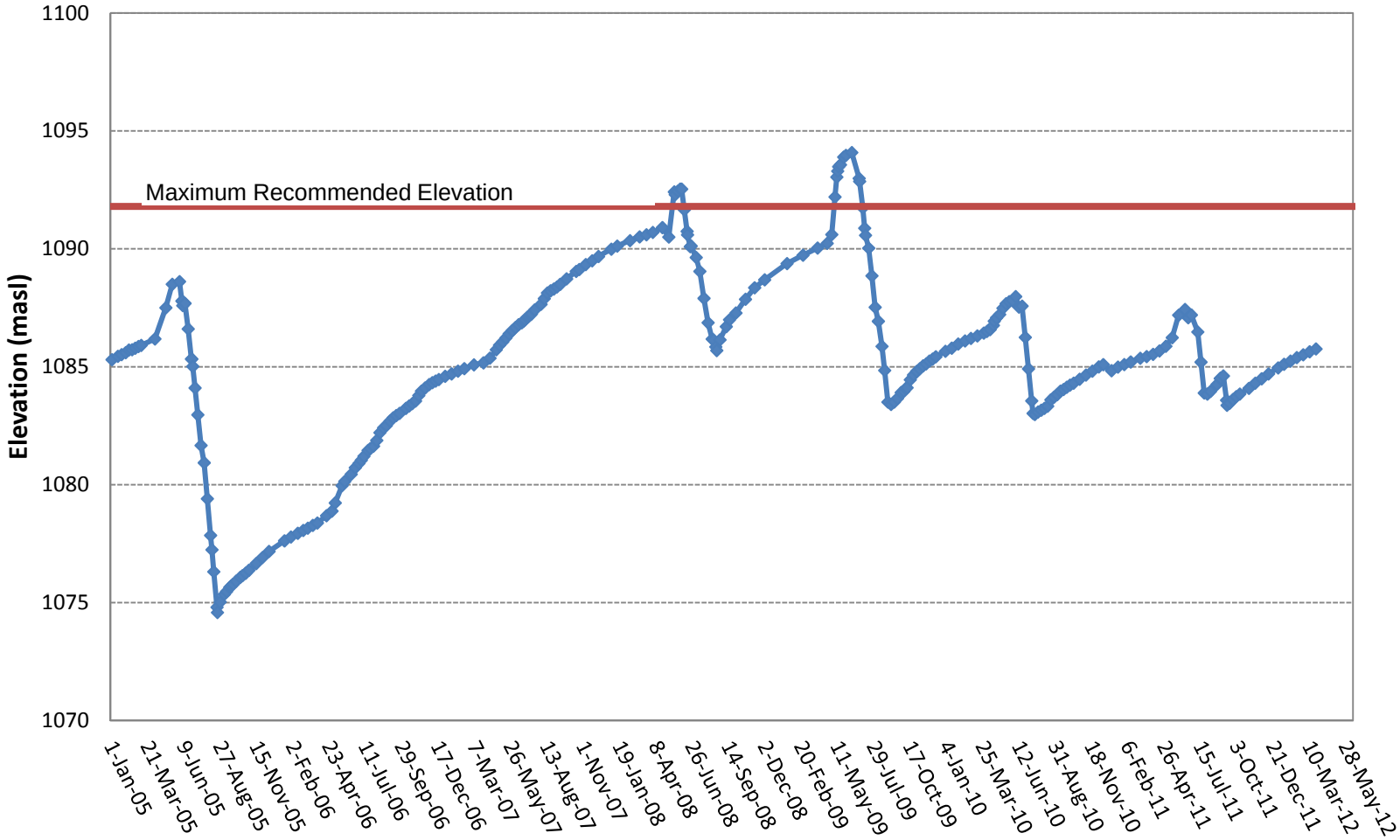

FIGURE 2
Vangorda Pit Water Level Elevations (Denison, 2012)
Faro Mine Remediation Project

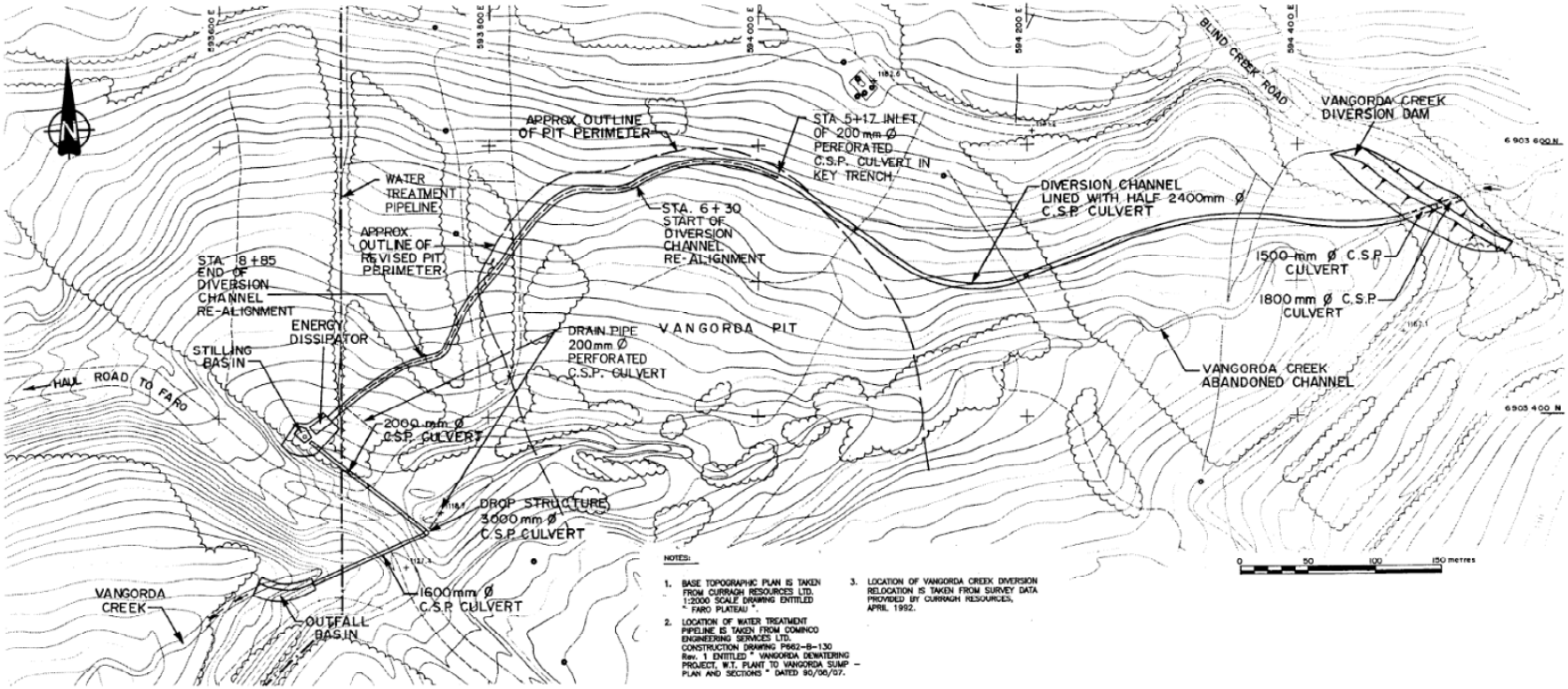

FIGURE 3
Vangorda Creek Diversion Alignment (**RGC,** 1996)
Faro Mine Remediation Project

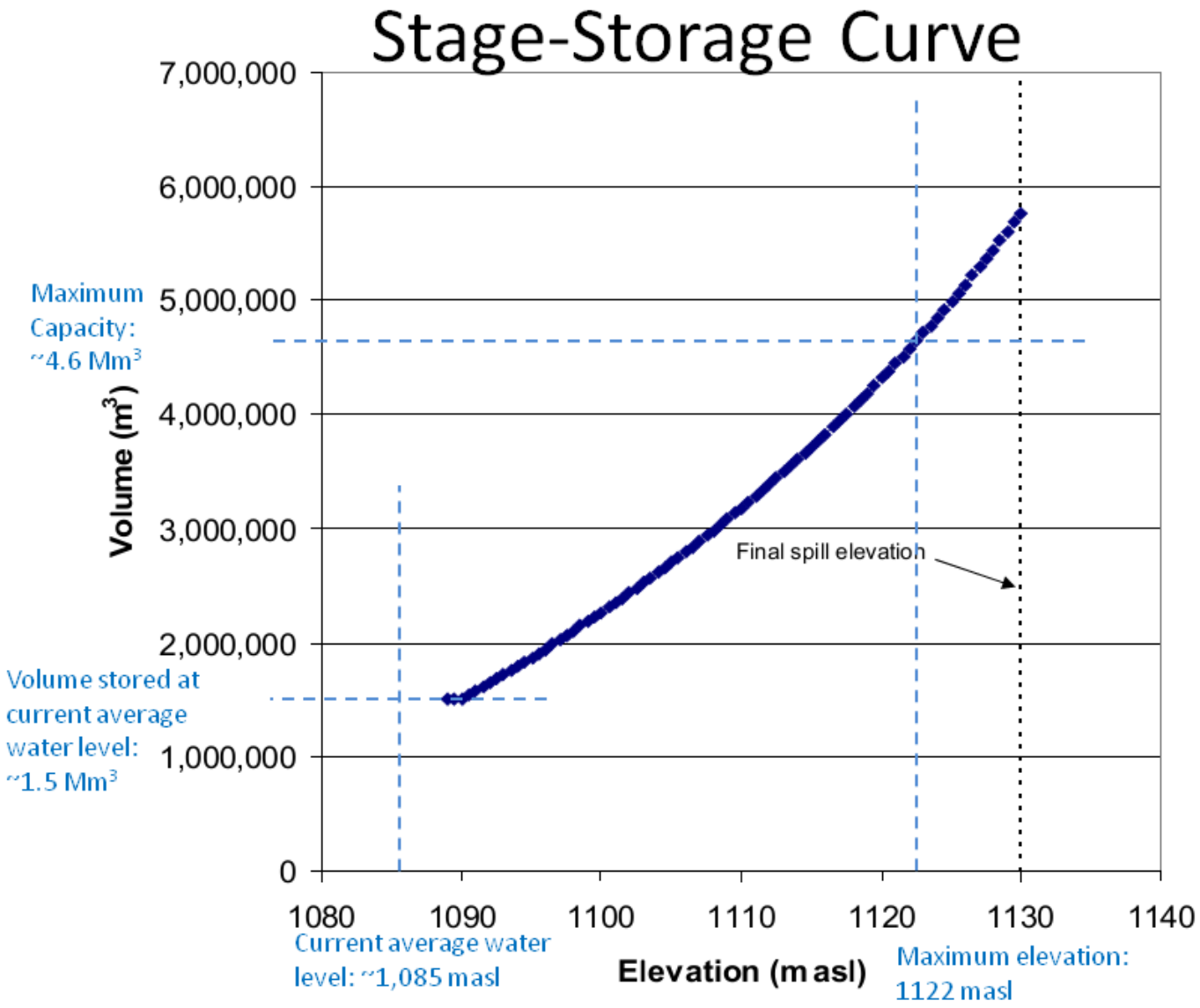

FIGURE 4
Vangorda Pit Stage – Storage Capacity Curve (SRK, 2006)
Faro Mine Remediation Project

ES102011123831RDD

Appendix 6G
Groundwater Baseline Report

Draft

Groundwater Baseline Report, Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 2014

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Attachment

6G-1 Time Series Chemical Plots

Acronyms and Abbreviations

CVD	Cross Valley Dam
DES	Denison Environmental Services
ETA	Emergency Tailings Area
FMC	Faro Mine Complex
GW	groundwater
ID	Intermediate Dam
km^2	square kilometre
L/sec	litre per second
m^3	cubic metres
m^3/yr	cubic metres per year
m	metre
m/day	metres per day
m/m	metres per metre
m/s	metres per second
masl	metres above mean sea level
mg/L	milligrams per litre
NFRC	North Fork of Rose Creek
RCAA	Rose Creek Alluvial Aquifer
RCD	Rose Creek Diversion
RCTA	Rose Creek Tailings Area
RGC	Robertson GeoConsultants, Inc.
SIS	seepage interception system
SRK	SRK Consulting Engineers and Scientists
TDS	Total Dissolved Solids
tpy	tonnes per year
VC	Valued Component

SECTION 1

Introduction

The purpose of this report is to describe the baseline conditions and trends for groundwater resources across the Faro Mine Complex (FMC). Understanding groundwater conditions and trends is integral to the prediction and interpretation of potential effects on key Valued Components (VCs), including water quality and fish habitat. The environmental effects assessment for the Faro Mine Interim Works does not identify groundwater as a VC because past mining activity at the site precludes use of onsite groundwater for future uses. However, the indirect effects of changes in groundwater quality and flows have been considered in evaluating effects on the other VCs.

This report is divided into two main sections. Section 2, Methods, defines the overall study area of the baseline analysis, describes the groundwater data and information sources necessary to conduct the analysis, and describes the analysis methods.

Section 3, Results, describes the results of the baseline characterization for groundwater. This section contains a brief description of the geologic and hydrogeologic setting and a more detailed description regarding groundwater quantity across the site. In addition, a discussion of surface water and groundwater interaction is provided to understand how and where surface water might be affected by groundwater discharge. Groundwater quality is also discussed in detail to assess the potential effect of contaminated groundwater on the surface water VC.

SECTION 2

Methods

Groundwater baseline conditions were characterized using various data sources and tools, as described in the following section. In general, information presented in previous environmental reports and historical groundwater monitoring data were used as a starting point for characterizing baseline conditions. The data were reviewed and used to construct a calibrated groundwater flow model for a portion of the site. Groundwater quality trend graphs were also used to develop a better understanding of the baseline groundwater quality conditions at the site, and how these conditions have changed over the past decade or more.

2.1 Study Area

The study area for groundwater resources is generally defined as the aquifers underlying the Faro Mine Area and the Vangorda/Grum Area. The aquifer systems that may potentially be affected by mine operations fall entirely within the surface water drainages that encompass the Faro Mine Area and the Vangorda/Grum Area. Groundwater flowing downgradient from the mine areas quickly discharges to surface water drainages (Rose Creek or Vangorda Creek); therefore, subsurface flow of mine-related contaminants through the aquifer system will be limited, and no extensive downgradient groundwater effects from mine operations are anticipated. For these reasons, a study area encompassing the mine areas will provide appropriate characterization to support the environmental effects assessment for relevant VCs.

The groundwater baseline local study area can be sub-divided into two distinct areas. The first is the Faro Mine Area, which generally covers the topographic drainage area upgradient from surface water station X14 on Rose Creek and includes the Rose Creek Tailings Area (RCTA), Zone II Pit, Emergency Tailings Area, and S-Wells area (see Figure 6G-1). The second is the Vangorda/Grum Area, which covers the entire topographic drainage area upstream from surface water station V27 on Vangorda Creek (see Figure 6G-2). Based on current information, all mine-affected groundwater in the Faro Mine Area will report to surface water at downstream locations along Rose Creek, and mine affected water in the Vangorda/Grum Area will report to several surrounding creeks including Vangorda Creek, AEX Creek and the West Fork of Vangorda Creek. Sources of Data and Information

Data and information sources for the evaluation of groundwater resources baseline conditions include the following:

- Information provided in previous environmental reports for the study area: a literature review and data compilation was completed to extract relevant information for this evaluation.
- Historical field monitoring data for groundwater levels and groundwater quality performed by various consulting firms, collected over the past decade or more and summarized in the reports described in the previous bullet or downloaded from a site-wide database of site water quality data from the various field events (emLine database) (Denison Environmental Services [DES], 2012a).
- Topography for pre-mining and post-mining surfaces from a combination of 10-metre (m) and 30-m digital elevation models, light detection and ranging data, and more detailed topographic mapping performed in 2012.
- Previously developed groundwater flow model of the RCTA (Robertson GeoConsultants, Inc. [RGC], 2006).
- Newly developed groundwater flow models of the Faro Mine Area (CH2M HILL, 2013).
- Field-acquired data from well construction and development activities and aquifer testing efforts.
- Photographs from site visits.

2.2 Data Analysis Methods

The characterization of baseline conditions primarily consisted of a detailed data compilation and literature review. Descriptions of local geology and hydrogeology from previous reports were reviewed and incorporated into this analysis. Hydrographs from historical groundwater level surveys were used to estimate changes in groundwater elevations and general groundwater flow patterns. Groundwater quality trend graphs from historical groundwater quality sampling and testing were used to estimate changes in chemical loading to groundwater as well as contaminant migration patterns. The review of groundwater quality data resulted in an estimation of levels of groundwater quality effects that have occurred within various subareas across the FMC and are used to understand the existing conditions at the site.

The magnitude of groundwater flow through the aquifer system present within the Rose Creek drainage basin was estimated using the following calibrated groundwater flow models:

- North Fork of Rose Creek (NFRC) subarea model, including NFRC, Zone II Pit and Outwash, and S-Wells areas
- Rose Creek Alluvial Aquifer (RCAA) subarea model, including the RCTA and the Cross Valley Dam (CVD) areas

The two groundwater flow model grids each mathematically represent a 262-square-kilometre (km^2) area encompassing a portion of the Rose Creek drainage basin. The locations of the lateral model domain boundaries shown in Figure 6G-3 were selected to coincide with natural hydrological features, such as watershed boundaries and streams, to help establish a regional hydrological framework around the subareas of interest. The model domains are discretized horizontally into grid-block (i.e., cell) spacings ranging from 10 to 100 m. The finer cell spacings (10 m) are located in the two general subareas of interest:

- **NFRC Subarea.** This subarea is of interest because of elevated concentrations of constituents of interest between the Faro Pit and NFRC, north of the RCTA (see Figure 6G-4).
- **RCAA Subarea.** This subarea is of interest because of the tailings situated upgradient from the proposed CVD SIS, which has been identified as the last line of defence for capturing contaminated groundwater before it migrates to downgradient receiving waters (see Figure 6G-5).

Cell spacings were refined in two separate model grids, as opposed to both subareas within one model grid, to avoid excessively long runtimes that would have resulted from having such refinements in one model grid.

The development of these two models is described in the *Fiscal Year 2012 Water Modelling Analysis Report* (CH2M HILL, 2013). For the Vangorda/Grum Area, the estimation of groundwater flow rates is more qualitative, as no groundwater models exist for this area and historical field data are sparse. Therefore, no quantitative analysis has been done to date to identify the amount of groundwater that flows through this area. Alternatively, pit water levels and extraction rates were used to estimate the magnitude of interaction of groundwater with the pit lakes. Measured groundwater elevations were also used to generally assess the direction of groundwater flow in the area.

SECTION 3

Results

The groundwater baseline characterization results are grouped into four sub-sections: (1) Geologic and Hydrogeologic Setting, (2) Groundwater Quantity, (3) Groundwater and Surface Water Interaction, and (4) Groundwater Quality.

3.1 Geologic and Hydrogeologic Setting

The following section provides a brief description of the surficial and bedrock geology and a summary of the geologic and hydrogeologic setting. A more detailed description is provided in the Conceptual Site Model report (CH2M HILL, 2012). Hydrogeology is described in terms of general groundwater flow and observed groundwater elevations, general subsurface properties such as hydraulic conductivity (permeability), and typical pumping well capacities in the project area.

3.1.1 Geologic Setting

The FMC is located on the Vangorda Plateau, a northwest-to-southeast-oriented upland area surrounded by the Anvil Range along the northern edge and Rose Mountains along the southern edge. The area is typical of a mountainous region that has been influenced by multiple past glaciations, consisting of broad, U-shaped valleys, rounded hills, and rough mountain peaks and deposits of glacial till and glaciofluvial materials. The FMC is north of a regionally dominant structural feature, the northwest-trending Tintina Fault (Trench), which separates the older sedimentary rocks deposited into a marine environment on the edge of the older continental craton and the more recent accretion terranes (Smith et al., 2004). Bedrock geology, including the main regional formations and faults, is shown on Figure 6G-6.

The Faro deposit, a lead-zinc massive sulphide deposit, is located in the Mount Mye Formation and consists of phyllites and schists. There are several faults bisecting the ore body that provide possible structural control for groundwater flow, as do other planes of weakness and deformation that are likely to be the most permeable pathways in the crystalline rock. This Cambrian-age formation is greater than 2,000 m thick. Mineralogical analyses suggest that, typically, the rocks of this formation contain between 0 and 4.8 percent total sulphur, with an average of 0.25 percent. A thin veneer of glacial till originally overlaid the Faro Pit and the surrounding south-facing hill slope (RGC, 1996). Faro Creek Valley to the northeast of the pit and the former Faro Creek Channel southwest of the pit contain thicker deposits of colluvium and fluvial deposits, indicated to be up to 100 m thick northwest of the pit and thinning to about 10 m south of the pit (RGC, 1996).

The Grum and Vangorda deposits are located in the Vangorda Formation, which consists predominantly of calcareous phyllite and calc-silicate rocks banded with meta-igneous greenstone and chloritic phyllite, carbonaceous phyllite, and minor limestone (AECOM, 2009). Up to 100 m of till overburden overlaid the Grum deposit; the overburden thinned out to less than 40 m in the northeastern and southeastern portions of the pit (RGC, 2006). The Grum deposit intersects the Mount Mye Formation at its base.

Similar to the Faro deposit, the Grum and Vangorda deposits have large-scale fault structures that provide possible permeable groundwater flow paths. This Cambrian/Ordovician formation is approximately 1,000 m thick. Mineralogy of the Vangorda Formation indicates the phyllites commonly contain 10 to 30 percent calcite and 1 to 2 percent sulphide minerals in the form of pyrite and lesser amounts of pyrrhotite (RGC, 1996).

The surficial geology in the FMC and the surrounding area is influenced by its glacial history, mountainous terrain, and past and current fluvial regime. Glacial till, glaciofluvial deposits, colluviums, and alluvium overlie much of the area. The anthropogenic overburden consists of mined materials, including the waste rock piles and tailings deposits. Typical of surficial geology present in mountainous areas, hilltops and upland areas have exposed bedrock or thin coverings of colluvium. On valley side slopes, deposits of colluvium and till increase in thickness towards the base of the valley, with valley bottoms containing thicker deposits of colluvium, till, and fluvial deposits. Surficial geology deposits in the valley bottoms are complicated by fingering or layering of fan

and outwash deposits, which were subsequently incised. Review of the surficial geology maps suggests the following (Gartner Lee Limited, 2008; RGC, 1996):

- Upland areas such as Mount Aho, Mount Mye, and the Rose Mountains are generally exposed bedrock or are covered in colluvium.
- Valley bottoms, including South Fork Rose Creek, North Fork Rose Creek, Vangorda Creek, and Faro Creek, comprise fluvial materials and glaciofluvial materials.
- Broad side hills and areas adjacent to river valleys are frequently composed of blanket or veneer glacial deposits.
- Till materials are predominantly identified surrounding all three open pits.
- Glaciofluvial deposits are identified in isolated pockets throughout the project area.
- Few organics are identified in the vicinity of the FMC (locations mapped are distal to mine components).

Figures 6G-7 and 6G-8 show the surficial geologic information (Bond, 1999) mapped for both the Faro Mine Area and Vangorda/Grum Area, respectively.

The FMC is located in the discontinuous permafrost Zone of the Canadian arctic and valley bottoms. North-facing slopes and forested areas may contain year-round frozen sediments at depth. On the Vangorda/Grum side, drilling at the Little Creek Dam identified discontinuous permafrost at about 11 m below ground surface; the vertical extent is unknown (SRK Consulting Engineers and Scientists [SRK], 2010b). About 300 million tonnes (154 million cubic metres [m^3]) of waste rock are located in areas adjacent to the three open pits. Surrounding the Faro Pit, there are about 30 separate waste rock piles containing segregated and nonsegregated waste rock spread over a footprint of 3.4 square kilometres (km^2) (RGC, 1996; SRK, 2010a).

South of the Faro Pit, is a secondary pit, the Zone II Pit, from which 6.8 million m^3 of material was removed and subsequently backfilled with rock removed during mining operations. Immediately to the west and south of the Grum Pit, there are about 28 million tonnes (14.4 million m^3)[1] of waste rock covering 1.48 km^2 of surface area. This includes a sulphide cell covering a surface area of about 0.28 km^2. This waste rock is underlain by thin colluvium and low-permeability bedrock. South and southwest of the Vangorda Pit, there are approximately 16 million tonnes (8.2 million m^3) of waste rock occupying about 0.4 km^2 of area. In addition, there is a 5,900-tonne (11,400-m^3) stockpile of the fines of the oxidized ore or baritic fines (RGC, 1996).

The 55 million tonnes (28.6 million m^3) of tailings in the RCTA generally exhibit a coarser-grained fraction on the northern edge of the Original and Second Impoundments, grading to finer-grained fraction to the south. In the Intermediate Dam (ID) Impoundment, tailings grade from coarse to fine from east to west. The thickness of the tailings increases towards the centre of RCTA—reaching about 25 m thick—and thin to zero towards the edges. Stratigraphy and geology underlying the RCTA may be important for containment and potential attenuation processes. Surficial geology underlying the tailings consists of sand and gravel of fluvial and glaciofluvial origin with till deposits identified along the edges of the valley but pinch out towards the central portion. Within the coarse-grained fluvial and glaciofluvial material are areas of interlayered fined-grained silts and clays typical of backwater areas or glaciolacustrine deposits. Underlying bedrock appears to be from the Vangorda Formation and consists of phyllite and bands of marble and is intruded by the Anvil Batholith. It was noted that the bedrock, where exposed, appears to weather readily (RGC, 1996).

The Emergency Tailings Area (ETA) contains about 123,000 tonnes (63,800 m^3) of tailings deposited into the former channel of Faro Creek. Tailings thickness varies between about 6 and 20 m and overlies the former Faro Creek Channel materials and calcareous phyllite of the Vangorda Formation (SRK, 2010b).

[1] Refined quantity estimates are in progress.

3.1.2 Hydrogeologic Setting

As is typical in mountainous environments, the upland mountain areas act as groundwater recharge areas and the valley bottoms as groundwater discharge areas. Locally, there may also be recharge to underlying aquifers from streams or rivers. In areas where low-permeability confining units are located, artesian conditions may be prevalent.

Pre-mining regional groundwater flow within the Faro Mine area likely mirrored the topographic gradient with flow oriented from the highlands towards the valley bottoms. This suggests the pre-mining groundwater moved south/southwest from Mount Aho and adjacent mountains in the north towards the Rose Creek Valley; and on the opposite side of the valley, north-to-northwest flow would be expected from the Rose Mountains towards Rose Creek. Between the Faro Mine Area and Vangorda/Grum Area, there is a surface drainage divide, which is assumed to be coincident with a groundwater flow divide. From this local topographic high, groundwater flow is expected to follow the gradient of Rose Creek and travel northwest to west toward the RCTA.

On the Vangorda/Grum side, pre-mining groundwater flow is assumed to have followed the topographic gradient and flowed from the mountains around Mount Mye in the north to northeast towards the Town of Faro and the Pelly River in the southwest. Mining activities have changed the landscape (e.g., generating new surface topography with open pits and waste rock piles, fracturing rock faces, and ponding water behind dams) and are actively controlling groundwater (i.e., depressurization of pit walls, groundwater capture via pumping wells and altering recharge patterns with diversion channels), which influences the direction and quantity of groundwater flow. Factors controlling the pre-mining groundwater flow regime are expected to be regionally similar post-mining, but in local areas, groundwater flow would be altered.

Figures 6G-9 and 6G-10 show generalized post-mining groundwater flow directions for the Faro Mine and RCTA, and the Vangorda/Grum Area, respectively.

3.1.2.1 Faro Mine Area Hydrogeology

Surrounding the Faro Pit, four hydrostratigraphic units are potentially present based on a review of geological data predominantly to the south and southeast of the Faro Pit (RGC, 1996):

- A thin, low-permeability layer of till overburden
- An overburden/weathered bedrock contact unit where permeability (hydraulic conductivity) is reported to be higher
- A bedrock horizon with a low-permeability unit of phyllite and schist but with some higher-permeability areas associated with schist with diorite intrusions and fractured/faulted bedrock
- The former Faro Creek Channel northeast and southeast of the Faro Pit

In general, the Faro Pit is expected to act as a groundwater sink. However, the operation of the groundwater extraction well in the Zone II Pit may result in some limited outflow from the southeastern portion of the Faro Pit. This outflow is likely captured by the extraction well and subsequently treated. The water level within the Faro Pit is actively managed by pumping, creating a local groundwater sink, potentially resulting in flow into the pit from most directions. Groundwater discharge to the pit occurs mainly from the natural former Faro Creek Channel and overburden/bedrock contact, whereas seepage from bedrock is limited except via limited faults and fractures (AECOM, 2009). The schematic cross section depicted on Figure 6G-11 shows the groundwater movement between the Faro Pit and the RCTA (refer to Figure 6G-9 for the cross-section location).

Faro Waste Dumps are expected to be largely unsaturated, with infiltrating precipitation collecting within topographic low areas of the pre-mining topography (such as former stream channels). However, based on the presence of seeps associated with the waste dumps, many with low pH and high sulphate and zinc concentrations, these waste dumps are a key source of surface water contamination. Depending on the subcatchment in which a particular waste rock pile is located, seepage from the waste rock piles surrounding the Faro Pit potentially report to Faro Pit, Zone II Pit, NFRC, Old Faro Creek, Guardhouse Creek, or Rose Creek Valley

(RGC, 1996). The schematic cross section depicted on Figure 6G-12 shows the groundwater movement between the Faro Pit and the Zone II Outwash (refer to Figure 6G-9 for the cross-section location).

Zone II Pit water elevations were historically managed to remain at a level no greater than 1,113 m (SRK, 2007). Since October 2010, the Zone II Pit water levels ranged between 1,103 and 1,111 metres above mean sea level (masl) (DES, 2012a). Following the installation of the new Zone II extraction well in 2012, the Zone II Pit target elevation was changed to allow for maintenance of groundwater levels within the Zone II Pit well below the stage of NFRC (which is approximately 1096 m). Maintaining Zone II Pit water levels below the NFRC stage ensures that seepage from the Zone II Pit will not flow toward and subsequently discharge into the NFRC. The new well was first used in June 2013, and Zone II Pit water levels were drawn down to about 1,098 m by late August 2013.

The NFRC area includes the Zone II Outwash and S-Wells areas, which are located between the Faro Waste Dumps and the NFRC. The stratigraphy within the Zone II Outwash and S-Wells areas consists of alluvial/outwash materials overlying bedrock. In locations towards the valley margins, till material may be present and form a low-permeability confining unit.

In the area of the S-Wells, a shallow aquifer unit of sand and gravel is underlain by low-permeability till with an underlying deeper aquifer of sand and gravel overlying weathered bedrock. The shallow unit has high water levels, which suggests that it is perched. The low permeability unit consists predominantly of fine-grained materials that appear to be laterally continuous but likely inter-finger with coarser grain materials. This unit represents a confining layer (with lower-permeability sediments of variable thickness) for the underlying deep aquifer, which includes deeper sand and gravel materials overlying bedrock. The bedrock in the S-cluster area consists of schist of the Mount Mye Formation and is defined as calcareous schist to calcareous silicate (AECOM, 2009).

The shallow sand and gravel layer in the vicinity of the S-Wells has been interpreted to consist of sediments from a pre-mining surface drainage that is now covered by the Intermediate Waste Dump. This aquifer is about 20 to 30 m wide and 3.5 m thick, and is characterized by hydraulic conductivity values ranging from 10^{-5} to 10^{-4} metres per second (m/s) (SRK, 2009a). The deep aquifer is around 350 m wide, has an average thickness of 15 m, and is characterized by hydraulic conductivity values of 10^{-6} to 10^{-4} m/s (SRK, 2009a). According to SRK's 2008 groundwater investigation (2009), the shallow aquifer pinches out near the NFRC and only the deep aquifer is present beneath the creek.

The following three hydrostratigraphic units have been identified in SRK's 2009 groundwater investigation (2010b) in the upper portion of the NFRC:

- A permeable alluvial deposit of variable thickness between 5 and 20 m
- An underlying lower-permeability phyllite bedrock unit
- A colluvium and till unit towards the valley margins (a low-permeability unit between the alluvial deposit and bedrock, which is not present in the central portion of the valley [SRK, 2010b]). Discontinuous permafrost has also been identified at shallow depths.

Groundwater flow in the NFRC valley is towards the southwest, aligned with valley orientation (AECOM, 2009). The gradient is estimated to be 0.02 metres per metre (m/m), consistent with the gradient of the NFRC (SRK, 2010b). The potentiometric surface adjacent to the upper end of the NFRC is shallow, with the water table identified within 2 m from the surface in wells installed in sand and gravel (SRK, 2010b). Groundwater levels in the Zone II Outwash area are up to 5 m below ground surface (AECOM, 2009) and appear relatively stable. Groundwater levels exhibit very little variation, less than 1 m seasonally and less than 2 m spatially, within the Zone II Outwash itself within the alluvial aquifer. Water levels within S-Well monitoring wells installed in till, overburden, and bedrock were within 10 m of ground surface. Seasonal variation of the potentiometric surface has typically been less than 1 m (AECOM, 2009).

The ETA is located in the former Faro Creek Channel, downstream from the Faro Pit. A prominent feature in this area is a 6- to 20-m-thick low permeability tailings unit overlying an alluvial/weathered bedrock unit of sand and gravel with higher permeability. This alluvial/weathered bedrock unit appears to thin from about 5 m near the waste dumps to about 1 m down-valley. Lower-permeability competent bedrock (calcareous phyllite of the Vangorda formation) provides the foundation (SRK, 2010b; AECOM, 2009). A significant groundwater and surface water source to the ETA is the upgradient waste dumps and associated seeps (including seep location X23, which is surface expression of the groundwater flow traveling along the Faro Creek Channel). At the ETA, groundwater elevations tend to fluctuate seasonally within a range of about 2 m. AECOM (2009) noted rapid responses in groundwater elevations in the area to snowmelt.

Key findings from review of the site characterization studies at the Faro Mine Area can be summarized as follows:

- The Faro Pit is generally considered a groundwater sink, except for limited outflow because of pumping at the Zone II Pit.
- Faro Waste Dumps are expected to be largely unsaturated with infiltrating precipitation but constitute a key source of surface water contamination.
- The stratigraphy within the Zone II Outwash and S-Wells areas consists of alluvial/outwash materials overlying bedrock.
- Groundwater flow in the NFRC valley is towards the southwest, aligned with valley orientation, and with a gradient assumed to be 0.02 m/m.
- Groundwater levels in the Zone II Outwash area are up to 5 m below ground surface and appear relatively stable with very little variation.
- Water levels within S-Well monitoring wells installed in till, overburden, and bedrock were within 10 m of ground surface. Seasonal variation of the potentiometric surface has typically been less than 1 m.
- At the ETA, groundwater elevations tend to fluctuate seasonally within a range of about 2 m.

3.1.2.2 Rose Creek Tailings Area Hydrogeology

The RCAA system is a classic fluvial depositional system deposited by Rose Creek and its tributary, the NFRC. The alluvial aquifer is composed of a heterogeneous mixture of silt, sand, gravel, and cobbles. The alluvial deposits are thickest near the centre of the valley, aligned with the ancestral thalweg of Rose Creek, with the thickest deposits around 50 m. Before tailings deposition, Rose Creek was flowing in a meandering stream channel that crossed the valley floor and was fed by several smaller streams that drained the hillsides of Rose Creek Valley. The water table of the underlying valley-fill aquifer was very close to the stream level, indicating a good hydraulic connection between the stream and the groundwater that flowed in the permeable valley sediments (RGC, 1996). Following the onset of mining operations, tailings were deposited over the alluvial valley-fill deposits to a maximum thickness of about 25 m. The greatest thicknesses of tailings were deposited in the Original and Second Impoundments, with thickness diminishing toward the edges of the valley (RGC, 1996).

Available stratigraphic information obtained primarily from the SRK 2009 groundwater investigation (2010b) below the CVD suggests there are up to four hydrostratigraphic units within the RCTA, as summarized in the following bullets.

- The tailings form a low-permeability unit overlying the central portion of the valley that ranges from approximately 250 m wide at the CVD to 800 m wide in the central portion of the valley, with a maximum thickness of about 25 m.
- An overburden unit (valley-fill) composed of highly permeable fluvial and glaciofluvial sand and gravels with thicknesses of up to 50 m towards the central portion of the valley, thinning towards the valley edges.
- A less-permeable glacial till unit underlying the overburden unit that can reach up to 25 m thick towards the valley edges and pinches out in areas towards the middle of the valley (SRK, 2010b).

- Phyllite and schist bedrock forming an underlying lower-permeability hydrostratigraphic unit.

The fluvial deposits are characterized in some areas by extremely high hydraulic conductivities, but also a high degree of heterogeneity. Hydraulic information collected downstream from the CVD supports this hypothesis. The boring log for pumping well PW-1, located in the central portion of the Rose Creek Valley, indicates the presence of numerous intervals of clean sand and gravel layers. In contrast, wells farther to the north, closer to the valley margin, indicate a stratigraphic section dominated by silty sand or gravel with only a few limited layers of clean sand and gravel. Productivity of wells completed in the "well-washed" sand and gravel deposits is very high, with wells capable of pumping in excess of 31.5 to 38 liters per second with very limited drawdown (less than 5 m). The permeability of the other lithologic units present (till, weathered bedrock, and bedrock) are orders of magnitude lower than the fluvial sediments, and therefore play a minor role in the bulk movement of groundwater through the aquifer system.

The pre-mining (1967) water levels were about 1.5 to 3 m below ground surface, and the horizontal gradient down-valley was about 0.011 m/m (RGC, 1996). No temporal trends in groundwater elevation data are apparent (AECOM, 2009). These data suggest a fairly low-gradient, unidirectional flow system typical of meandering stream valleys. In contrast, a static groundwater-level survey of the RCTA in the vicinity of the ID and CVD, performed on September 2006 (RGC, 2006), shows significant complexity in the groundwater flow field because of the presence of the ID, the CVD, and the Rose Creek Diversion (RCD).

Groundwater levels in the aquifer at the toe of the CVD Pond are significantly lower than the water level in the Polishing Pond. Similarly, the groundwater levels in the aquifer at the toe of the ID are significantly lower than in the ID Pond. According to RGC (2006), the groundwater flow field suggests that the Polishing Pond and the ID Pond are "underdrained" because of the large contrast in permeability between the pond sediments/tailings and the underlying aquifer material.

Vertical hydraulic gradients measured in multi-level wells installed within the RCTA indicate the presence of downward gradients between the tailings and the underlying alluvial deposits, suggesting that either contaminants mobilized because of infiltration of precipitation through the tailings or that contaminants entering the tailings through discharge from the ETA could be carried downward and discharged into the underlying RCAA. Additional vertical hydraulic data indicate that gradients within the RCAA are upward between the deepest alluvial deposits and the more shallow portions of the alluvial system. These data suggest that regional groundwater flow moves laterally towards the valley-fill deposits and discharges upward into the more permeable alluvial horizons before migrating downgradient (down valley) with the alluvial flow system.

In 2005, RGC conducted drilling and aquifer test activities at the toe of the CVD (RGC, 2006). Aquifer tests were conducted with a sustained pumping rate of about 2,400 litres per minute from the central well (RGC-PW02) for 24 hours and at about a rate of 1,800 litres per minute from the northern most well (RGC-PW01) for 56 hours. Results from these aquifer tests indicated hydraulic conductivity for the RCAA between $5x10^{-4}$ and $7x10^{-4}$ m/s.

The *Water and Load Balance Study for Rose Creek Tailings Storage Facility* (RGC, 2005) presents scenarios of sulphate and zinc loading to Rose Creek based on current and future conditions and assuming alternatives for remediation. Simulations were based on the review of site characterization studies of the tailings and underlying aquifer materials, as well as historical monitoring data for surface water and groundwater quality.

The following are key findings from review of the site characterization studies:

- Seepage sources to the RCAA include the tailings, Faro Creek seepage (from the ETA) upstream from the RCTA, and seepage from the CVD Pond and ID Pond.
- The average groundwater velocity in the RCAA was estimated to range between about 0.03 and 2 metres per day (m/day), based on an average hydraulic conductivity of $1.2x10^{-4}$ m/s for the RCAA.
- Seepage from the RCD was estimated to take place at about 200 litres per second (L/sec) between the ID and the end of the diversion.

- The area between the CVD and X14 in Rose Creek represents a major groundwater discharge Zone (with an estimated combined flow of 83 L/sec).
- Rose Creek remains a gaining stream downstream from the confluence with RCD, where it returns to its natural streambed; groundwater discharge into Rose Creek between X14 and station RC1 (Next Creek) is estimated to flow up to 200 L/sec.
- In the summer of 2012, CH2M HILL performed additional aquifer tests at existing and new monitoring wells along the CVD. The data collected during these aquifer tests were used to calibrate the RCAA Subarea groundwater model. Modelled horizontal hydraulic conductivity values resulted in the following:
  - Northern Rose Creek Valley near the CVD (alluvium): 5 to 50 m/day
  - Basal till in the CVD area: 0.01 to 0.1 m/day
  - Slope till in the CVD area: 1 to 3 m/day
  - Bedrock in the CVD area: $2x10^{-3}$ m/day

Results show that the RCAA area has high permeability and would allow for the effective operation of a groundwater extraction system to intercept contaminated groundwater before it travels downgradient.

3.1.2.3 Vangorda/Grum Area Hydrogeology

Similar to the Faro Pit, the area around the Grum Pit has a low-permeability overburden (glacial till) unit overlying low-permeability bedrock. A second confined (limited extent) overburden unit, called the Thalweg aquifer, may also be present. This is composed of high-permeability sands and gravels, about 20 to 30 m thick. Above the bedrock contact, a permeable unit of unknown extent may also be present and may be connected to the Thalweg aquifer (RGC, 1996). Investigations to the south and west of Grum Pit reported in the 2009 groundwater investigation (SRK, 2010b) typically identified calcareous phyllite of the Vangorda Formation underlying silty to sandy glacial till in both areas. Three hydrostratigraphic units were identified as consisting of a surficial silt, sand, and gravel unit; weathered bedrock; and competent bedrock (SRK, 2010b). The schematic cross section depicted on Figure 6G-13 shows the groundwater movement between the Grum Pit and the Vangorda Waste Rock Dump (refer to Figure 6G-10 for the cross-section location).

West of the Grum Waste Dumps, Grum Creek and several tributaries drain towards Vangorda Creek. Generally, alluvium material is found over till material with varying degrees of sand, gravel, and clay. Weathered bedrock, transitioning to competent bedrock, provides the foundation. The thicker overburden and fluvial sediments of the Grum Creek area have been interpreted to provide the greatest conduit for groundwater movement. At one borehole in the Grum Creek area, two permeable water-bearing units were observed above the bedrock: a coarse-grained gravel and boulder layer and a sand and silt unit, separated by a low-permeability silt layer (RGC, 1996). Although limited data are available, a confined aquifer, overlain by an unconfined aquifer, was identified at depths below approximately 12 m. Lateral extents, recharge, or discharge zones for the confined aquifer are unknown (SRK, 2006). Drainage from the Grum Waste Dump is anticipated to predominately flow towards the south/southeast, particularly in thicker overburden materials of Grum Creek and associated smaller tributaries (RGC, 1996).

Similar to the Grum Pit area, three hydrostratigraphic units appear to be identifiable in the Vangorda Pit area. However, at Vangorda, there is an overlying confining, low-permeability overburden composed of silty, sandy glacial till (about 30 m thick) that sits atop a saturated sand and gravel unit overlying weathered bedrock that transitions into competent and lower-permeability calcareous phyllite. Several fault zones have been identified in the bedrock (RGC, 1996).

Similar to the Grum Creek area, the greatest conduit for groundwater movement away from the Vangorda Waste Dumps is expected to be via sediments underlying the Vangorda Creek area. Typically, overburden consisting of compact silty and sandy glacial till overlies a more permeable basal sand and gravel unit. Underlying this unit is the low permeability calcareous phyllite bedrock of the Vangorda Formation (RGC, 1996). In the investigated areas of Vangorda Creek Valley, fluvial sediments up to about 20 m thick offer greater permeability. A confining unit of low-permeability till with silty to sandy composition overlies more permeable

sand/weathered bedrock. Thickness of each unit varies but, combined, they are not typically greater than 30 m (SRK, 2010b).

In general, water levels downgradient of the Vangorda/Grum Pits exhibit about 1 m of seasonal fluctuations. Groundwater in the alluvium appears deeper (about 7 to 10 m below ground surface) and shallower in the overburden (about 2 to 6 m below ground surface). Water levels reported for the bedrock are relatively stable, about 7 m below ground surface (AECOM, 2009).

Key findings from review of the site characterization studies at the Vangorda/Grum Area can be summarized as follows:

- The area around the Grum Pit includes three hydrostratigraphic units: a surficial silt, sand, and gravel unit; weathered bedrock; and competent bedrock.
- Drainage from the Grum Waste Dump is anticipated to predominately flow towards the south/southeast, particularly in thicker overburden materials of Grum Creek and associated smaller tributaries.
- At Vangorda, an overlying confining, low-permeability overburden composed of silty, sandy glacial till (about 30 m thick) sits atop a saturated sand and gravel unit overlying weathered bedrock that transitions into competent and lower-permeability calcareous phyllite.
- The greatest conduit for groundwater movement away from the Vangorda Waste Dumps is expected to be via alluvial deposits underlying the Vangorda Creek area.

3.2 Groundwater Quantity

The two calibrated groundwater flow models for the Rose Creek Drainage Basin, as described above and in the *Fiscal Year 2012 Water Modelling Analysis Report* (CH2M HILL, 2013), were used to estimate groundwater flow rates through the Faro Mine area and the RCAA. The groundwater flow modelling domain is shown in Figure 6G-3. The Rose Creek Drainage Basin groundwater models use meteorological and hydrological data, along with drainage basin and aquifer characteristics, to compute groundwater flows and groundwater elevations (heads) throughout the modelled domain under assumed hydrogeological and operational conditions. Modelled potentiometric surfaces for each of the six model layers in the areas of interest are shown in Figure 6G-14. This figure shows that the groundwater flow at the site recharges the RCAA before continuing further downstream along Rose Creek. Modelled depths to groundwater are shown on Figure 6G-15 and vary from about 75 m below ground surface at the waste dumps to less than 10 m at the Mill Building area, the ETA, and the Impoundments. Groundwater balances for the Faro Mine Area and the RCTA are provided in the following subsections. A calibrated groundwater flow model does not currently exist for the Vangorda and Grum areas. No quantitative analysis has been done to date to identify the amount of groundwater that flows through this area. As an alternative, pit water levels and extraction rates were used to estimate the magnitude of interaction of groundwater with the pit lakes. Measured groundwater elevations were also used to generally assess the direction of groundwater flow in the area.

3.2.1 Faro Mine Area

The NFRC model was used to compute a steady-state groundwater balance in an approximately 4.2-km^2 area encompassing the Northeast Rock Dump, NFRC, Zone II Pit and Outwash, and S-Wells areas (see Figure 6G-16). Table 6G-1 lists the components of the combined modelled groundwater balance for Model Layers 1 through 6 in the NFRC model subarea. These data indicate that approximately 20 L/sec of groundwater flows through the NFRC.

TABLE 6G-1
Modelled Groundwater Balance in the NFRC Model Subarea
Faro Mine Interim Works

Groundwater Inflow Component	Groundwater Inflow Rate (L/sec)	Groundwater Outflow Component (L/sec)	Groundwater Outflow Rate (L/sec)
GW Recharge from Precipitation	4	GW Pumping	2
GW Recharge from Streams	8	GW Discharge to Streams	5
GW recharge from Ponds and Pit Lakes	3	GW Discharge to Ponds and Pit Lakes	2
Subsurface Inflow	5	Subsurface Outflow	11
		GW Discharge to Drains	0
Total GW Inflows	**20**	**Total GW Outflows**	**20**

Notes:
Values are rounded to the nearest L/sec.
GW = groundwater

3.2.2 Rose Creek Tailings Area

The RCAA model was used to compute a steady-state groundwater balance in an approximately 4.6-km^2 area encompassing the RCTA, the CVD, and an area downstream from CVD slightly below the confluence of the RCD with the Rose Creek Channel (see Figure 6G-16). Table 6G-2 below lists the components of the combined modelled groundwater balance for Model Layers 1 through 6 in the RCAA model subarea. These data indicate that approximately 211 L/sec of groundwater flows through the RCAA.

TABLE 6G-2
Modelled Groundwater Balance in the RCAA Model Subarea
Faro Mine Interim Works

Groundwater Inflow Component	Groundwater Inflow Rate (L/sec)	Groundwater Outflow Component (L/sec)	Groundwater Outflow Rate (L/sec)
GW Recharge from Precipitation	2	GW Pumping	0
GW Recharge from Streams	134	GW Discharge to Streams	147
GW recharge from Ponds and Pit Lakes	0	GW Discharge to Ponds and Pit Lakes	0
Subsurface Inflow	75	Subsurface Outflow	15
		GW Discharge to Drains	49
Total GW Inflows	**211**	**Total GW Outflows**	**211**

Notes:
Values are rounded to the nearest L/sec.

3.2.3 Vangorda/Grum Area

Before development of Grum Pit, a small lake existed at this location, representative of a pre-mining water table (RGC, 1996). The Thalweg aquifer along the north-northeast portion of the pit provides recharge to the pit. Groundwater flow is estimated to be in a predominately southerly direction. Between 1990 and 1995, approximately 1.5 million cubic metres per year (m^3/yr) of water was pumped from the Grum Pit for dewatering during mining operations; of this, about 900,000 m^3/yr was estimated to be from aquifer storage (RGC, 1996).

Since mining operations and pit pumping ceased, the Grum Pit water level elevation has risen. On average, the Grum Pit water level rate of increase has been about 3 metres per year (DES, 2012b). In 2011, the pit gained approximately 464,084 m^3/yr of water (DES, 2012b). Since 2004, the average annual increase in water gained by the Pit has fluctuated between less than 300,000 m^3/yr in 2006, 2007, and 2010, to more than 500,000 m^3/yr in 2008 and 2012. The decreased rate of water flow to the pit (compared to during mining conditions) may indicate a reduction in groundwater infiltration as the pit water level has increased. Decreased groundwater discharge to the pit under these conditions would be expected because of the reduced magnitude of the hydraulic gradient driving groundwater flow into the pit. The rate of groundwater discharge to the pit likely fluctuates throughout the year, as groundwater levels and pit levels vary.

The Vangorda Pit water level elevation averages 1,085 masl and had ranged between 1,074.6 and 1,094.1 masl since 2004 (DES, 2012a). Seasonal pumping maintains Vangorda Pit as a groundwater sink. The amount of water pumped from Vangorda Pit ranged from none to 925,678 m^3/yr between 2002 and 2010 (an average of 580,903 m^3/yr, or 746,875 m^3/yr if the years with zero pumping are excluded (2006 and 2007)—this means that the following year, higher pumping rates are needed to address 2 years of storage) (DES, 2011). In this particular case, pumping volumes are not an accurate gage of natural inflow volumes to the Pit, because of the contribution from other sources such as pumping from Little Creek Pond as well as some inflow from the Sheep Pad Ponds during freshet in many years.

Groundwater flow is expected to be toward the south/southwest, predominately sourced from the sand and gravel units associated with Vangorda Creek and its associated small tributaries. As the water level in the pit is retained below surrounding groundwater elevations (as it will be for the long term), flow may be received from all directions. During mining, total groundwater discharge to Vangorda Pit averaged between 350,000 m^3/yr from 1992 to 1993 and about 220,000 m^3/yr from 1994 to 1995. Post-mining estimates of discharge to Vangorda Pit from deep groundwater discharge along structural features in bedrock is estimated at less than 100,000 m^3/yr (RGC, 1996).

3.3 Groundwater and Surface Water Interaction

Knowledge of surface water/groundwater interaction is somewhat limited across the site because of the limited number of data available to support the characterization of the nature of stream-aquifer interaction at the site. Ongoing and planned studies are being conducted to determine locations where groundwater discharges to surface water, or where groundwater is replenished by surface water seepage into the subsurface.

3.3.1 Faro Mine Area

Groundwater discharge to the Faro Pit occurs mainly from the natural Old Faro Creek Channel and overburden/bedrock contact, whereas seepage from bedrock is limited except via limited faults and fractures (AECOM, 2009).

Groundwater flow beneath the ETA is expected to discharge in the form of seeps south of the mine road or discharges to the Old Faro Creek channel in the historic Faro Creek Valley upon which the ETA sits or it will travel southwest in the overburden/weathered bedrock unit and flow to the RCAA beneath the RCTA. The horizontal hydraulic gradient in the ETA has been estimated as 0.05 m/m (SRK, 2010b). Old Faro Creek gains significantly along its length, with much of the groundwater contributions to the stream likely occurring between X23 and the mine access road (SRK, 2006).

Before tailings deposition, Rose Creek was flowing in a meandering stream channel in the valley floor. Rose Creek was fed by several smaller streams that drained the hillsides of Rose Creek Valley. The water table of the underlying valley-fill aquifer was very close to the stream level indicating a good hydraulic connection between the stream and the groundwater flowing in the permeable valley sediments. Depending on local conditions, groundwater was either discharging into Rose Creek or was being recharged by the stream (RGC, 1996).

Groundwater levels are elevated beneath the ID Pond and CVD Pond (Polishing Pond) because of vertical leakage from the impoundments. This condition results in the development of significant upward gradients within the alluvial aquifer just downgradient from the CVD and the presence of an associated groundwater

discharge area in that location. One location in the central portion of the valley was observed to have artesian conditions (SRK, 2010b). Groundwater elevation data in the alluvium aquifer downgradient from the CVD indicate groundwater is within 5 m of the ground surface. Groundwater contours also indicate elevated groundwater levels on the south side of the valley in the vicinity of the CVD, suggesting that leakage from the RCD is recharging the aquifer system in this vicinity. Observed stratification of groundwater quality in this area, with higher sulphate concentrations observed in the northern portion of the aquifer and lower concentrations to the south, support the hypothesis that RCD leakage is occurring in this area and providing cleaner diluted water to the southern portion of the aquifer.

Additional field work using streambed piezometers was being completed by CH2M HILL in the fall of 2012 below the CVD and in the summer of 2013 on the NFRC. Preliminary results suggest that the NFRC is gaining upstream and in the vicinity of Zone II Outwash (see Figure 6G-17). In addition, preliminary results also confirmed gaining conditions along Rose Creek downstream from the CVD (see Figure 6G-18). These conditions suggest that subsurface contamination could readily be discharged into the surface water system in these areas.

3.3.2 Vangorda/Grum Area

At the upper end of Vangorda Creek below the Vangorda Pit, limited data suggest groundwater levels are higher than the creek levels in both the overburden and bedrock, indicating a gaining creek (SRK, 2010b). No other field work has been performed to date to be able to estimate the groundwater and surface water interaction in more detail.

3.4 Groundwater Quality

This section describes the current distribution of groundwater contamination. The data will be used to evaluate the areas of highest groundwater contamination and assess the chemical breakthrough of constituents of concern such as zinc and sulphate. Chemical time series plots for selected locations throughout the study area are shown in Attachment 6G-1.

Groundwater quality at the site is changing and evolving as a result of the ongoing geochemical processes within mine-impacted areas. The three main contributors of contaminant load to groundwater are as follows:

- The waste dumps: the Northeast Waste Dump, Northwest Waste Dump, Main Waste Dump, Intermediate Waste Dump (including the infilled Zone II Pit)
- The three open pits: the Faro, Grum, and Vangorda pits (including discrete inputs into the pits--that is, pit walls, seepage interception systems [SIS], and surface runoff)
- Tailings: ETA and RCTA

The following paragraphs present mine-related water contamination information for known impacted areas of the FMC, while the following subsections summarize the current observed chemical loading and contributors to groundwater quality degradation at the various sites of interest.

Metal attenuation can be a result of adsorption to natural organic matter or to secondary oxyhydroxides, or coprecipitation of secondary mineral phases. This attenuation may act to retard the migration of trace metals away from the waste dumps within the shallow groundwater system, especially in the early stages of seep development when pH is near neutral, but zinc and sulphate are elevated. Sulphate is a relatively conservative and abundant constituent that generally is a good indicator for acid rock drainage. Zinc is used as an indicator metal representing several other trace metals that are released during acid rock drainage production because of its more consistently higher concentrations making the analytical measurements and trends more reliable. Given this source material, zinc is the best indicator of trace metal breakthrough from sulphide mineral sources because of its higher concentrations and higher mobility compared to other metals such as cadmium. For the purposes of this discussion, the relative levels of contamination are categorized according to the concentrations listed below for use in illustrating figures and differentiating areas of impact within the text. These categories are based on zinc and sulphate concentrations (and further described in the conceptual site model [CH2M HILL, 2012; AECOM 2009]):

- Not impacted or minimally impacted: sulphate ≤ 40 milligrams per litre (mg/L) and zinc ≤ 0.05 mg/L.
- Slightly impacted: sulphate > 40 mg/L and ≤ 400 mg/L or zinc > 0.05 mg/L and ≤ 0.5 mg/L.
- Moderately impacted: sulphate > 400 mg/L and ≤ 4,000 mg/L or zinc > 0.5 mg/L and ≤ 5 mg/L. This corresponds to sulphate and zinc concentrations one order of magnitude greater than the "slightly impacted" range.
- Highly impacted: sulphate > 4,000 mg/L or zinc > 5 mg/L. This corresponds to sulphate and zinc concentrations one order of magnitude greater than the "moderately impacted" range.

In general, spring samples collected during the influence of freshet tend to show lower concentrations, except in years when the freshet comes too late or too early relative to the sampling event. By contrast, samples collected in summer and fall tend to show the highest concentrations.

3.4.1 Faro Mine Area

Groundwater quality for the Faro Mine Area is described for each major area of interest in the following subsections. Figures 6G-19 and 6G-20 show the overall water quality effects at the Faro Mine Area for alluvial wells and bedrock wells, respectively.

3.4.1.1 Faro Pit

Faro Pit water quality is highly impacted with moderate sulphate concentrations (less than 1,000 mg/L) and high zinc concentrations (above 5 mg/L) for data reviewed between 1998 and 2012 (DES, 2012b). Contaminated water from the S-Wells SIS and from the Zone II Pit are currently pumped to Faro Pit. Seep water flowing to Faro Pit (discharging from the Faro Waste Dump) ranges in water quality from not impacted to highly impacted, as shown in Figure 6G-21. Sulphate levels in Faro Pit water have remained steady while zinc concentrations have steadily increased over the last decade (see Attachment 6G-1). The most current field sampling results show that seepage from the Main Waste Dump at X23 continues to deteriorate as sulphate, manganese, and dissolved metals concentrations increased and seepage became more acidic (RGC, 2013).

3.4.1.2 North Fork of Rose Creek

The North Fork of Rose Creek Valley is a typical alluvium-filled fluvial valley that runs along the southeastern margin of the FMC. The Faro Creek diversion discharges Faro Creek flows into the NFRC just upstream from the Northeast Waste Dump From this point, the creeks flows to the southwest at the base of the Northeast and Intermediate Waste Dumps and flows beneath the Haul Road through the North Fork Rock Drain. The creek then continues past the S-Wells area, eventually joining the South Fork of Rose Creek before entering the RCD. The two most extensively studied areas with the NFRC Valley are the Zone II Outwash area and the S-Wells area. Numerous wells have been installed in both locations to characterize the alluvial thickness, depth to bedrock, groundwater flow patterns, and groundwater quality. Wells also exist in other areas of the valley, usually in close proximity to the NFRC. Groundwater quality has been substantially impacted in both the Zone II Outwash and S-Wells areas because of subsurface migration of mine-affected water from waste dumps in the Zone II Pit area and from the Intermediate Waste Dump, respectively. Field investigations conducted in 2013 suggest that the NFRC is a gaining stream along the majority of its length between its confluence with the Faro Creek Diversion and the North Fork Rock Drain. These conditions suggest that groundwater contamination in the vicinity of the stream represent a viable pathway for contaminants of concern to enter the stream system and degrade surface water quality. To address this concern, a seepage interception system has been installed at the S-Wells site that consists of a shallow permeable trench and a series of deeper weathered bedrock extraction wells. Recent groundwater quality data also indicate that sulphate and zinc concentrations are increasing in groundwater at the base of the Northeast Waste Dump, suggesting that this area may also represent a conduit for metals loading to the NFRC.

Zone II Pit and Outwash Area

Groundwater flows from the waste dumps west of the Zone II Outwash area. Groundwater in the waste-rock-filled Zone II Pit is managed (pumped) to mitigate potential seepage from the pit to the Zone II Outwash area. As

discussed above, groundwater contamination in the vicinity of the Zone II area may travel along two potential pathways: groundwater contamination could discharge to NFRC, in which case it would likely bypass the RCAA through the RCD, or it may travel as subsurface underflow, resulting in continued loading to the RCAA. Leakage from the NFRC or RCD to the RCAA might also represent a possible pathway for contaminant loading to the groundwater system.

Water in the Zone II Pit (well X26) is highly impacted. Sulphate concentrations have been more variable than zinc concentrations since 2008, however, both sulphate and zinc concentrations within the pit continue to increase. Zinc and sulphate loads collected from the Zone II Pit were 5.8 tonnes per year (tpy) and 184 tpy, respectively, in 2011. Between July and September 2012, loads collected from the pit were approximately 3 tpy of zinc and 134 tpy of sulphate. Contaminant concentrations at X26 tend to be lower in the spring when meteoric water inputs are greater. Several seeps are present in the vicinity of the Zone II Pit on the Faro Pit side of the waste dump, but no seeps locations are noted at the toe of the waste dump in the immediate vicinity of the Zone II Outwash. There are seeps observed both downgradient and upgradient from the Zone II Outwash areas (RGC, 2012).

The Zone II Outwash area surface water and groundwater monitoring locations are shown on Figures 6G-22 and 6G-23. In the alluvial aquifer, two wells are highly impacted, five wells are moderately impacted, one well is slightly impacted, and one well is not impacted. In the bedrock aquifer, four out of five monitored wells are moderately impacted and one is highly impacted. Most groundwater both in the shallow and bedrock aquifers in the Zone II Outwash is moderately impacted, with some highly impacted groundwater near the toe of the waste dump (locations BH2, BH6, and BH8). Concentrations have generally remained stable or show gradual increasing trends in Zone II Outwash wells over the monitoring period (see Attachment 6G-1). Monitoring wells to the north of Zone II Outwash have had substantial mine-related contamination increases in recent years. The *2012 Groundwater Quality Review* (RGC, 2013) suggests that the breakthrough of more highly contaminated groundwater might occur in this area from the toe of the Intermediate Waste Dump to the west.

S-Wells Area

Contaminated groundwater daylights both as seeps along the Intermediate Waste Dump face to the north of the S-Wells area and also flows south toward NFRC within alluvial, weathered bedrock, and bedrock aquifers. Groundwater contamination in this area discharges to NFRC and could contribute loading to the RCAA as leakage from the NFRC or RCD. The 2008 S-Cluster groundwater investigation (SRK, 2009) concluded “the plume of contaminated groundwater [in the S-Wells area] is likely moving underneath the NFRC in permeable materials and discharging to the NFRC at indeterminate locations.” The S-Wells groundwater monitoring locations are shown on Figures 6G-24 and 6G-25.

In general, groundwater in the S-Wells area is moderately to highly impacted, with some slightly impacted alluvial and overburden locations on the far eastern portion of the site. The shallow groundwater system generally has the highest contamination, with 11 out of 21 wells classified as highly impacted (and 8 wells classified as moderately impacted). Groundwater contamination does extend into the bedrock as well, with highly impacted groundwater detected in one bedrock well (SRK-08-SPW2) and moderately impacted groundwater detected in the remaining bedrock wells (RGC, 2012).

An SIS was constructed in 2009 to intercept contaminated groundwater flowing from the Intermediate Waste Dump before it reached NFRC. It consists of three parts (RGC, 2012):

- A shallow rock-filled interceptor trench located in the shallow aquifer (overburden) with one pumping well (SRK08-PW3).
- Two pumping wells (SRK08-SPW1 and SRK08-SPW2) screened in the deeper bedrock aquifer. Only one well typically operates because the other well contains high iron concentrations.
- Surface water interception via a rock drain at the toe of the Intermediate Waste Dump. Water is diverted to the shallow aquifer interceptor trench.

S-Wells SIS water is pumped to the Faro Pit and currently operates year-round (RGC, 2012). Zinc and sulphate loads in 2011 captured by the S-Wells SIS were 21.3 tpy and 300 tpy, respectively. Between May 2012 and December 2012, 17.8 tonnes of zinc and 272.5 tonnes of sulphate were captured at the S-Wells SIS.

Groundwater quality in wells classified as slightly to moderately impacted have relatively stable concentration trends. However, some wells along the southern toe of the Intermediate Waste Dump continue to deteriorate gradually (SRK05-SP1A/B and SRK05-SP2). Groundwater quality in the till unit, located to the west of the SIS, also continues to degrade (this water is not captured by the SIS). Groundwater quality in the bedrock aquifer is improving overall as a result of pumping the S-Wells SIS bedrock wells (see Attachment 6G-1). However, operation of the shallow aquifer interceptor trench of the S-Wells SIS has not made a noticeable impact on shallow groundwater quality (RGC, 2012).

Northeast Rock Dumps Area

The Northeast Rock Dumps are located to the northeast of the Zone II Pit and southeast of the Faro Pit and cover an area of about 0.51 km^2, with a maximum elevation of 1,290 masl. The “near pit” dumps are located immediately to the south and southwest of the pit, just north of the Main and Intermediate Dumps, and cover an area of 0.2 km^2, with a maximum elevation of 1,200 masl (RGC, 1996). Groundwater quality at areas in the vicinity of the Northeast Waste Dumps can be summarized as follows:

- Areas downgradient from the Northeast Waste Dump: Three well pairs (BH12A/B, BH13A/B, and BH14A/B) are located at the toe of the Northeast Waste Dump and are screened mainly in weathered bedrock and deeper bedrock (Figure 6G-26). Groundwater conditions in this area have worsened substantially over the last 10 years (see Attachment 6G-1), and zinc concentrations up to about 10 mg/L have been detected at the well pair closest to Zone II (BH14A/B; highly impacted). The well pairs located farther northeast have moderate groundwater effects. Mine-related contamination is expected to increase in this area and additional investigation is required to evaluate the extent of contamination (RGC, 2012).
- NFRC upgradient from Northeast Waste Dump: Three wells are located near NFRC upgradient from Northeast Waste Dump (P09-UN1 through P09-UN3) and are screened in alluvial sediments or weathered bedrock (Figure 6G-27). The area is characterized by sulphate concentrations less than 200 mg/L and zinc concentrations up to 1 mg/L. The moderate contamination effects shown in this area are a result of mine-impacted groundwater flow from the Northeast Waste Dump (RGC, 2012).

3.4.1.3 Emergency Tailings Area

The ETA has some of the highest contaminated groundwater and surface water in the Faro Mine Area and represents a major source of contaminant loading to the RCAA (AECOM, 2009). The ETA seep, surface water, and groundwater monitoring locations are shown on Figures 6G-28 and 6G-29. The *Anvil Range Mining Complex 2005 Seepage Investigation at the Emergency Tailings Area* (SRK, 2006) concluded that a significant contaminant load discharged to the Faro Creek Canyon and Rose Creek Valley from the ETA. Flow monitoring and sampling completed in 2005 and 2006 along Faro Creek below the ETA indicated that the total zinc load discharged from the ETA (surface flow and subsurface seepage discharging downstream from the mine access road) ranged from about 35 to 80 tpy (RGC, 2007). The contaminated seepage is a combination of surface flow originating as toe seepage from the Main Waste Dump and groundwater flow from the waste dump through highly permeable alluvial sediments from the Old Faro Creek. The ETA tailings also contribute significantly to the groundwater and surface water contaminant loading (SRK, 2006). Seeps discharging to the ETA at the base of the Main Waste Dump, which form flowing surface water across the ETA in Old Faro Creek and Mill Canyon Creek, are highly impacted and show increasing contaminant load trends as evidenced by the water quality at X23 (Figure 6G-28).

Surface water and groundwater quality in the ETA have increasing trends for acidity, sulphate, and zinc, and this trend is expected to continue (see Attachment 6G-1). Seepage from the Main Waste Dump has become noticeably more acidic over the last 3 years, suggesting ongoing ”breakthrough” of ARD products and a decline in the buffering capacity of the Main Waste Dump waste rock and ETA alluvial soils (RGC, 2012). Groundwater seepage from the ETA expresses downgradient from the mine access road. In 2006, an interim SIS was constructed at the southeast end of the ETA (just downgradient from the mine access road) to collect surface

water runoff and seepage (from two prominent seeps). The SIS operates during the ice-free seasons, and collected water is pumped to the Faro Water Treatment Plant or the Faro Pit. The ETA SIS intercepted an estimated 31.2 tpy of zinc and 488 tpy of sulphate in 2011 and an estimated 86 tpy of zinc and 940 tpy of sulphate in 2012. Seepage not intercepted by the SIS was observed discharging directly to the Faro Creek Canyon. Overburden and weathered bedrock groundwater quality and surface water quality downstream from the ETA is highly impacted (locations P09-ETA2 and FCS-4), and the seasonal operation of the ETA SIS does not appear to be improving this condition. However, groundwater in deep bedrock downgradient of the ETA does not show indications of mine-related contamination based on data from monitoring well P09-ETA1 (RGC, 2012).

Background groundwater quality concentrations can be estimated from wells located far away from the waste rock dumps and with unimpacted water quality conditions. Based on a review of available groundwater quality data, well TH86-17 appears to be an accurate indicator of background groundwater quality (Figure 6G-27). This well is located in the alluvial aquifer upstream from the RCTA. Sulfate concentrations at this well have been stable between 10 and 20 mg/L for the last decade. Zinc concentrations have been consistently below 0.02 mg/L, sodium concentrations below 5 mg/L, and pH has been neutral.

3.4.2 Rose Creek Tailings Area

Generally, low metals bearing groundwater from the south and southeast flows to the RCTA, and Faro-Mine-contaminated groundwater flows to the RCTA from the north, with a significant portion of contamination associated with the Faro Creek Canyon. Locally, the tailings contribute to groundwater contamination in the RCTA as well. The extensive leakage of clean water from the RCD (south of the RCTA) has a major influence on the spatial water quality trends in the RCAA, especially further downgradient near the CVD. There is a significant spatial trend from south to north of not impacted groundwater transitioning to moderately impacted groundwater in the western half of the RCTA. This section provides summary information on the water contamination in the RCTA.

3.4.2.1 Impoundments

Groundwater in the Original and Second Impoundment area ranges from not impacted to highly impacted, with the highest sulphate and zinc concentrations in the tailings. Higher concentrations are generally observed in groundwater in the northern portion of the RCAA likely because of contaminant discharges from the Faro Creek Canyon. The Original and Second Impoundment groundwater monitoring locations are shown on Figure 6G-30. The upper portions of the underlying alluvial aquifer are highly-impacted. The highest sulphate and zinc concentrations are detected in tailings porewater in the southeastern (multilevel wells P03-01 and P03-03) and northwestern (multilevel well P03-06) areas of the Second Impoundment. Zinc concentrations tend to be highest near the interface of the sand and gravel RCAA and the overlying tailings. Groundwater contamination in the far southeast section of the impoundment areas is thought to be mainly a result of direct tailings-related contamination (RGC, 2012).

There are continued increases in contamination in the alluvial aquifer near the mouth of Faro Creek Canyon (multilevel well P03-06), which is a primary flow path for contamination from the Faro Mine Area to the RCTA (see Attachment 6G-1). The increased contamination near well P03-06 may also be a result of either increased waste dump- and ETA-related contamination or seepage from the coarse tailings beach of the Original Impoundment (Figure 6G-30). Contamination in the alluvial aquifer is also increasing within the central portion of the Second Impoundment. The increase in contamination may indicate that the neutralizing capacity of the aquifer is being exhausted in this area (AECOM, 2009).

Groundwater in the Intermediate Impoundment area ranges from not impacted to highly impacted as well, with the highest sulphate and zinc concentrations in the tailings. Sulphate and zinc concentrations are very high in shallow tailings porewater and have been relatively stable for the last 10 years. In contrast, alkalinity and pH have decreased substantially since 2009, indicating a breakthrough of the acid front in the Intermediate Impoundment area. Concentrations in the RCAA are gradually increasing in the Intermediate Impoundment, and seepage from the coarse tailings beach of the Second Impoundment and input from the Faro Creek Canyon are

likely sources. Concentrations are expected to increase until they are similar to conditions observed in the Second Impoundment (RGC, 2012).

3.4.2.2 Toe of Intermediate Dam

Groundwater in the RCAA at the toe of the ID is moderately impacted in the alluvium and till, as shown in Figure 6G-31. Concentrations of mine-related contaminants have generally increased since 2001 in this area, and seepage from the coarse tailings beaches of the upgradient impoundments and input from the Faro Creek Canyon are likely sources. Conditions are expected to deteriorate in the coming years as the groundwater contamination front in the RCTA progresses. Groundwater in the southern portion of the area is generally less contaminated than in the northern portion because of the inflow of clean groundwater leaking from the RCD to the south. However, concentrations in this area do show a significant increasing trend for sulphate, iron, magnesium, and manganese. It is believed that the mine-related total dissolved solids (TDS) plume front has reached this area (RGC, 2012).

3.4.2.3 Toe of Cross Valley Dam

Groundwater in the RCAA on the southern edge of the Rose Creek Valley, downgradient from the CVD, remains only slightly impacted by mine-related groundwater contamination, as shown on Figure 6G-31. Contamination concentrations increase from south to north at the toe of the CVD, as expected based on clean water inputs from the RCD. Groundwater contamination in the northern area has higher sulphate and magnesium concentrations, indicative of the leading edge of the TDS plume. Concentrations of sulphate and metals are gradually increasing in shallow groundwater along the north side of the valley downgradient of the CVD, but zinc concentrations remain low (less than 0.05 mg/L) (RGC, 2012) (see Attachment 6G-1). Groundwater in bedrock at the toe of the CVD follows similar trends from south to north across the valley, as shown in Figure 6G-32. Bedrock groundwater in the north portion of the valley (P09-C1) is moderately impacted because of elevated sulphate and zinc concentrations. However, in the central portion of the valley (well P09-C2), bedrock groundwater is not impacted (RGC, 2012).

Groundwater farther downgradient from the CVD (wells X16A/B) are not impacted. However, the well pair upgradient from this location (X17A/B) has had increases in mine-related contamination since 2008, which is likely to continue. This water is now within the slightly impacted range, indicating continued movement of the leading edge of the TDS plume front down the valley (RGC, 2012). The deeper Well X17B exhibits distinct seasonal variations with highest concentrations observed in the spring. This may be because of upwelling of deep groundwater from underlying bedrock, or might indicate that tailings impacted groundwater is flowing beneath the CVD (AECOM, 2009).

3.4.3 Vangorda/Grum Area

Most groundwater monitoring locations in the Vangorda/Grum Area are between the toes of the waste dumps and Vangorda Creek, as shown in Figures 6G-33 and 6G-34. In general, the Vangorda/Grum Area is characterized by low-permeability materials with some higher permeability alluvial material associated with current and former stream channels. Therefore, seepage from waste dumps is expected to follow preferential flow paths.

3.4.3.1 Grum Pit and Waste Rock

Wells installed in the overburden and bedrock south of the Grum Pit suggest hydraulic containment of the pit lake because water levels in both wells were similar to the water level in Grum Slot, an area of standing water south of the pit (SRK, 2010b). The Thalweg aquifer appears to be hydraulically connected to the standing water in the Grum Slot (RGC, 1996).

Grum Pit is expected to be a groundwater sink (groundwater flows to the pit) and is not considered a source of contamination to the Vangorda Creek drainage as long as the water is kept contained. The pit water quality is considered highly impacted, based on elevated zinc concentrations. One well pair is located on Grum Waste Dump (P09-GS1A/B), as shown on Figures 6G-33 and 6G-34. Groundwater quality in the overburden is classified as highly impacted (based on zinc concentrations), and groundwater in the underlying bedrock is classified as moderately impacted in this area (based on sulphate concentrations). The high zinc concentrations in the

overburden may be related to in situ leaching of mineralized waste rock in the area, but contamination may be influenced by seepage from the Grum Waste Dump (RGC, 2012).

At the southeast and western toes of the Grum Waste Dump and within Grum Creek, seep and shallow groundwater data indicate slight to moderate effects on groundwater quality from the Grum Waste Dump and seepage from Moose Pond. Groundwater quality appears to be greatly influenced by recharge events. The sulphate and other TDS plume parameters have migrated into the Vangorda Creek Valley and do extend beyond specific drainage channels, but zinc concentrations are still low in the area (typically less than 0.05 mg/L) (RGC, 2012).

Weathered bedrock and bedrock at the toe of the Grum Waste Dump generally have slightly impacted groundwater with less sulphate than the overburden (RGC, 2012).

According to RGC's 2012 Groundwater Quality Review (2013), groundwater quality in the shallow overburden soils to the south, southwest, and west of the Grum Waste Dump continues to gradually deteriorate (see Attachment 6G-1). Currently, contamination is limited to conservatively transported species, such as sulphate and manganese, and deeper groundwater near the bedrock-overburden interface in this area is still unimpacted by waste rock seepage. Concentrations are typically lowest during the spring freshet (May) and highest during the summer months.

3.4.3.2 Vangorda Pit and Waste Rock

Vangorda Pit is expected to be a groundwater sink and is not considered a source of contamination to the Vangorda Creek drainage if the pit is maintained at or below its current water level (RGC, 2012). The pit water quality is highly impacted based on elevated zinc concentrations. Sulphate and zinc concentrations at the surface of Vangorda Pit have been steadily increasing since 2000.

Groundwater in monitoring wells and seep collection wells located both within the Vangorda Waste Dump and at the toe of the waste dump is generally moderately to highly impact. Sulphate and TDS constituents in shallow groundwater downgradient of the Vangorda Waste Dump have been increasing, even in areas downgradient of the till berms installed in the waste dump to reduce seepage, while zinc generally remains low (less than 0.12 mg/L). The highest zinc concentrations are detected in more permeable alluvial sediments (associated with preferential flow paths) and have recently increased near the northwestern toe of the Vangorda Waste Dump (RGC 2013).

Little Creek Pond, located northwest of the Vangorda Waste Dump on Little Creek, holds water from the Vangorda Waste Dump seepage collection system, which is pumped to Vangorda Pit. Seepage from Little Creek Dam, where Vangorda Waste Dump seepage is collected, appears to have slight effects on downgradient water quality toward Vangorda Creek (RGC, 2012). The sulphate and zinc concentrations of surface water in Little Creek Dam have steadily increased since 2004 (see Attachment 6G-1). However, the alluvial aquifer and bedrock wells in the vicinity of Little Creek Pond are considered slightly impacted with neutral pH (see Figures 6G-33 and 6G-34).

Weathered bedrock and bedrock at the toe of the Vangorda Waste Dump have slightly impacted groundwater with less sulphate than detected in the overburden (RGC, 2012).

SECTION 4

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Figures

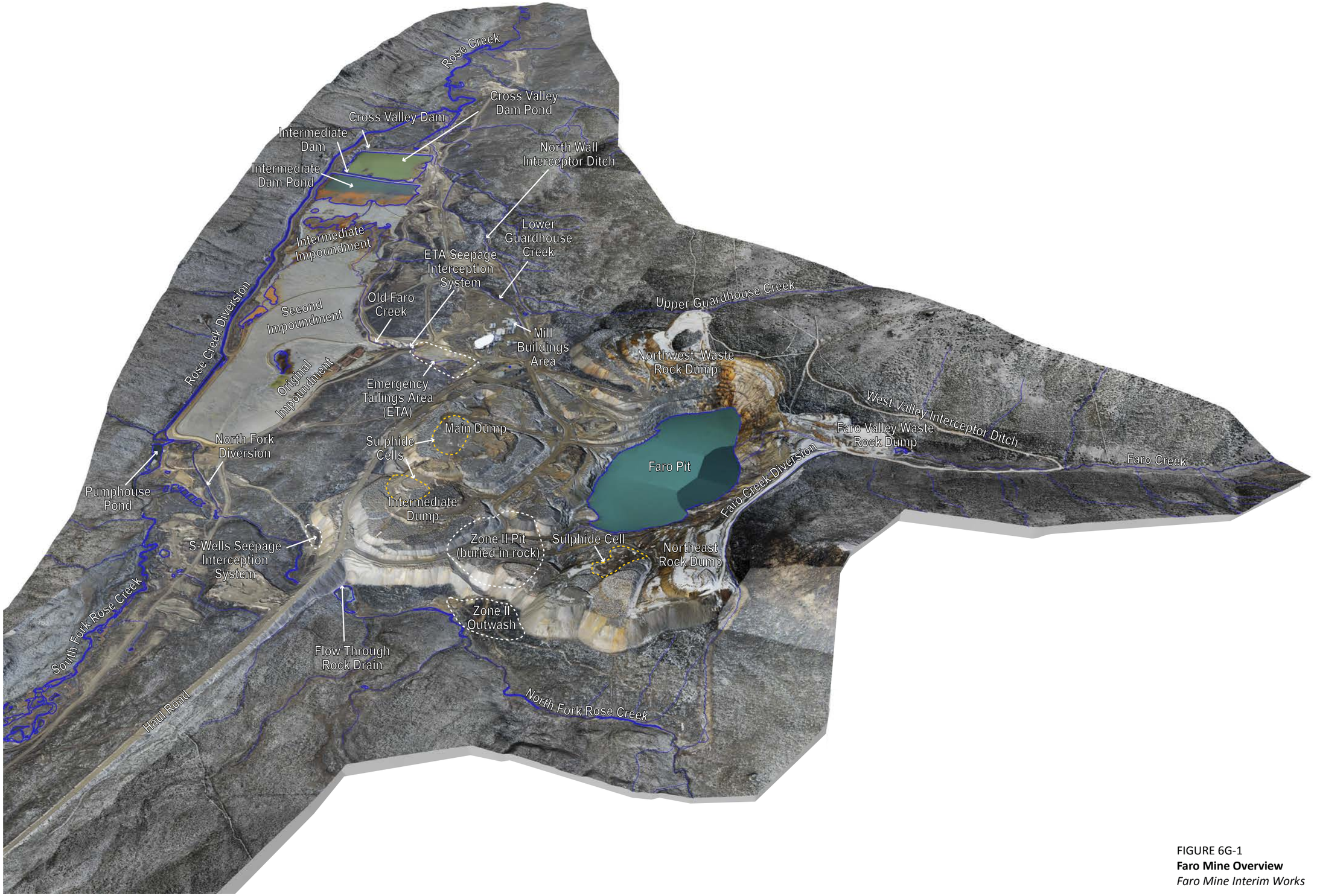

FIGURE 6G-1
Faro Mine Overview
Faro Mine Interim Works

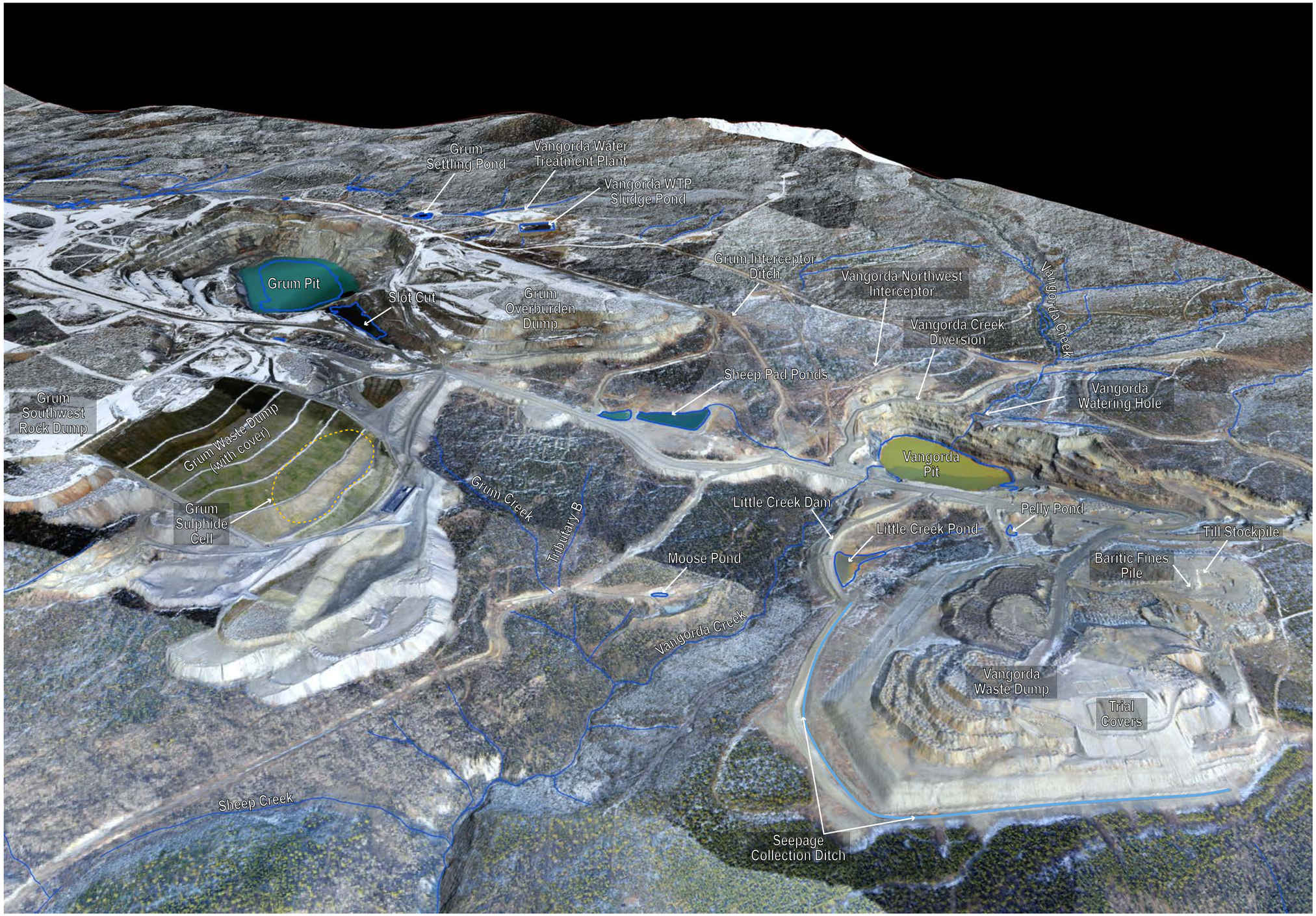

FIGURE 6G-2
Vangorda/Grum Area Overview
Faro Mine Interim Works



VICINITY MAP



LEGEND

- Roads Unpaved
- Groundwater Flow Modelling Boundary

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

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0 900 1,800 2,700 3,600

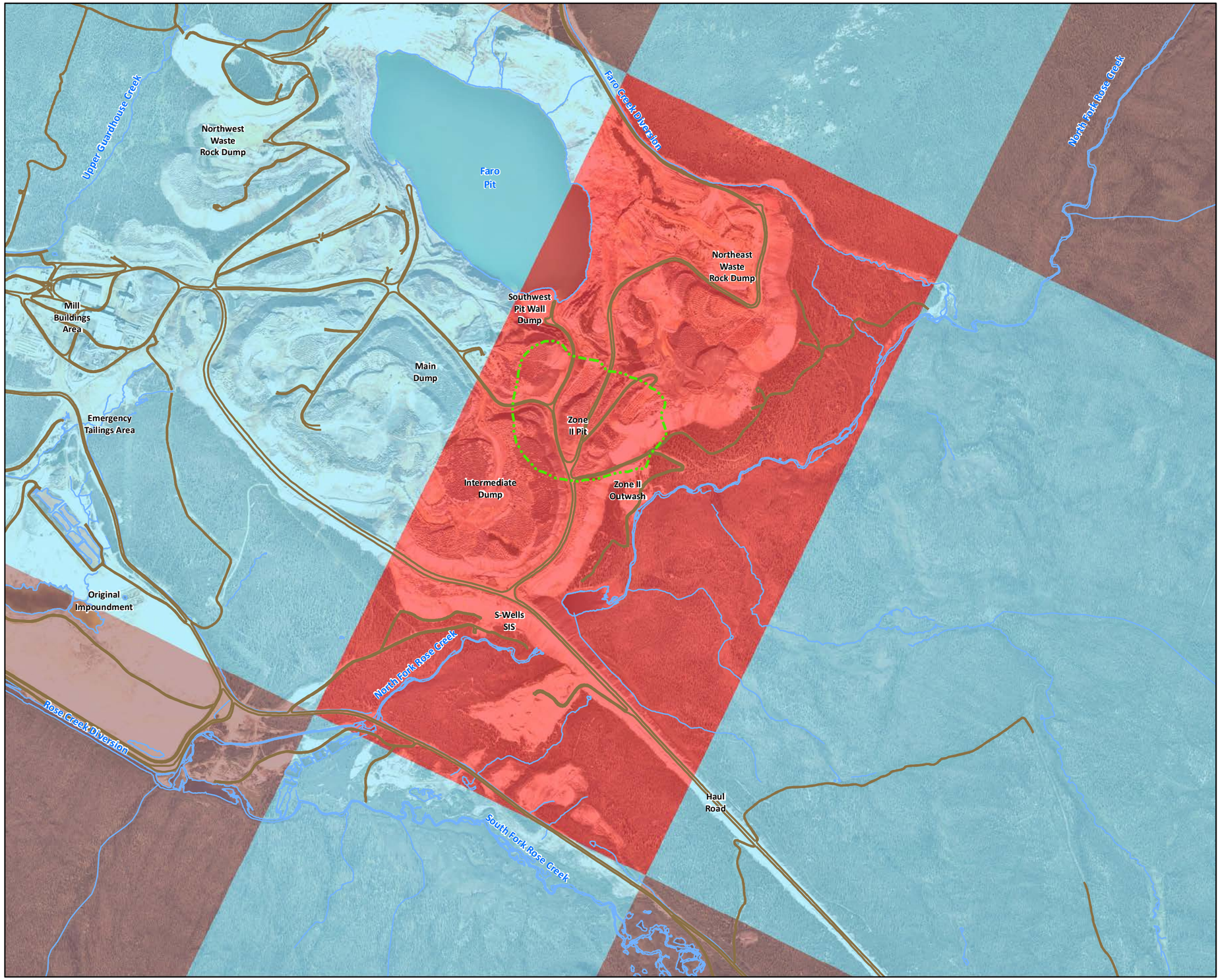
Metres

Created by: CRITIGEN

FIGURE 6G-3

Active Groundwater Flow Modelling Domain within the Rose Creek Drainage Basin

Faro Mine Interim Works



VICINITY MAP



LEGEND

- Roads Unpaved
- Approximate Zone 2 Pit Outline

Model Grid Spacing Zone

- Region of 10×10 m Cells
- Region of Transition Cells
- Region of 100×100 m Cells

Notes:

1. Profile views of the model grid along A-A' and B-B' are provided on Figure 3-8, whereas those along C-C' and D-D' are provided on Figure 3-9.
2. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
3. Orthophotography prepared by Critigen Canada Corp.

N

0 175 350 525 700

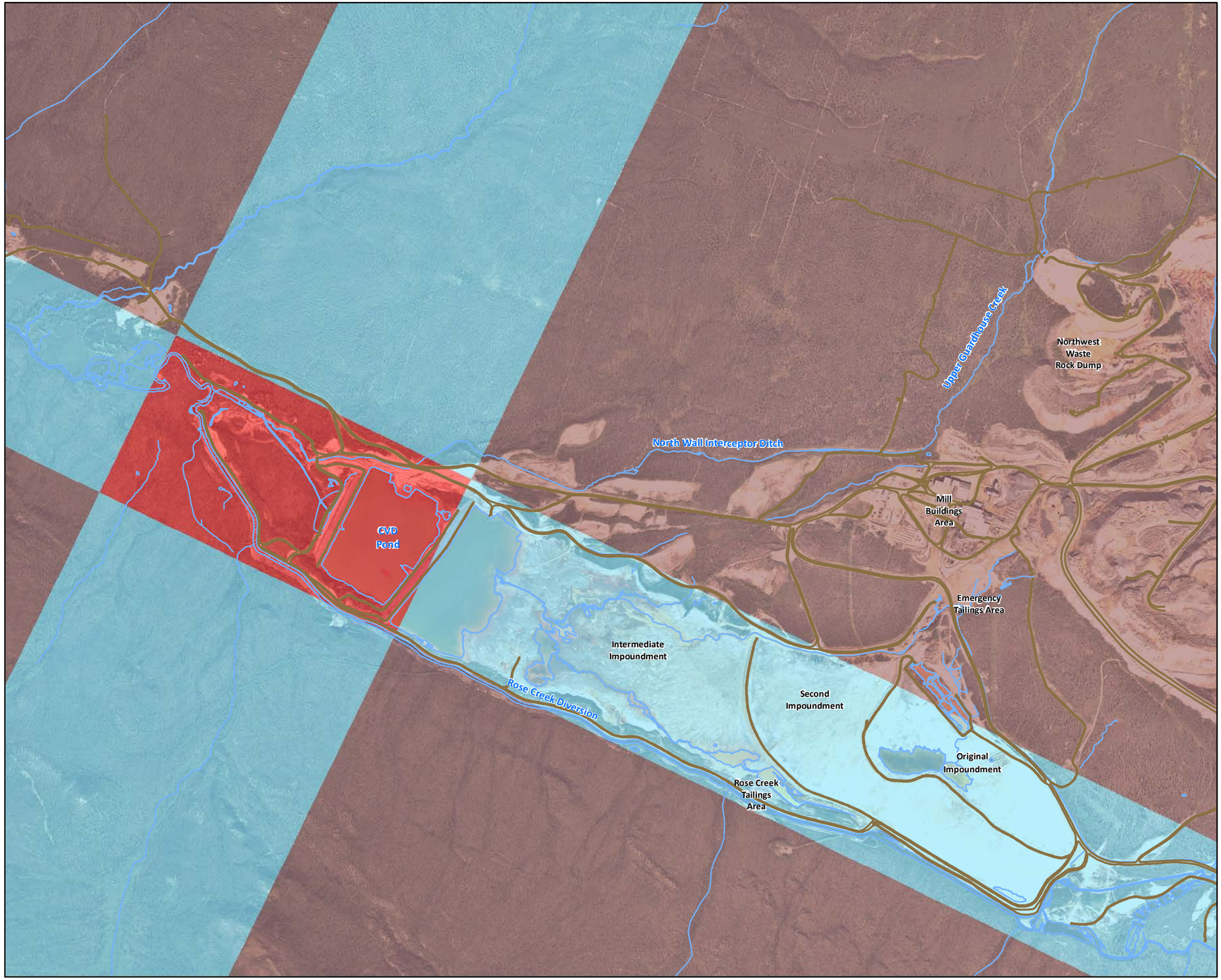
Metres

Created by: CRITIGEN

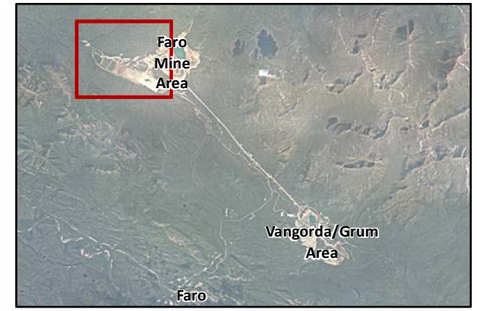
FIGURE 6G-4

Active Groundwater Flow Model Grid Spacing in the NFRC Subarea: Areal View

Faro Mine Interim Works



VICINITY MAP



LEGEND

Roads Unpaved

Model Grid Spacing Zone

Region of 10×10 m Cells

Region of Transition Cells

Region of 100×100 m Cells

Notes:
1. Profile views of the model grid along E-E', F-F', and G-G' are provided on Figure 3-10.
2. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
3. Orthophotography prepared by Critigen Canada Corp.

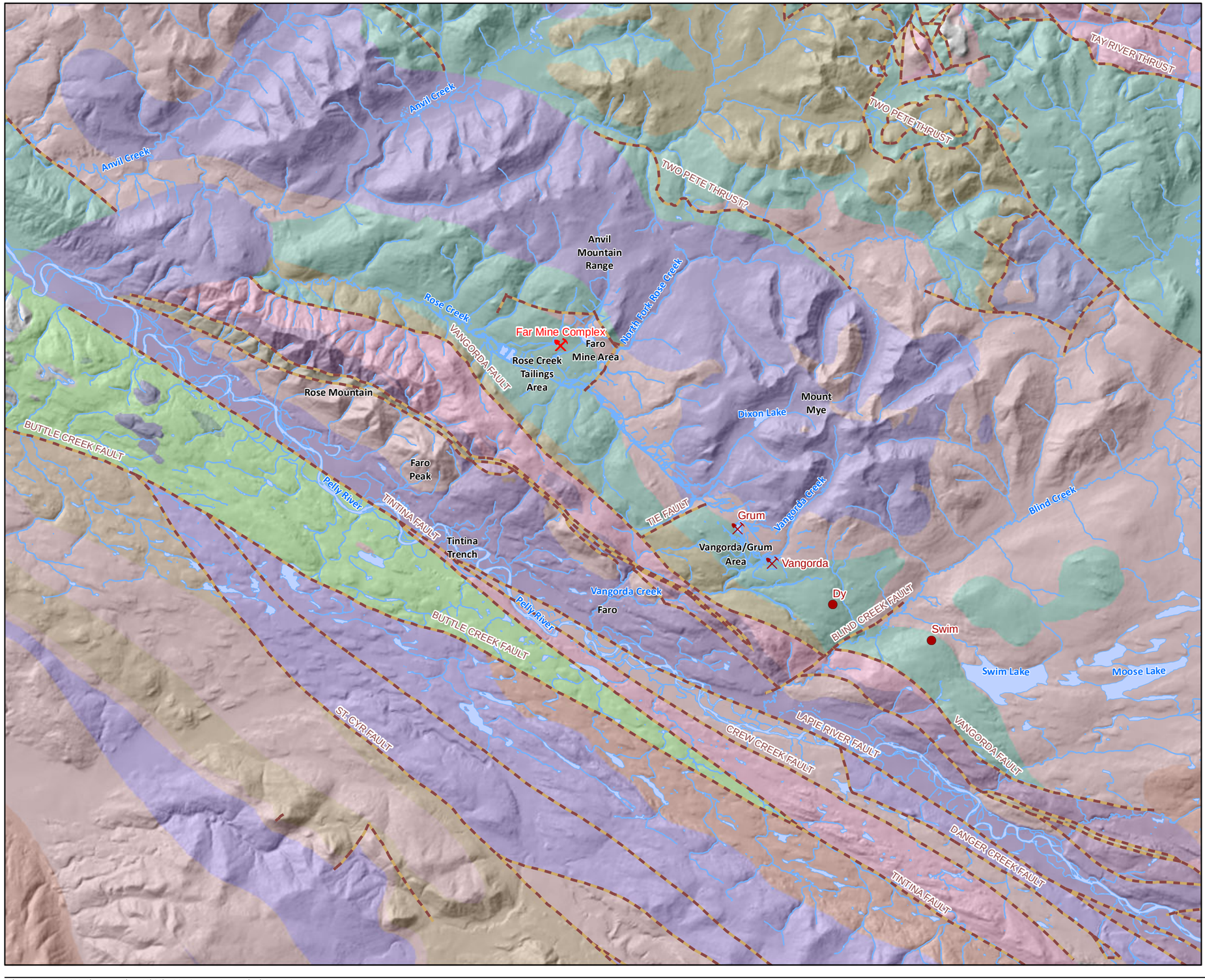
N

0 175 350 525 700

Metres

Created by:
CRITIGEN

FIGURE 6G-5
Active Groundwater Flow Model Grid Spacing in the RCAA Subarea: Areal View
Faro Mine Interim Works



VICINITY MAP



LEGEND

- Faro Mine Complex
- Dy and Swim Deposit
- Vangorda/Grum Area
- Fault Line

Yukon Bedrock Geology

- chert
- clastic
- clastic/chert
- clastic/chert/limestone
- clastic/dolostone
- clastic/limestone
- clastic/limestone/dolostone
- clastic/v_mafic/v_felsic
- felsic
- limestone/dolostone
- mafic
- mclastic
- mv_mafic
- p_felsic
- p_interm
- p_ultram
- v_mafic
- v_mafic/p_ultram/clastic/chert/limestone
- v_mafic/v_felsic

Notes:

1. Yukon Geology Source: GSC, 1999.
2. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
3. Orthophotography prepared by Critigen Canada Corp.

N

0 2 4 6 8

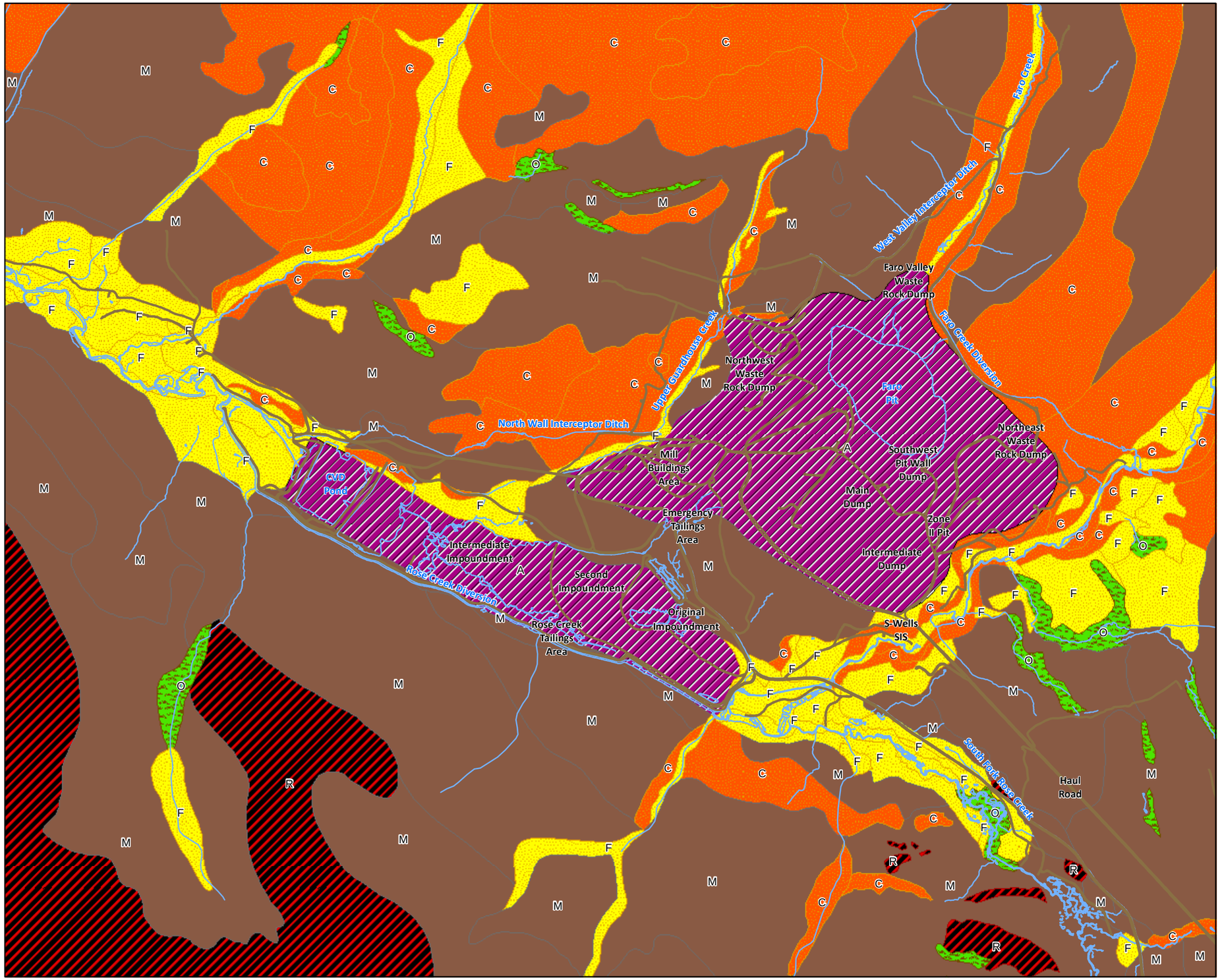
Kilometres

Created by: CRITIGEN

FIGURE 6G-6

Faro Mine Complex Bedrock Geology

Faro Mine Interim Works



VICINITY MAP



LEGEND

Surficial Material

- Anthropogenic (A)
- Colluvium (C)
- Fluvial (F)
- Lacustrine (L)
- Morainal/Till (M)
- Organics (O)
- Bedrock (R)

Note:
Surficial Geology Source
http://ygsftp.gov.yk.ca/standardized_geodatabases_ArcGIS_9

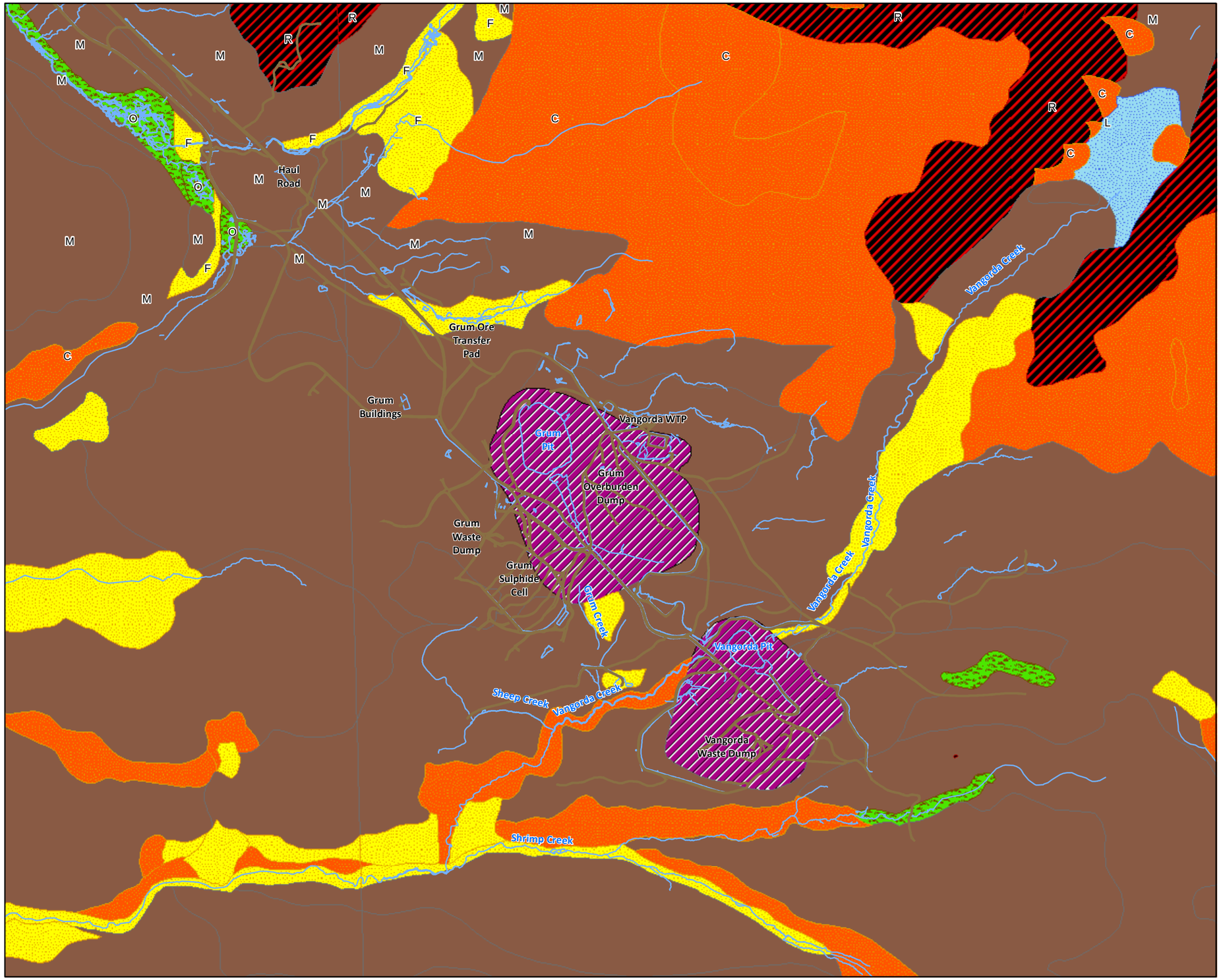
N

0 300 600 900 1,200
Metres

Created by:
CRITIGEN

FIGURE 6G-7
Surficial Geology in the Faro Mine Area
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Surficial Material

- Anthropogenic (A)
- Colluvium (C)
- Fluvial (F)
- Lacustrine (L)
- Morainal/Till (M)
- Organics (O)
- Bedrock (R)

Note:
Surficial Geology Source
http://ygsftp.gov.yk.ca/standardized_geodatabases_ArcGIS_9

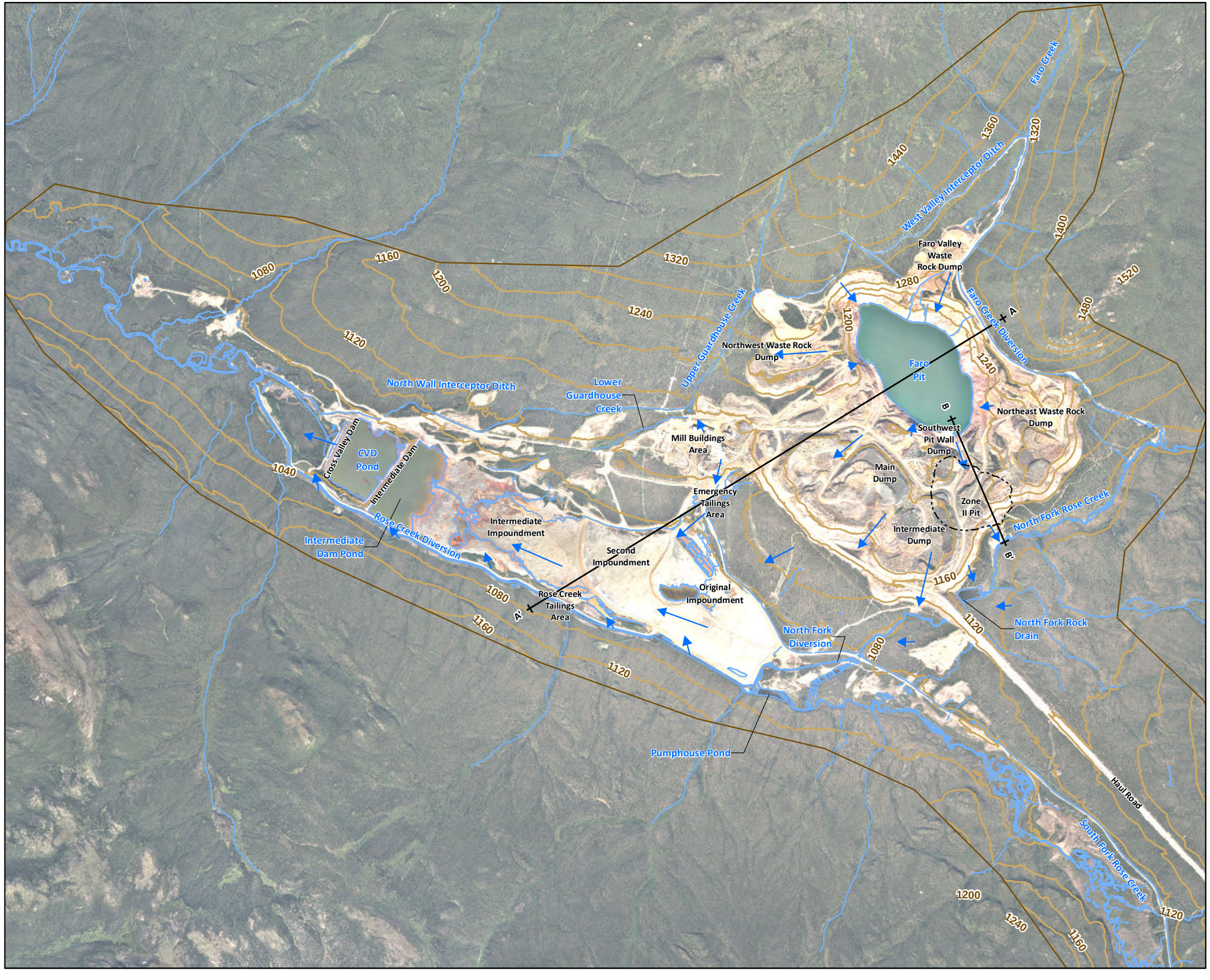
N

0 300 600 900 1,200
Metres

Created by:
CRITIGEN

FIGURE 6G-8
Surficial Geology in the Vangorda/Grum Area
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

- Cross Section Location
- Generalized Groundwater Flow Direction

2011 Topography

- Index Contour (40m Interval)
- Index Depression Contour (40m Interval)

N

0 700 1,400

Metres

Created by:

CRITIGEN

FIGURE 6G-9

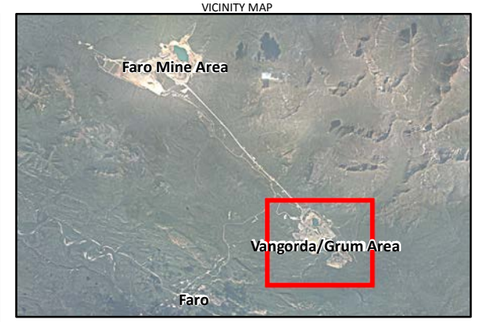
Faro Mine Cross Section Locations and Generalized Groundwater Flow

Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

- Cross Section Location
- Generalized Groundwater Flow Direction

2011 Topography

- Index Contour (40m Interval)
- Index Depression Contour (40m Interval)

N

0 500 1,000

Metres

Created by:
CRITIGEN

FIGURE 6G-10
Vangorda/Grum Cross Section Location and Generalized Groundwater Flow
Faro Mine Interim Works

CH2MHILL

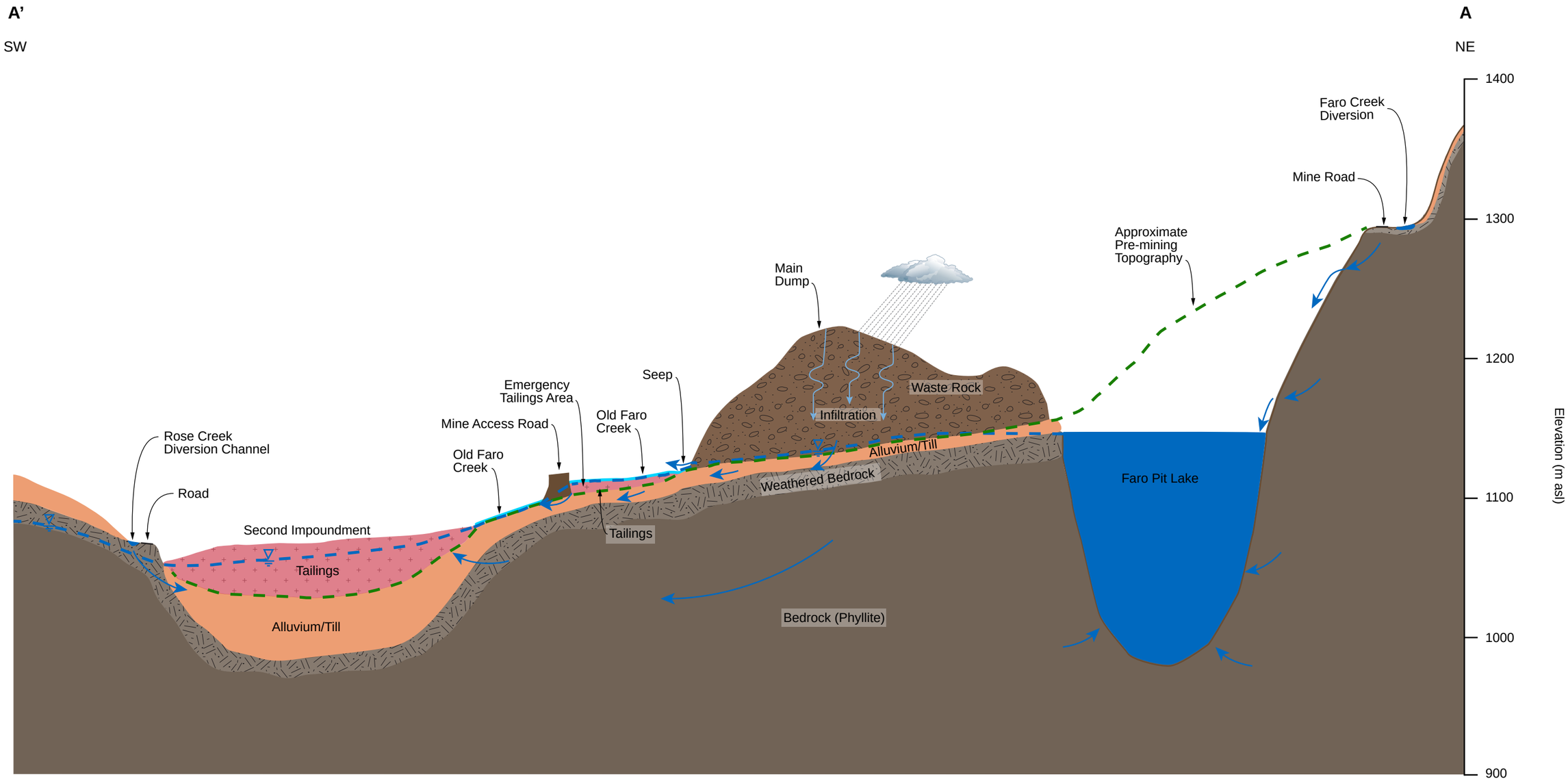


FIGURE 6G-11
Schematic Cross Section from Faro Pit to Rose Creek Tailings
Faro Mine Interim Works

B’

SE

B

NW

Zone 2 Pit (backfilled with waste rock)

Approximate
Pre-mining
Topography

CH12-Z2-PW01

X26

Waste Rock

North Fork
Rose Creek

Alluvium/Till

Weathered Bedrock

Approximate Pit Surface
Prior to Backfilling

(When Zone 2
Pit Pumping Well
Operates)

Bedrock (Phyllite)

Faro Pit Lake

1400

1300

1200

1100

1000

900

Elevation (m asl)

LEGEND

Water Table

Generalized Groundwater
Flow Direction

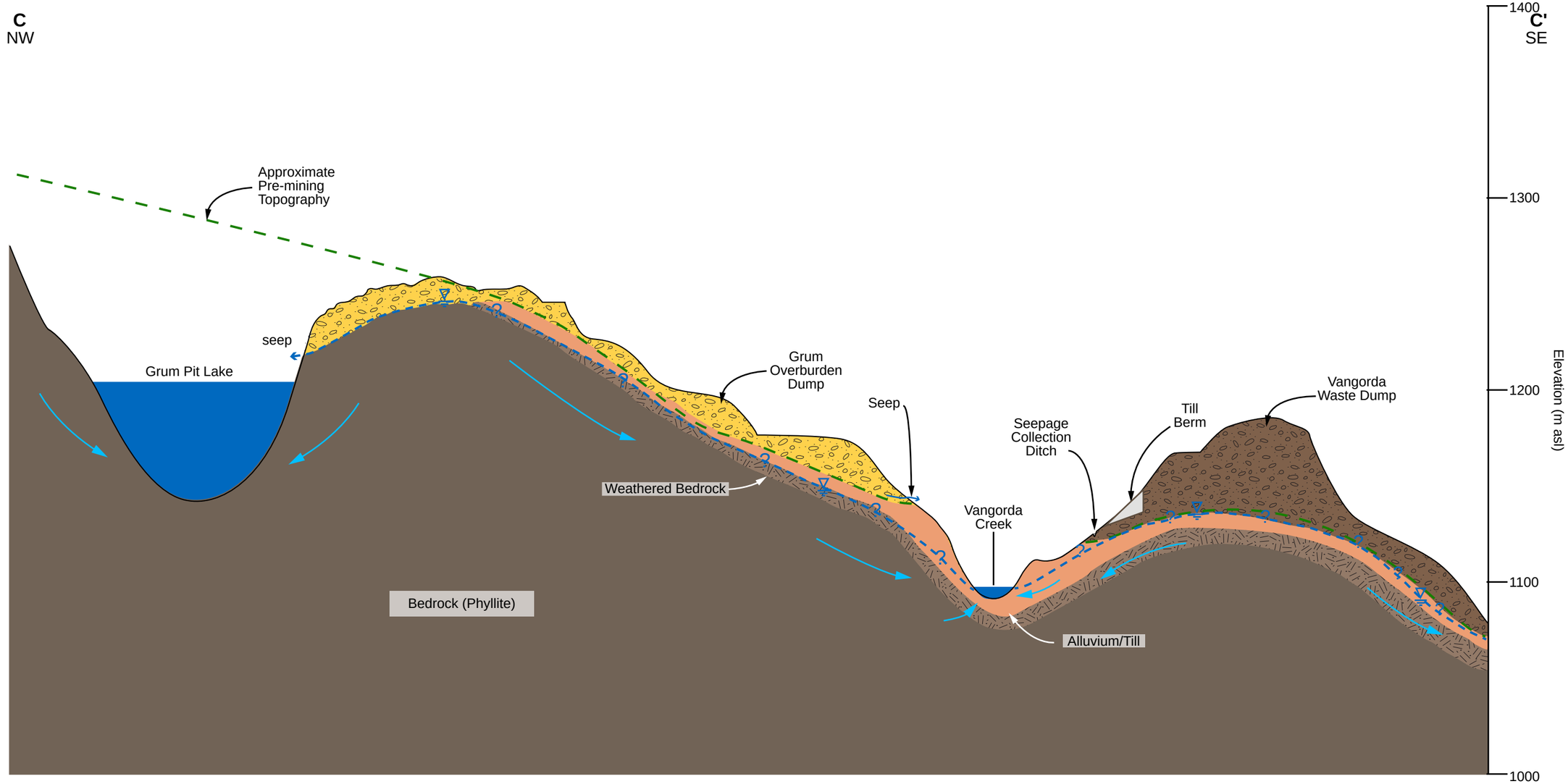
0 200m

Vertical Exaggeration: 1.4x

FIGURE 6G-12

Schematic Cross Section from Faro Pit to Zone 2 Outwash

Faro Mine Interim Works



LEGEND

Water Table

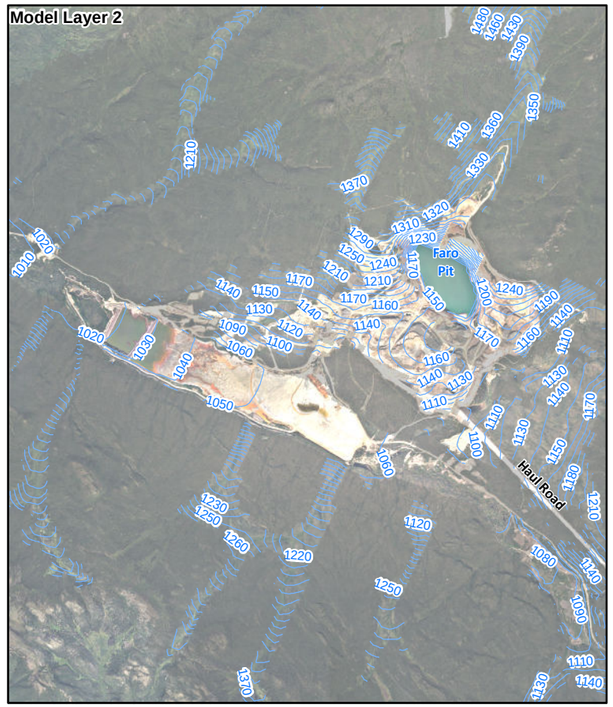
Generalized Groundwater
Flow Direction

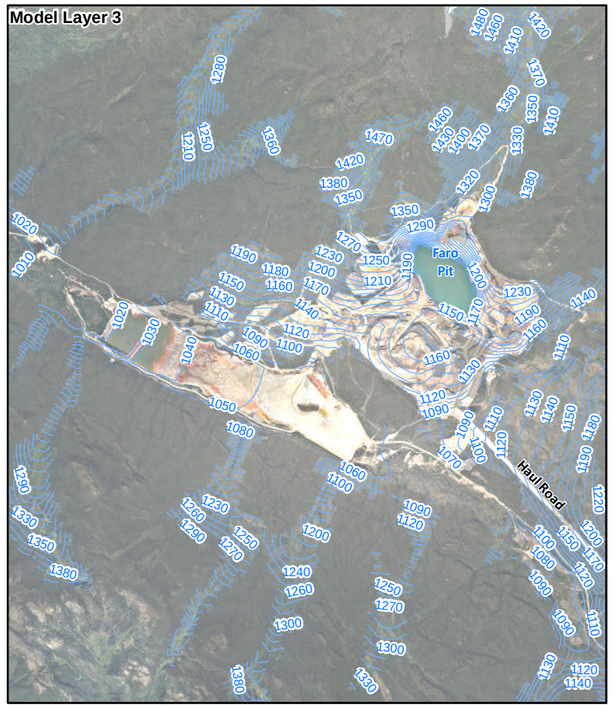
0 500m

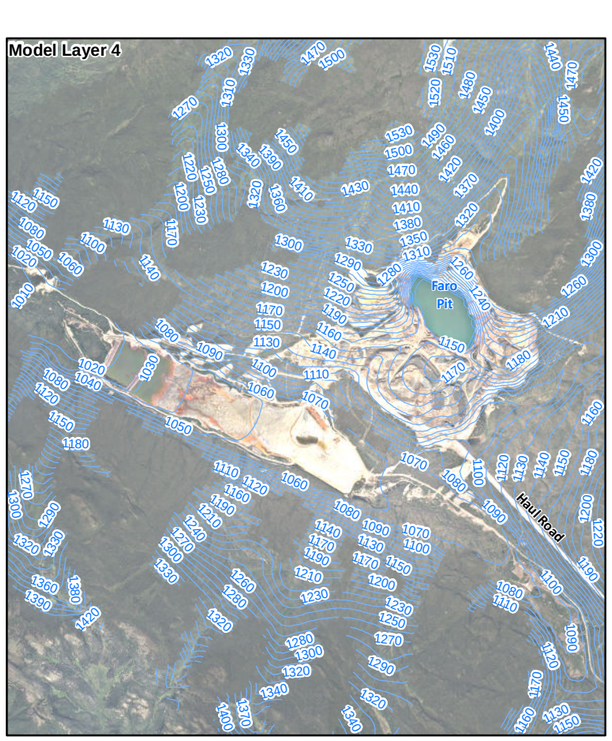
Vertical Exaggeration: 5x

FIGURE 6G-13
Schematic Cross Section from Grum Pit to Vangorda WD
Faro Mine Interim Works

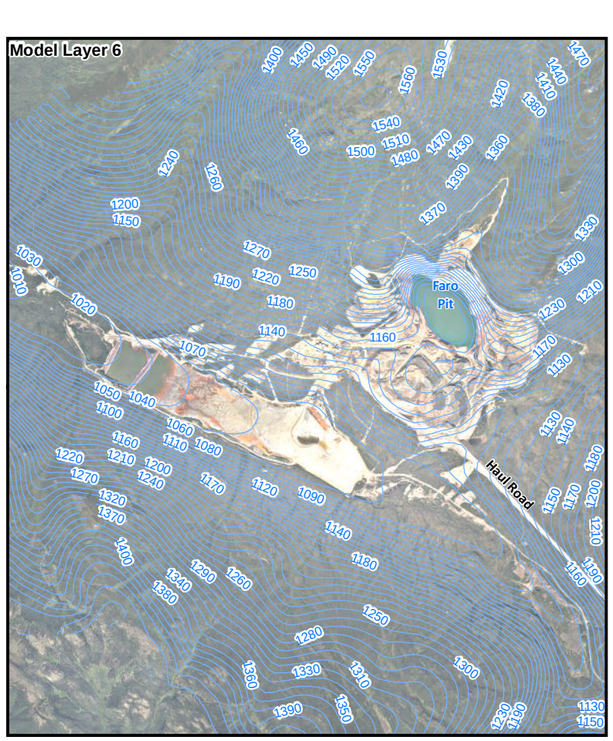


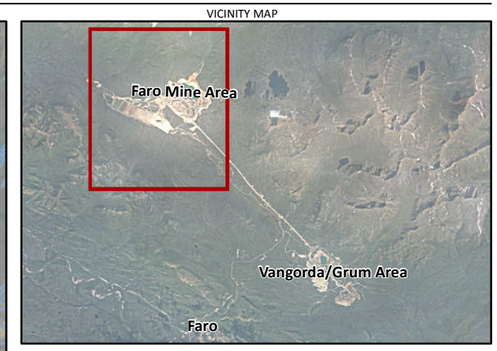










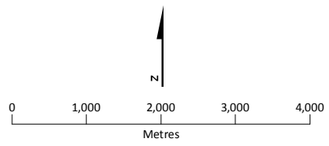


LEGEND

Potentiometric Surfce Condition (m CGVD28)

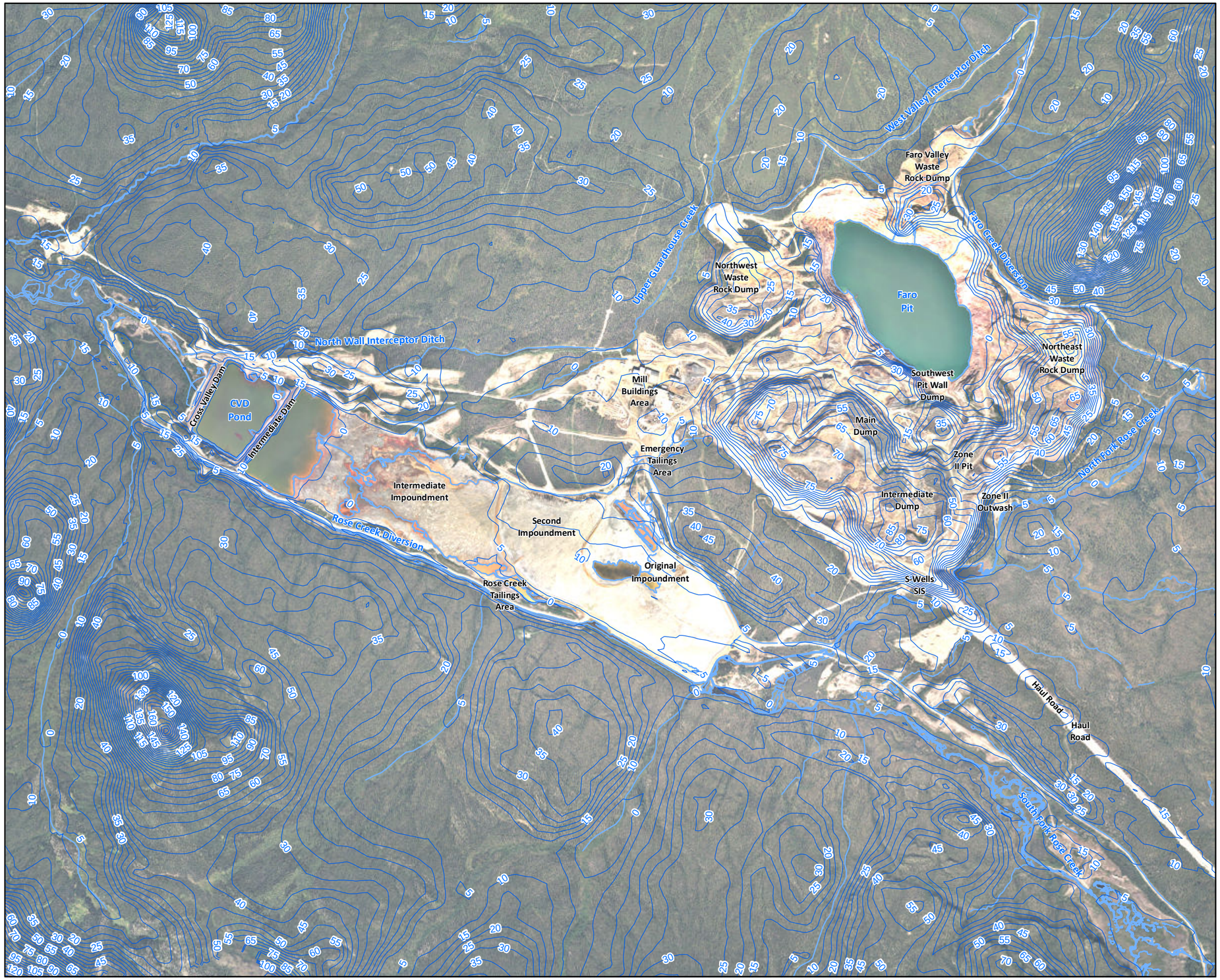
Dry Cell

Notes:
1. Contours are displayed at an interval of 10 metres.
2. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
3. Orthophotography prepared by Critigen Canada Corp.



Created by: CRITIGEN

FIGURE 6G-14
Modelled Potentiometric Surfaces
Faro Mine Interim Works



VICINITY MAP

LEGEND

Contour of Depth to Groundwater (m bgs)

Notes:
1. Contours are displayed at an interval of 5 m.
2. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
3. Orthophotography prepared by Critigen Canada Corp.

N

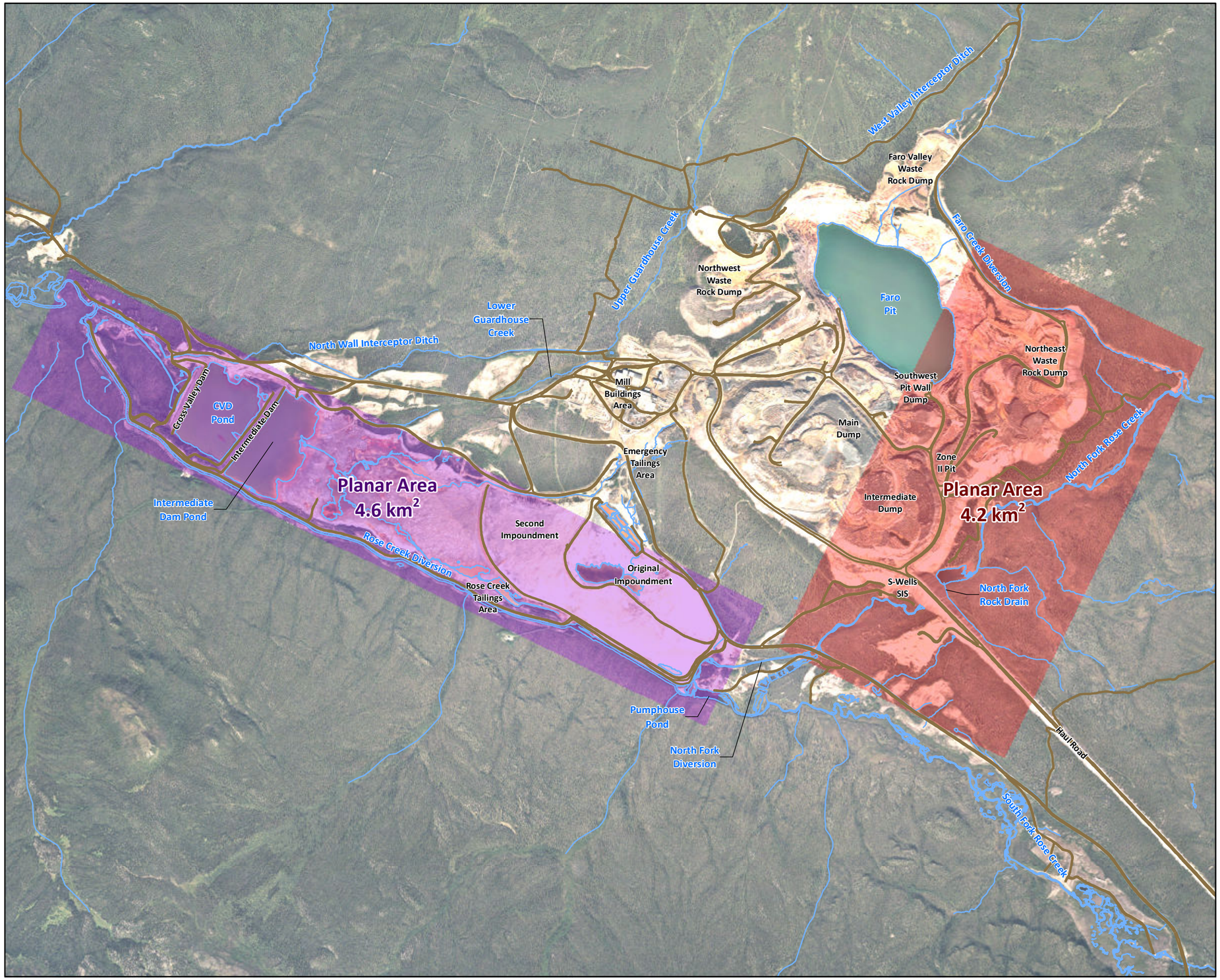
0 250 500 750 1,000
Metres

Created by: CRITIGEN

FIGURE 6G-15
Modelled Depth to Groundwater
Faro Mine Interim Works

CH2MHILL

DVR \\MNUSTRICTGFS01\PROJECTS\FAROMINE_20000342\MAPFILES\WATERMODELANALYSISRPT\FIG3-17.MXD ECLARK 2/14/2014 10:41:57 AM



VICINITY MAP



LEGEND

- Roads Unpaved
- Groundwater Balance Subarea: RCAA Subarea Model
- Groundwater Balance Subarea: NFRC Subarea Model

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

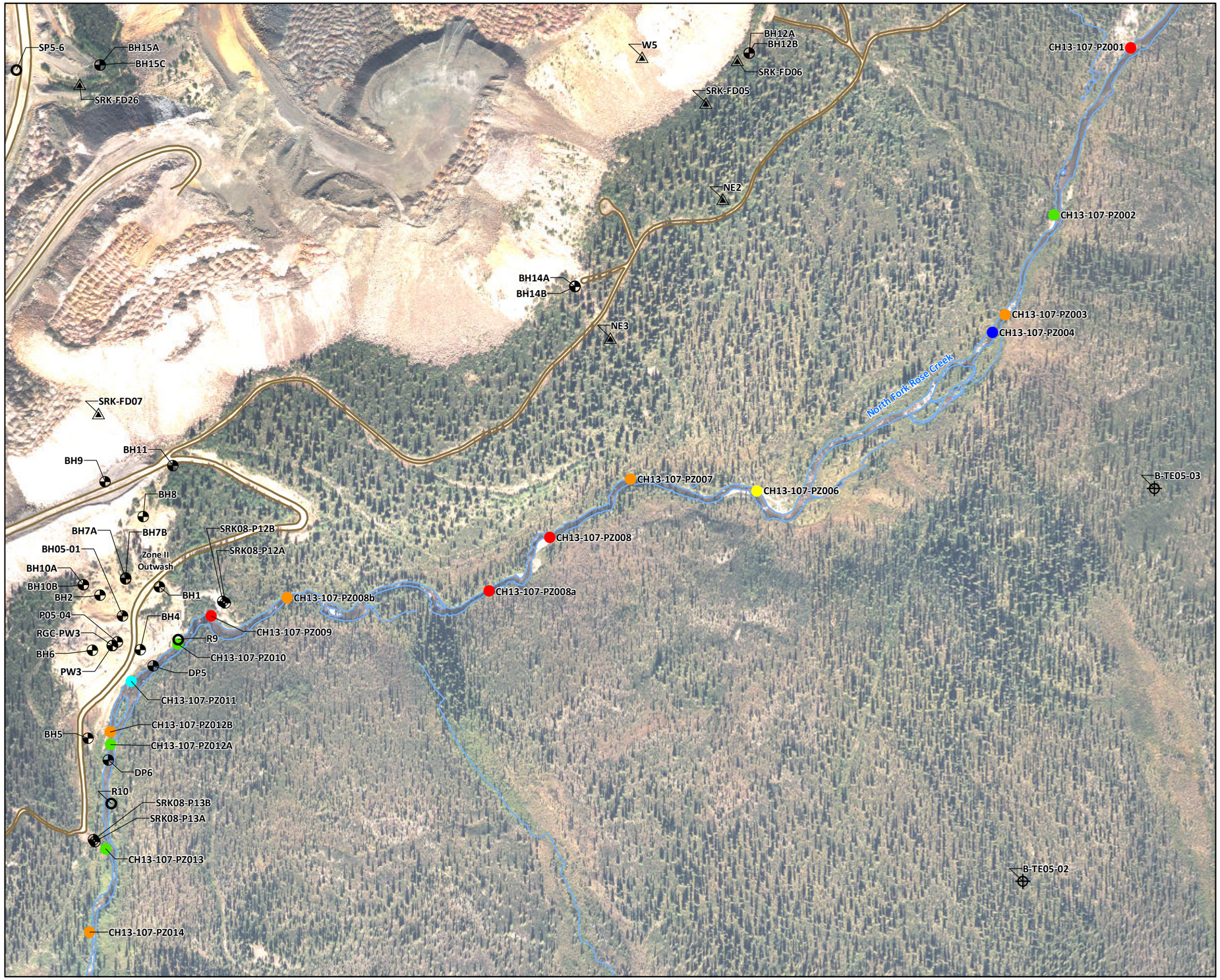
N

0 250 500 750 1,000
Metres

Created by: CRITIGEN

FIGURE 6G-16
Subareas Used to Compute Groundwater Balances in the NFRC and RCAA Subarea Models
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

- Borehole Location
- Monitoring Well Location
- Surface Water Location
- Seep Location

Streambed Piezometer VHG

- -0.10 to -0.05
- -0.05 to -0.02
- -0.02 to -0.01
- -0.01 to 0.00
- 0.00 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05

Notes:
1. Vertical Hydraulic Gradient (VHG) were measured from 8/27/13 to 8/31/13.
2. Negative VHG indicates the direction of flow is from the groundwater to the stream (gaining stream conditions).
3. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
4. Orthophotography prepared by Critigen Canada Corp.

N

0 50 100 150 200

Metres

Created by: CRITIGEN

FIGURE 6G-17

Approximate Streambed Piezometer Locations and Vertical Hydraulic Gradient on NFRC, Summer 2013

Faro Mine Interim Works



VICINITY MAP



LEGEND

- Surface Water Location

Streambed Piezometer VHG

- -0.25 to -0.10
- -0.10 to -0.02
- -0.01 to -0.01
- -0.01 to 0.00
- 0.00 to 0.01
- 0.01 to 0.10
- 0.10 to 0.70

Notes:
1. Vertical Hydraulic Gradient (VHG) were measured from 9/23/12 to 10/6/12.
2. Negative VHG indicates the direction of flow is from the groundwater to the stream (gaining stream conditions).
3. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
4. Orthophotography prepared by Critigen Canada Corp.

N

0 50 100 150 200

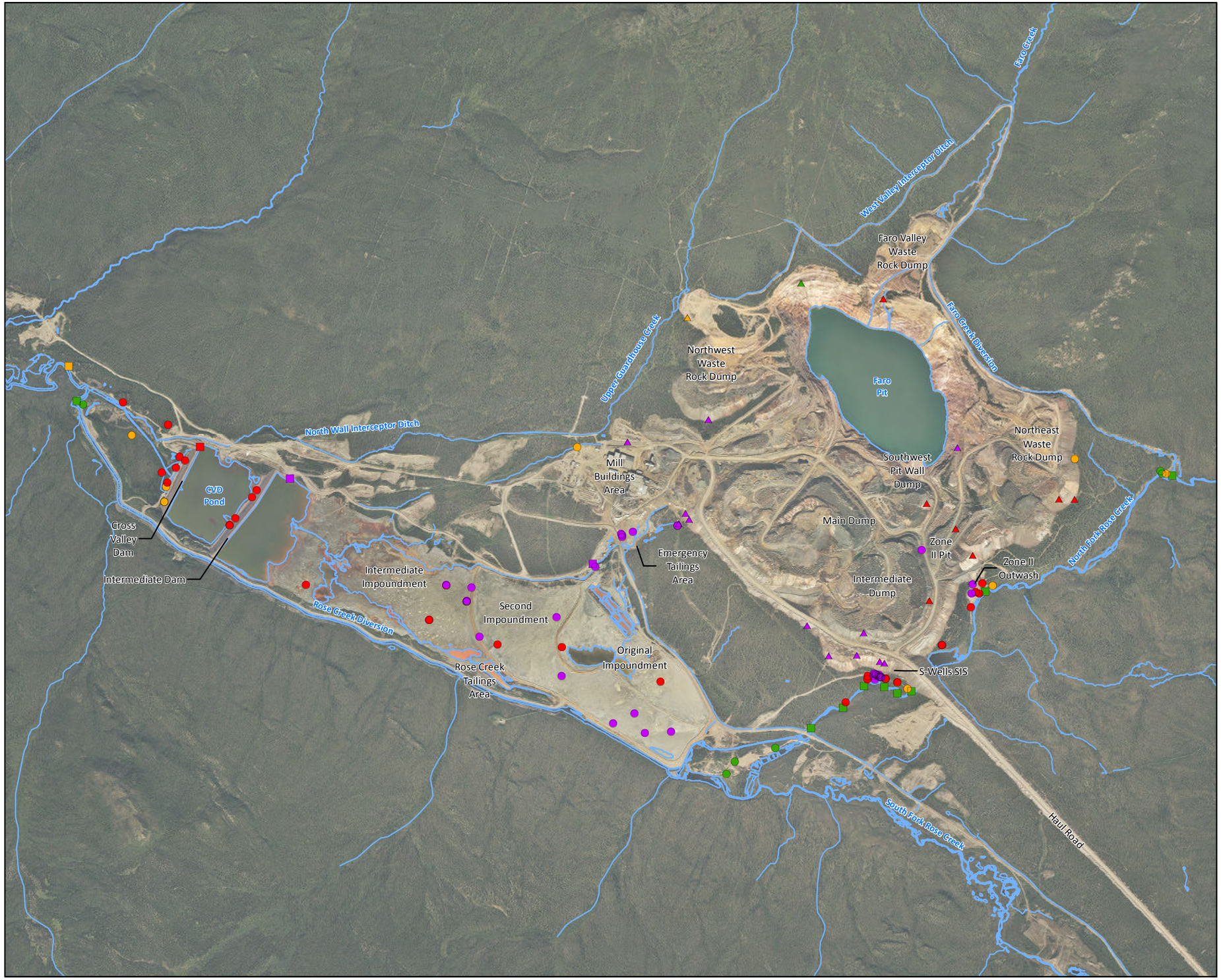
Metres

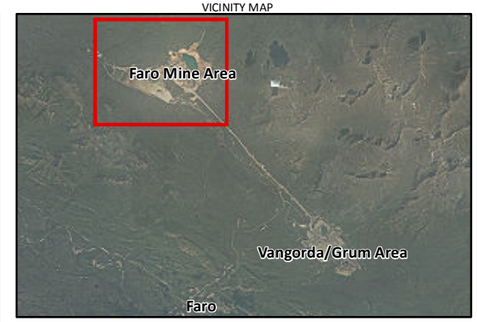
Created by: CRITIGEN

FIGURE 6G-18

Approximate Streambed Piezometer Locations and Vertical Hydraulic Gradient, Fall 2012

Faro Mine Interim Works





LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Symbol colour shows the highest impact at each well pair or cluster location.

N

0 640 1,280

Metres

Created by: CRITIGEN

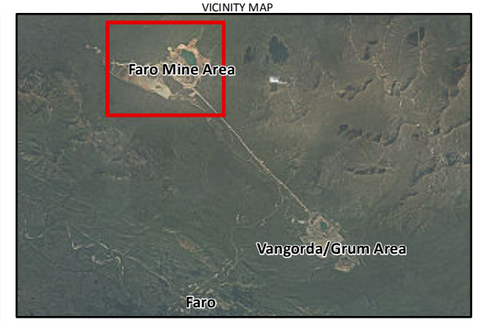
FIGURE 6G-19

Water Quality at Seeps and in the Alluvial Aquifer of the Faro Mine Area

Faro Mine Interim Works



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted ($SO_4 \geq 4{,}000$ mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted ($SO_4 \geq 400$ and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted ($SO_4 \geq 40$ and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted ($SO_4 < 40$ mg/L and Zn < 0.05 mg/L)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Symbol colour shows the highest impact at each well pair or cluster location.

N

0 560 1,120

Metres

Created by: CRITIGEN

FIGURE 6G-20

Water Quality in the Bedrock Aquifer of the Faro Mine Area

Faro Mine Interim Works



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

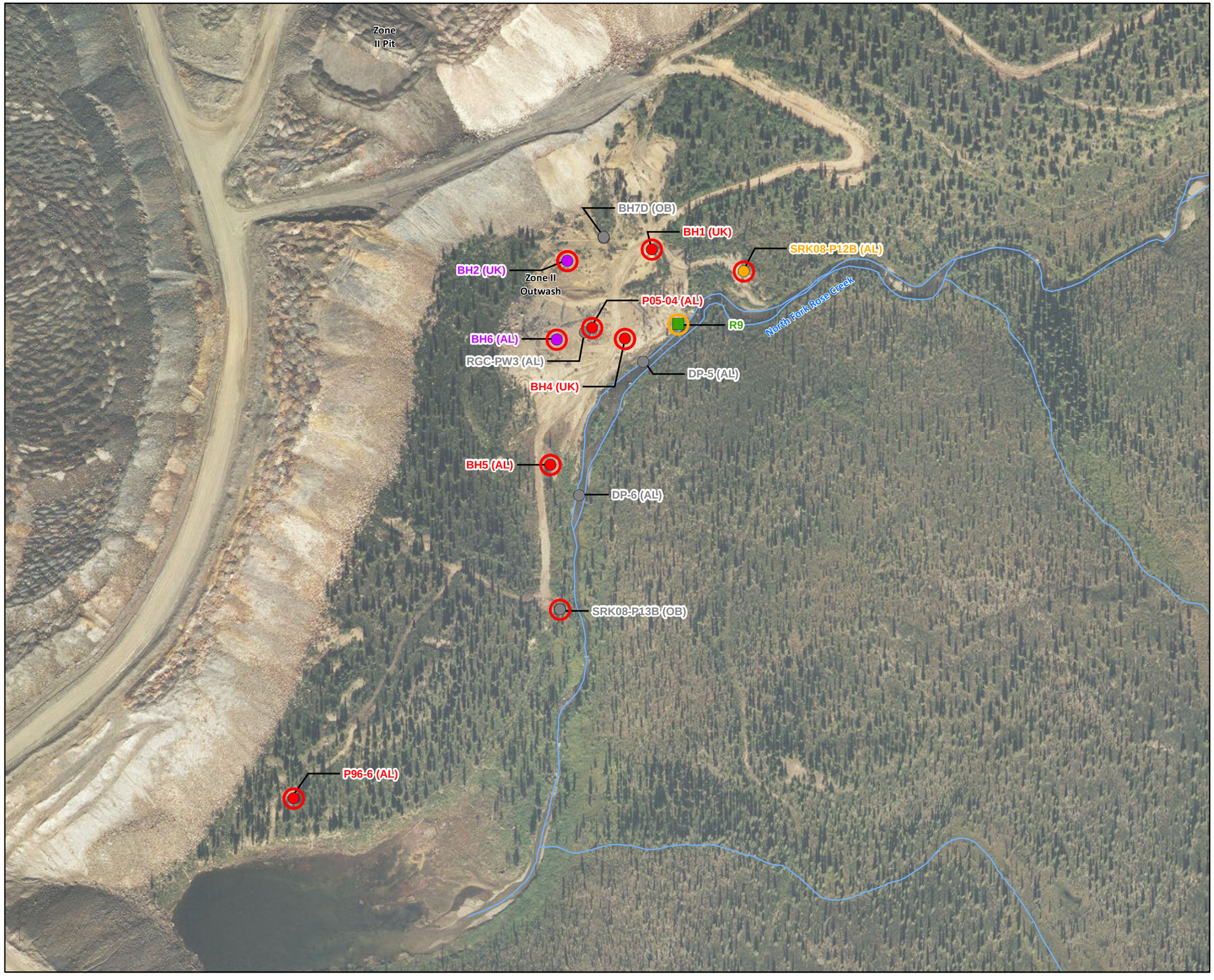
0 75 150
Metres

N

Created by:
CRITIGEN

FIGURE 6G-21
Water Quality:
Faro Pit Seeps
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 30 60
Metres

N

Created by: CRITIGEN

FIGURE 6G-22
Water Quality:
Zone 2 Alluvial Aquifer
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

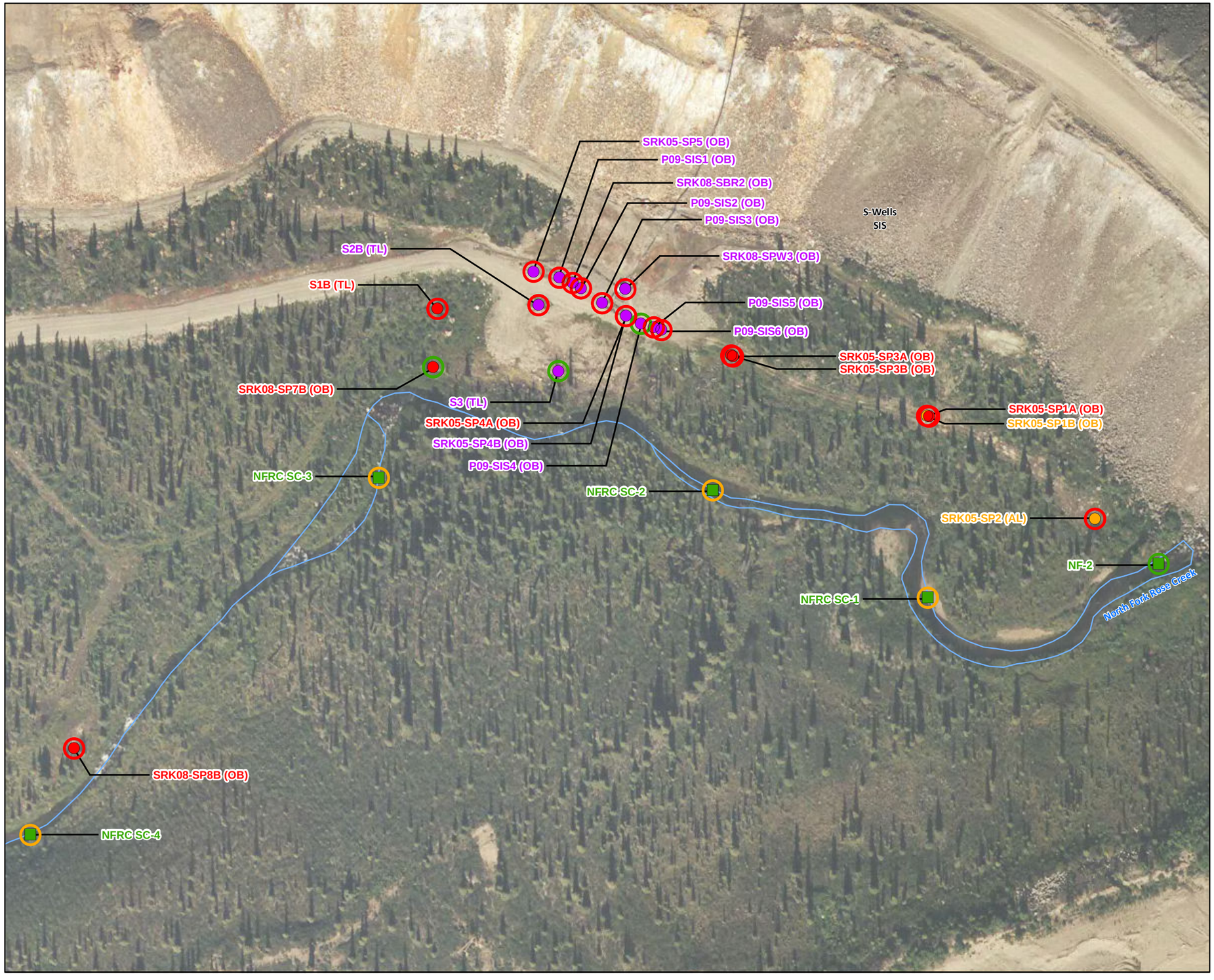
0 30 60
Metres

N

Created by: CRITIGEN

FIGURE 6G-23
Water Quality:
Zone 2 Bedrock Aquifer
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

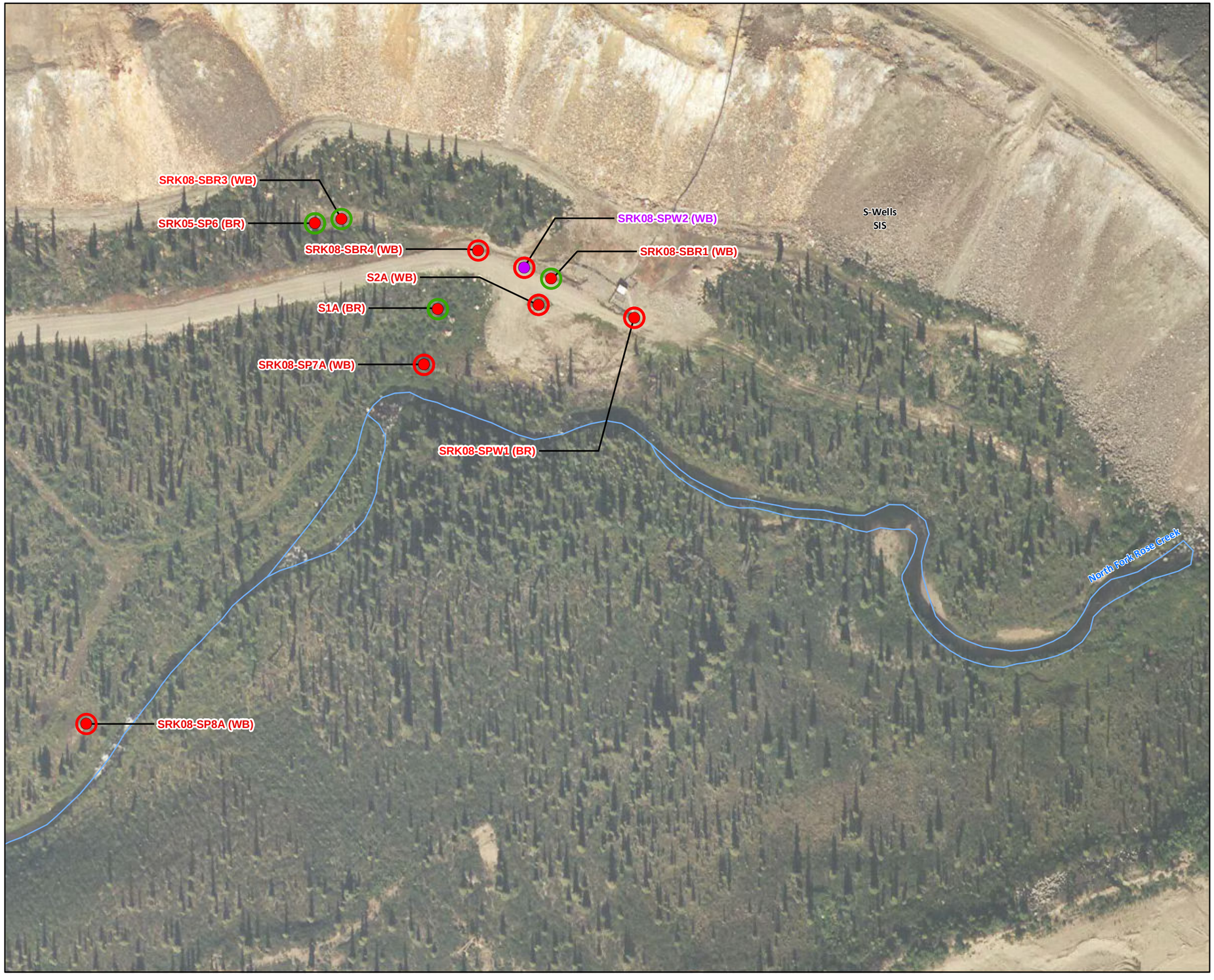
0 10 20
Metres

N

Created by: CRITIGEN

FIGURE 6G-24
Water Quality:
S-Wells Alluvial Aquifer
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 10 20
Metres

N

Created by: CRITIGEN

FIGURE 6G-25

Water Quality:

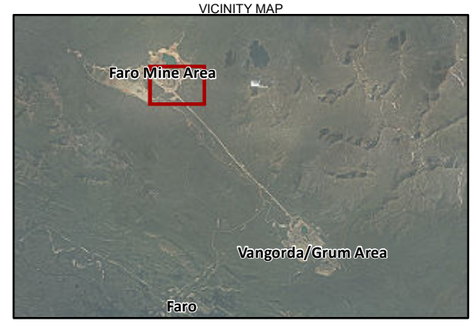
S-Wells Bedrock Aquifer

Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 140 280
Metres

N

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FIGURE 6G-26

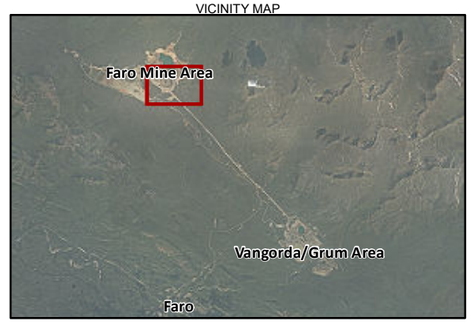
Water Quality:

Other Faro Mine Areas Bedrock Aquifer

Faro Mine Interim Works



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

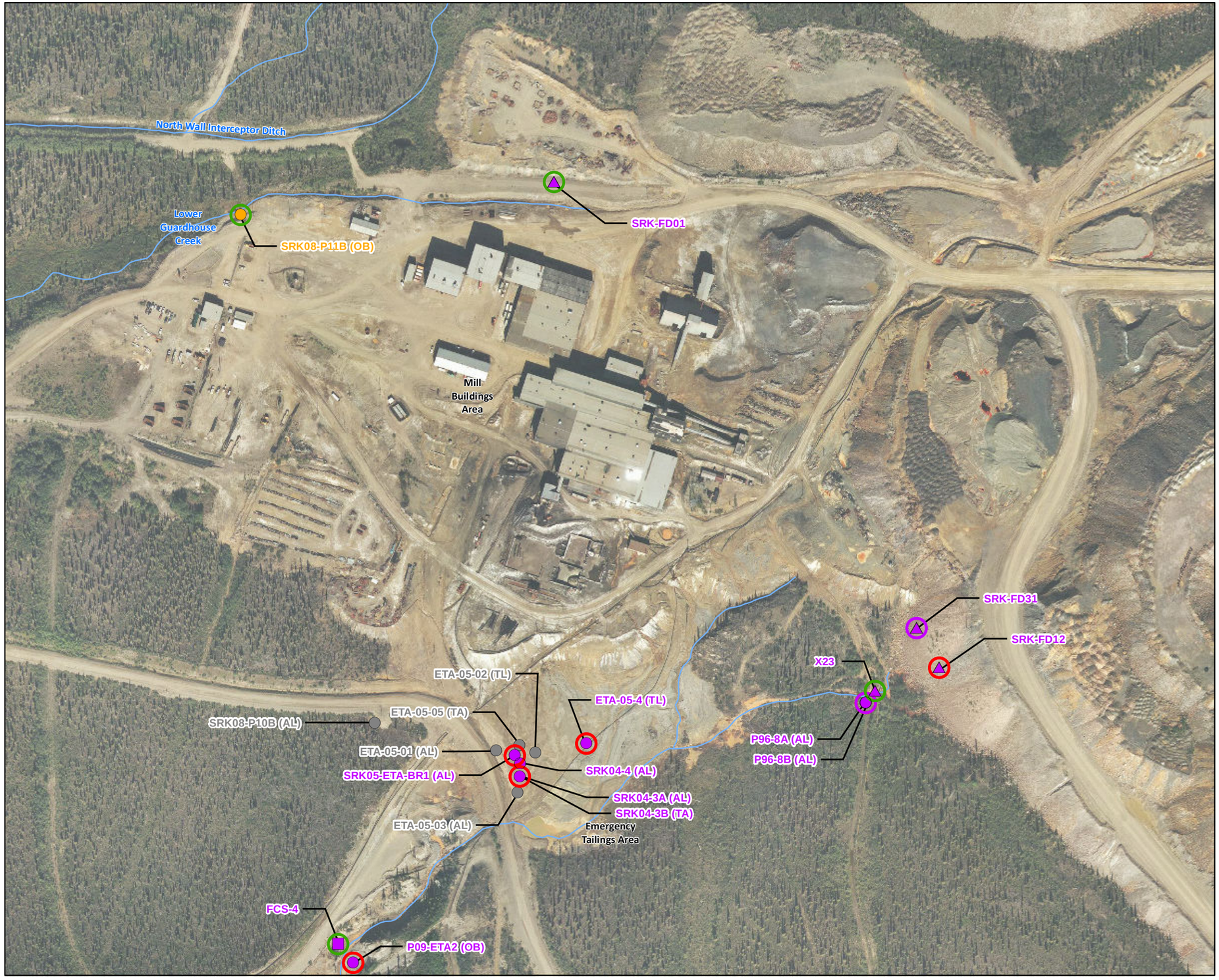
1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 140 280
Metres

N

Created by: CRITIGEN

FIGURE 6G-27
Water Quality:
Other Faro Mine Areas Alluvial Aquifer
Faro Mine Interim Works



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 50 100
Metres

N

Created by: CRITIGEN

FIGURE 6G-28
Water Quality:
Emergency Tailings Area Alluvial Aquifer
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 50 100
Metres

N

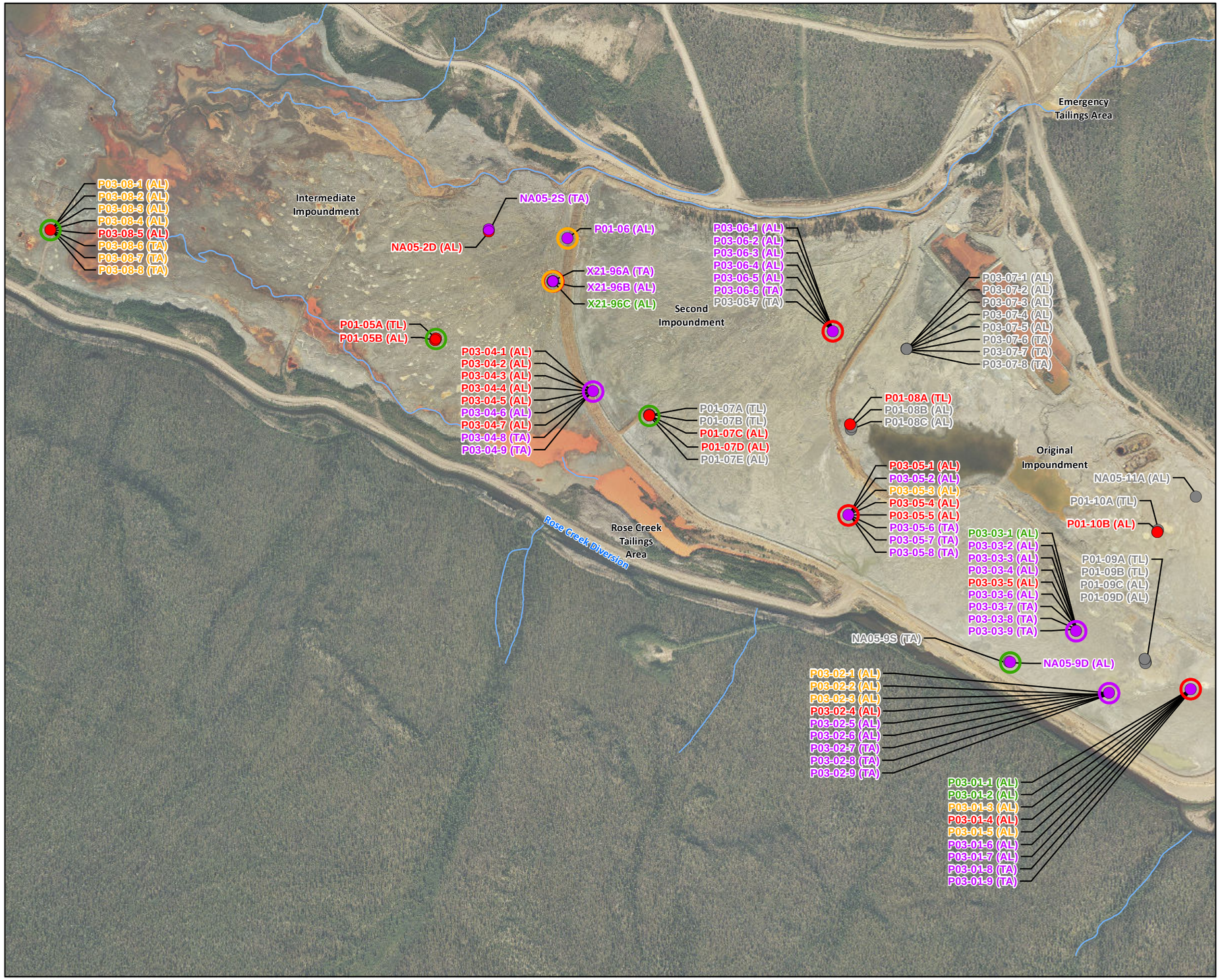
Created by: CRITIGEN

FIGURE 6G-29

Water Quality:

Emergency Tailings Area Bedrock Aquifer

Faro Mine Interim Works





LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

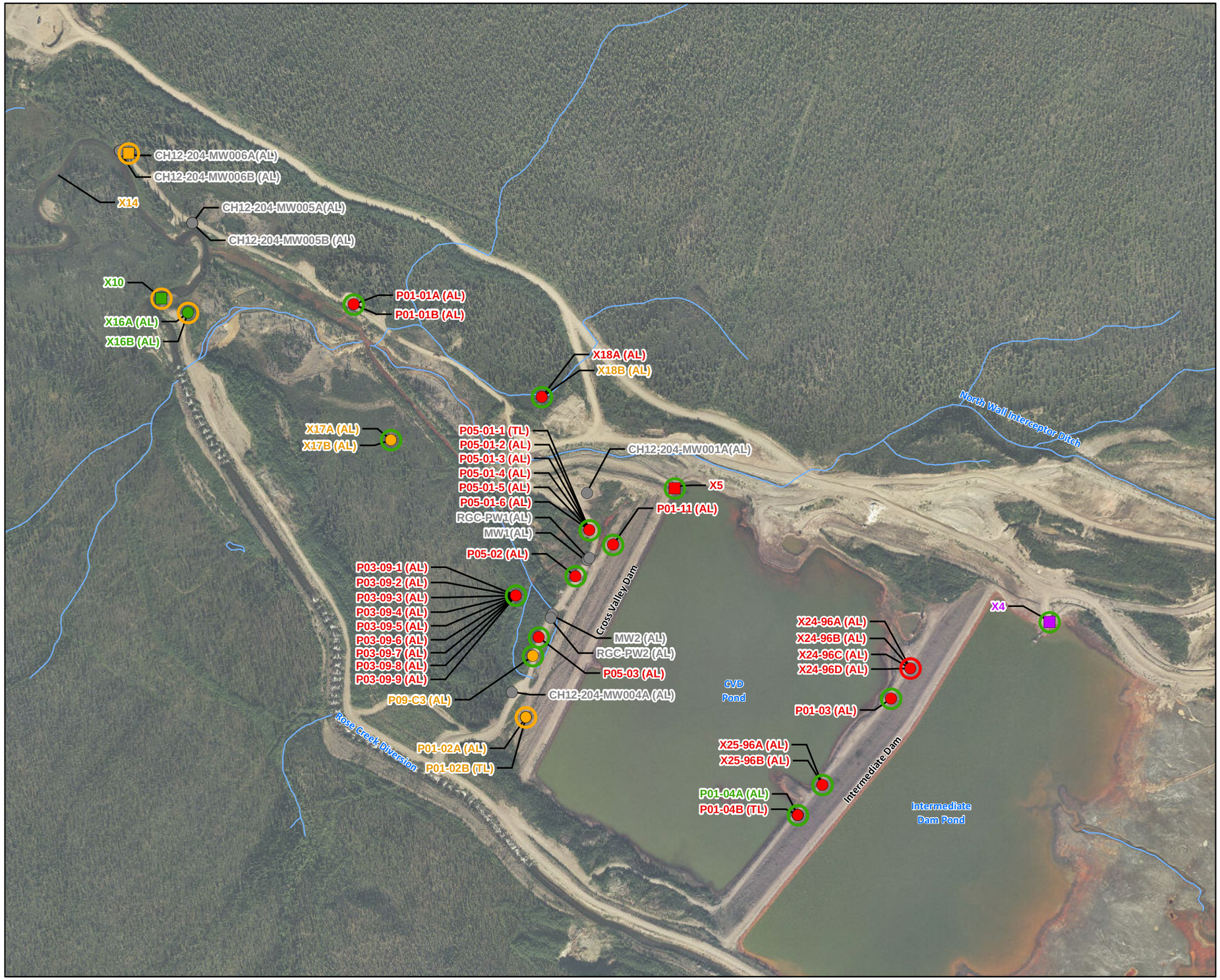
0 100 200
Metres

N

Created by: CRITIGEN

FIGURE 6G-30
Water Quality:
Tailings Area Alluvial Aquifer
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 75 150
Metres

N

Created by: CRITIGEN

FIGURE 6G-31
Water Quality:
Cross Valley Dam Alluvial Aquifer
Faro Mine Interim Works



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

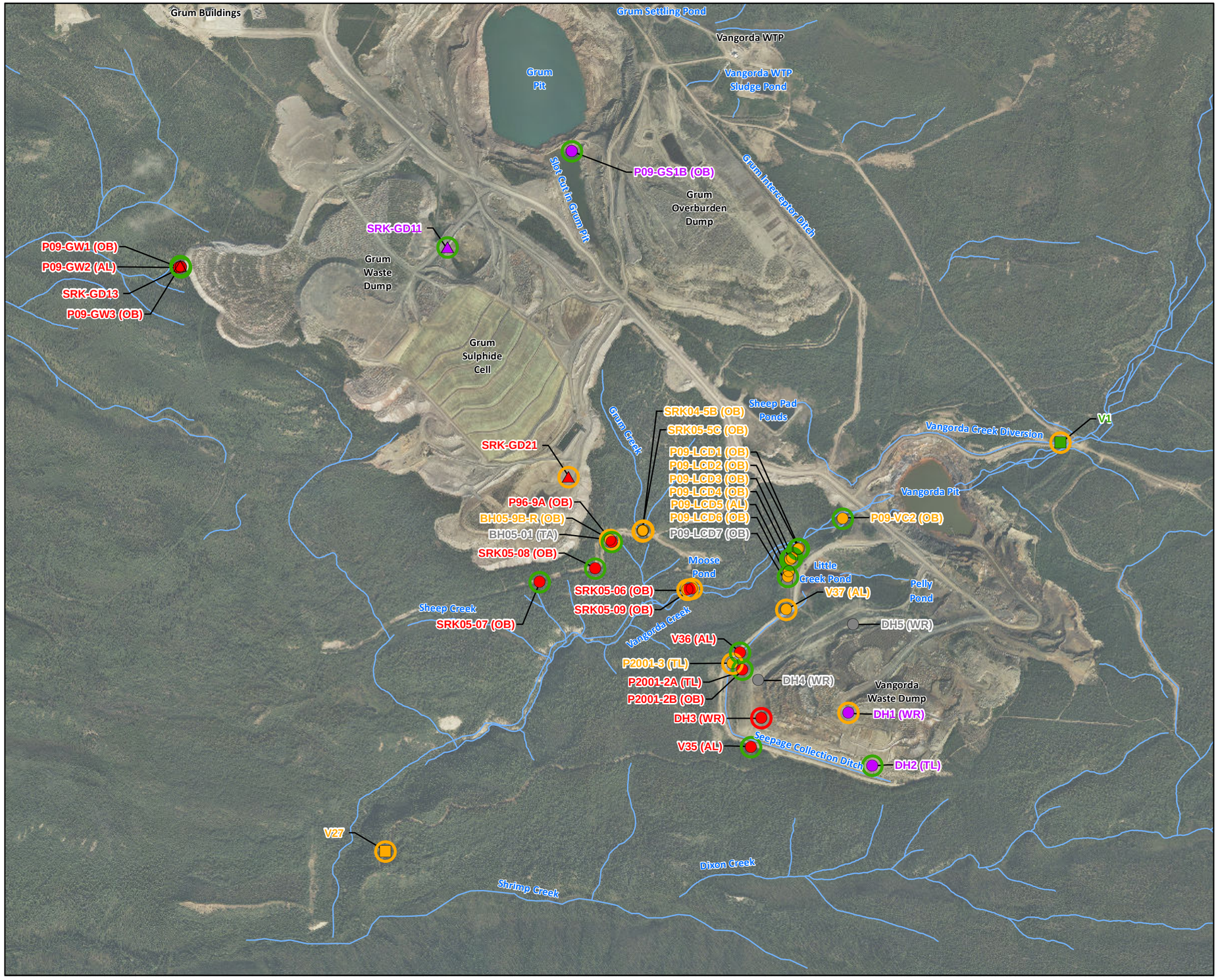
1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 75 150
Metres

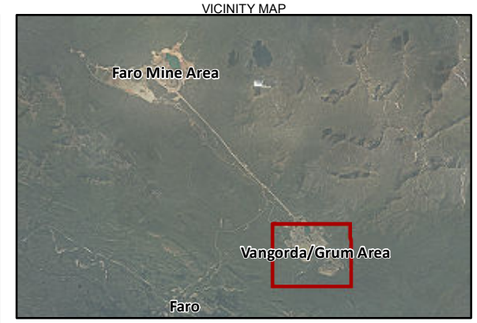
N

Created by: CRITIGEN

FIGURE 6G-32
Water Quality:
Cross Valley Dam Bedrock Aquifer
Faro Mine Interim Works



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 190 380
Metres

N

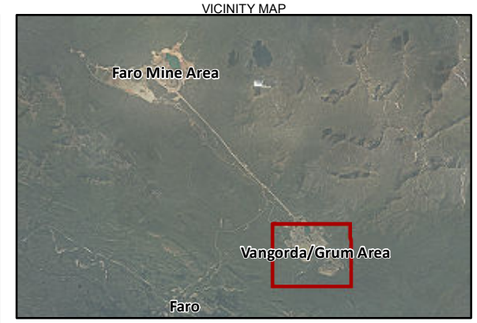
Created by: CRITIGEN

FIGURE 6G-33
Water Quality:
Vangorda/Grum Alluvial Aquifer
Faro Mine Interim Works

CH2MHILL



VICINITY MAP



LEGEND

Location Type

- Groundwater Monitoring Well Location
- Surface Water Sampling Location
- Seep Sampling Location

Impact Level

- Highly Impacted (SO_4 ≥ 4,000 mg/L or Zn ≥ 5 mg/L)
- Moderately Impacted (SO_4 ≥ 400 and < 4,000 mg/L or Zn ≥ 0.5 and > 5 mg/L)
- Slightly Impacted (SO_4 ≥ 40 and < 400 mg/L or Zn ≥ 0.05 and > 0.5 mg/L)
- Not Impacted to Mildly Impacted (SO_4 < 40 mg/L and Zn < 0.05 mg/L)
- No Data

pH

- High (pH ≥7.5)
- Neutral (pH ≥6.5 and <7.5)
- Low (pH ≥5 and <6.5)
- Very Low (pH <5)

Notes:

1. All locations are approximate pending results of the 2012 field survey.
2. Abbreviations:
   (AL) = Alluvium
   (BR) = Bedrock
   (OB) = Overburden
   SO_4 = Sulphate
   (TA) = Tailings
   (TL) = Till
   (UK) = Unknown
   (WB) = Weathered Bedrock
   (WR) = Waste Rock
   Zn = Zinc
3. Symbol colour shows the highest impact at each well pair or cluster location. Sample location text colour shows impact level of that particular location.

0 190 380
Metres

N

Created by: CRITIGEN

FIGURE 6G-34
Water Quality:
Vangorda/Grum Bedrock Aquifer
Faro Mine Interim Works

Attachment 6G-1
Time Series Chemical Plots

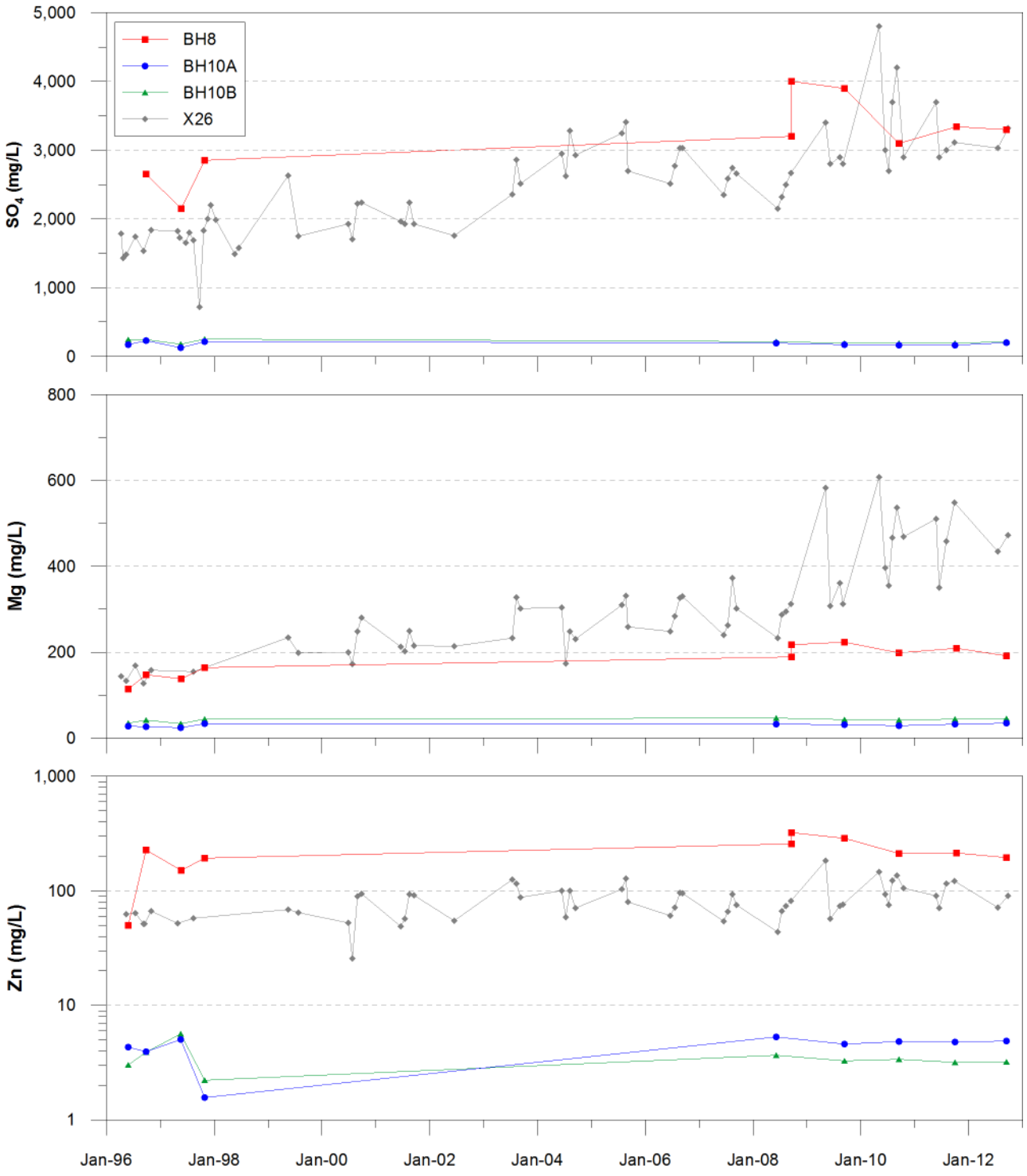


FIGURE 6G-1-1
Time Trends for SO_4, Mg and Zn for Zone II Pit and Bedrock Wells
Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

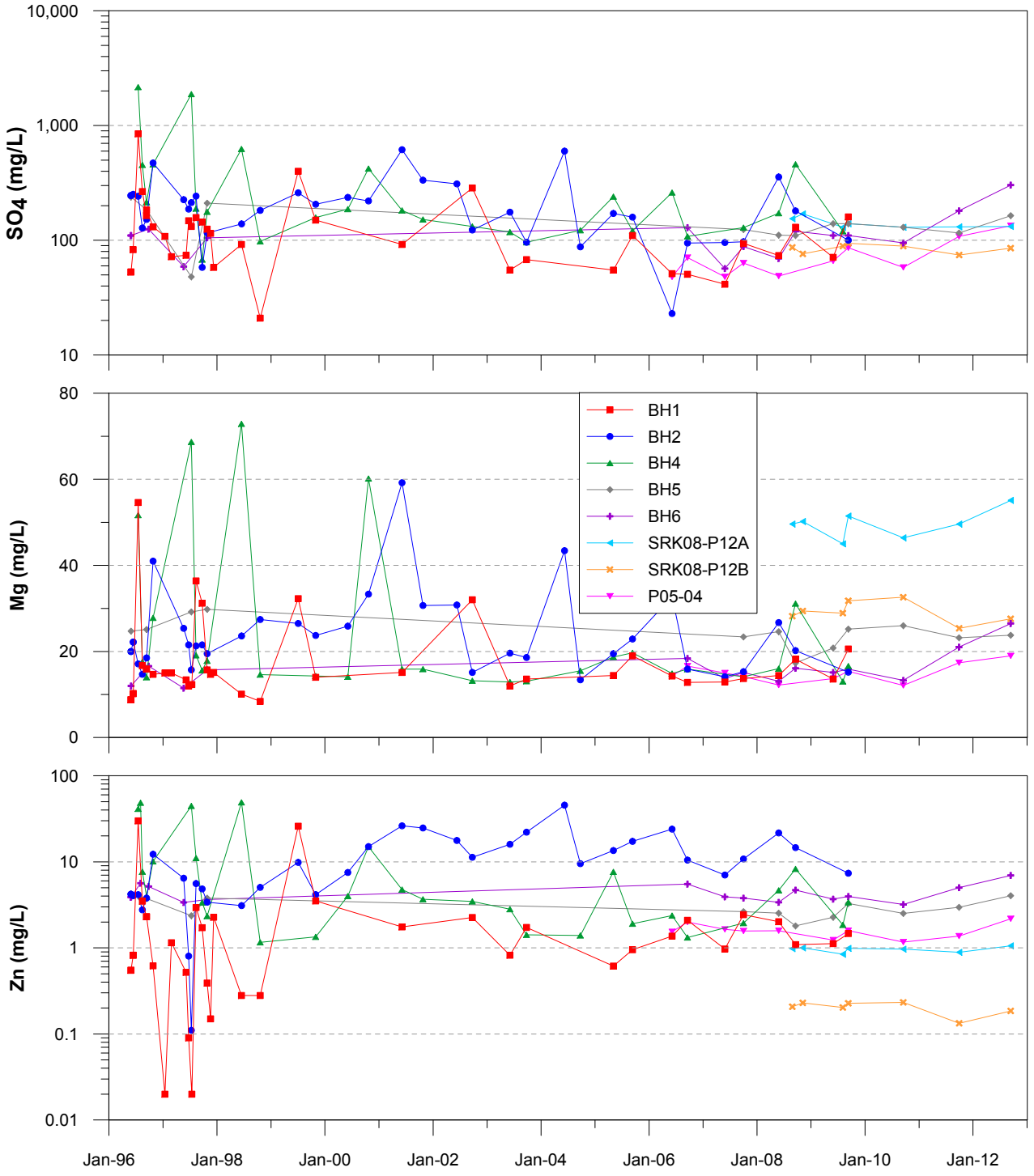


FIGURE 6G-1-2
Time Trends for SO_4, Mg and Zn for Wells in Zone II Outwash Area
Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

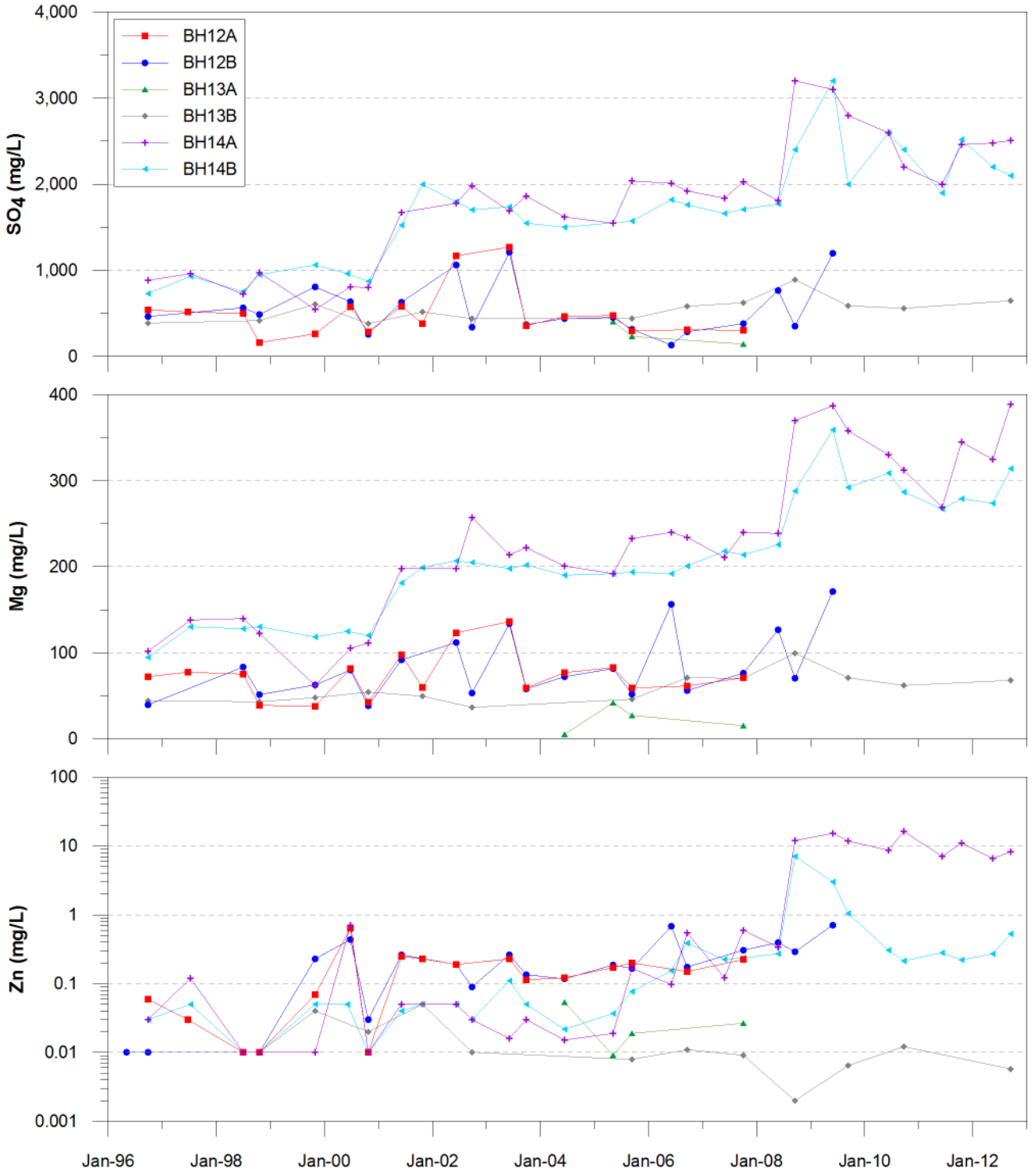


FIGURE 6G-1-3
Time Trends for SO_4, Mg and Zn in Wells at the Toe of Northeast Waste Rock Dump
Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

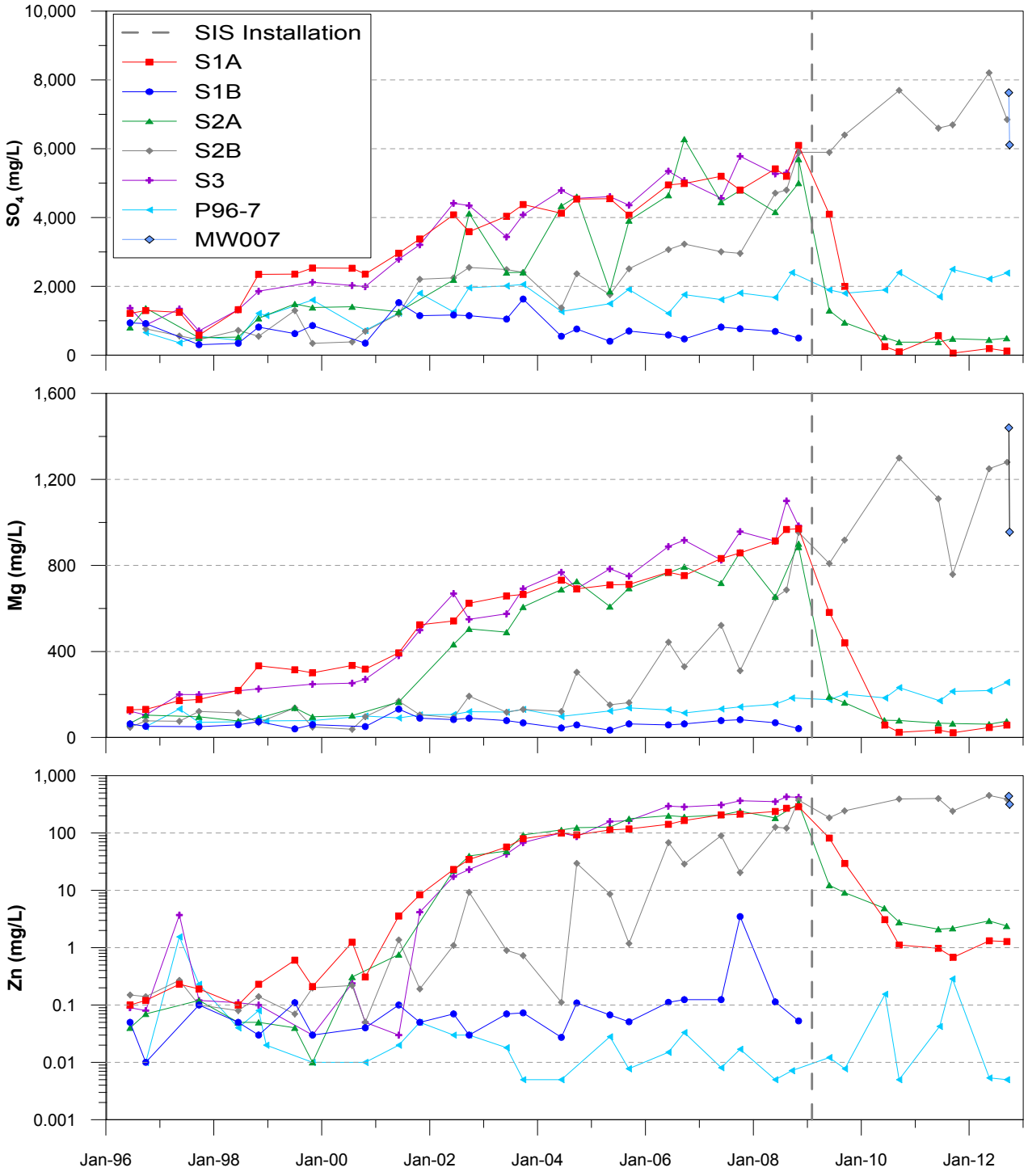


FIGURE 6G-1-4
Time Trends for SO_4, Mg, and Zn in S-Cluster Wells
Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

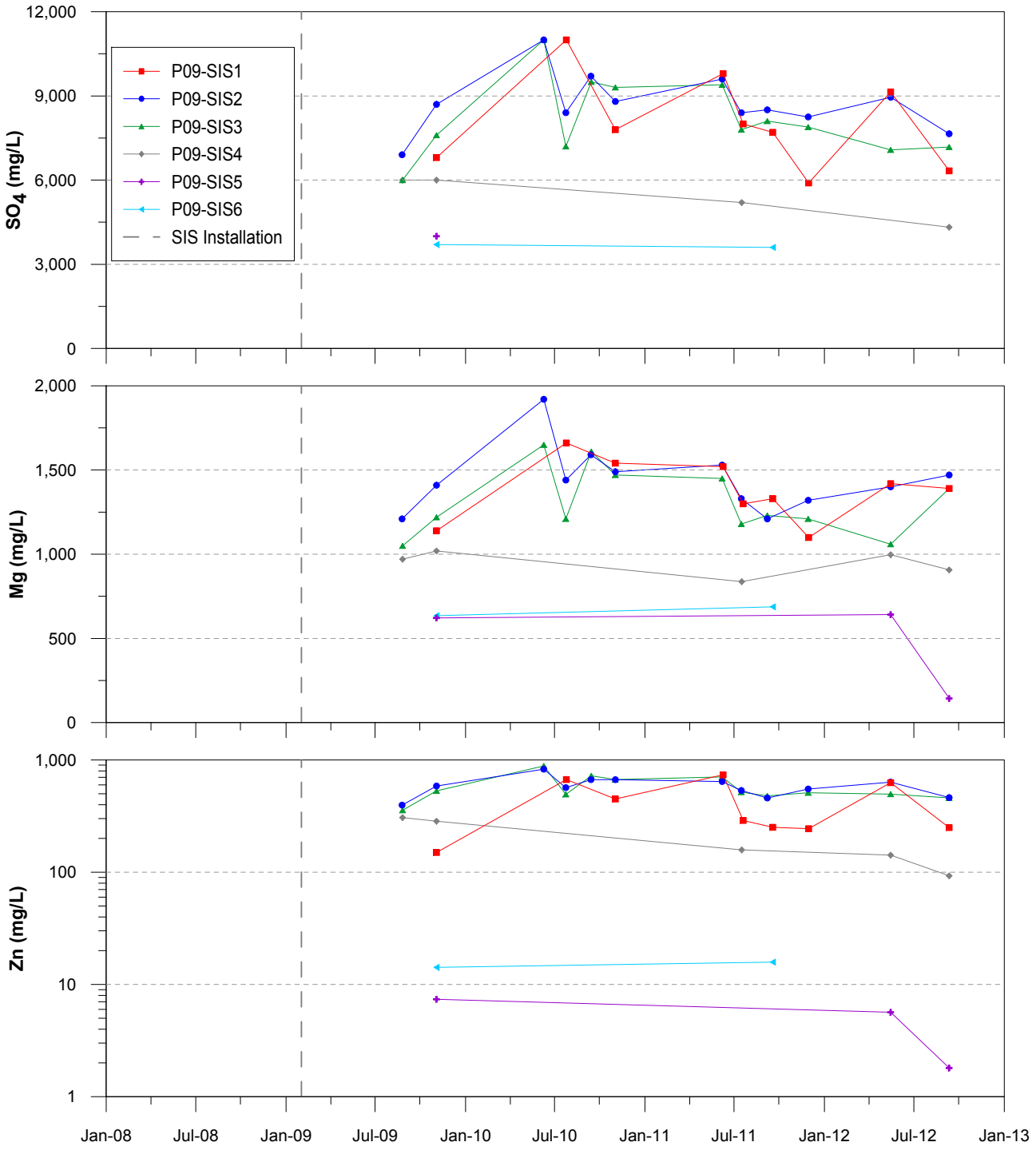


FIGURE 6G-1-5

Time Trends for SO_4, Mg, and Zn in P09-SIS Wells, S-Cluster Area

Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

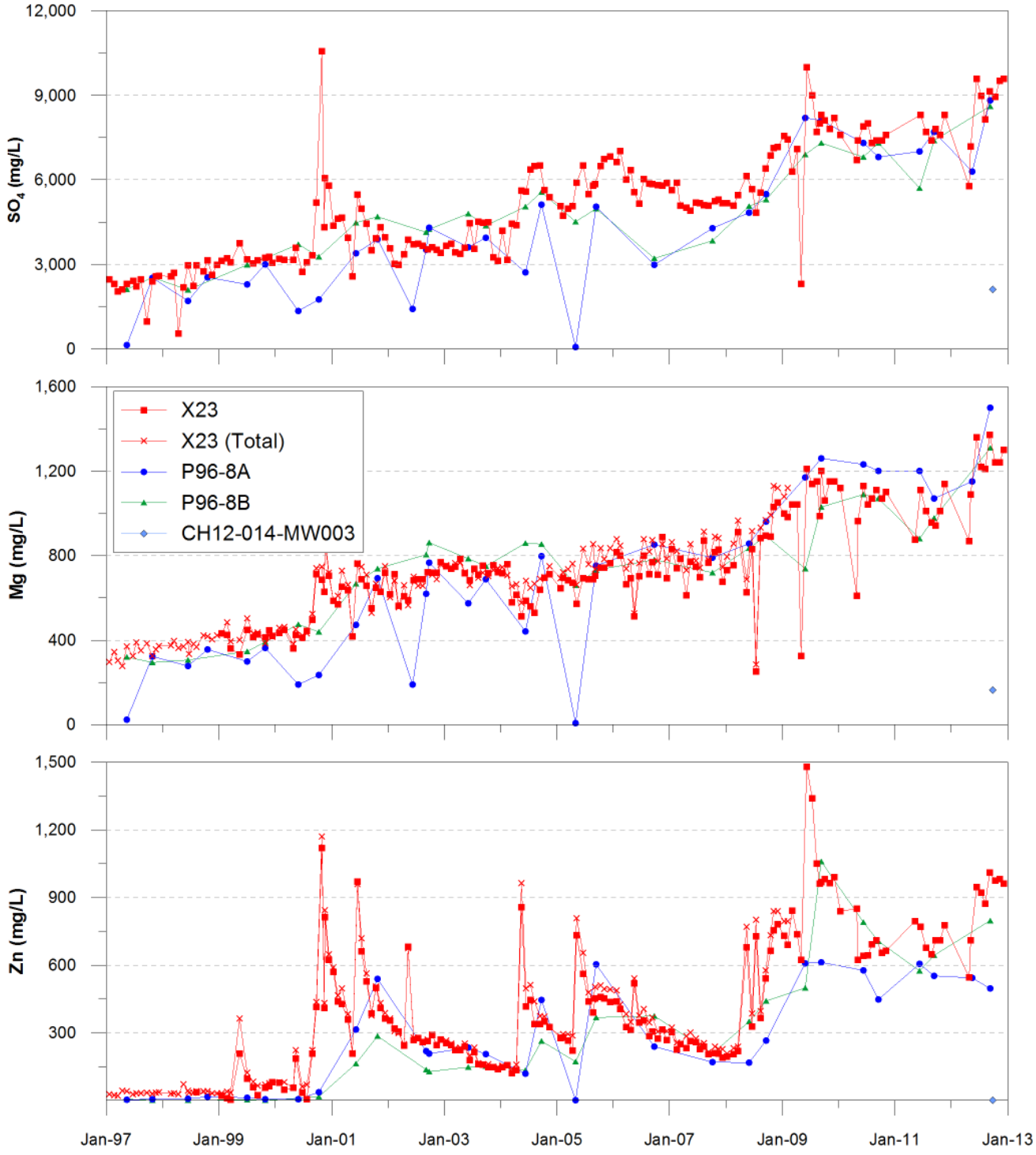


FIGURE 6G-1-6

Time Trends for SO_4, Mg, and Zn at X23 and P96-8A/B Wells

Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

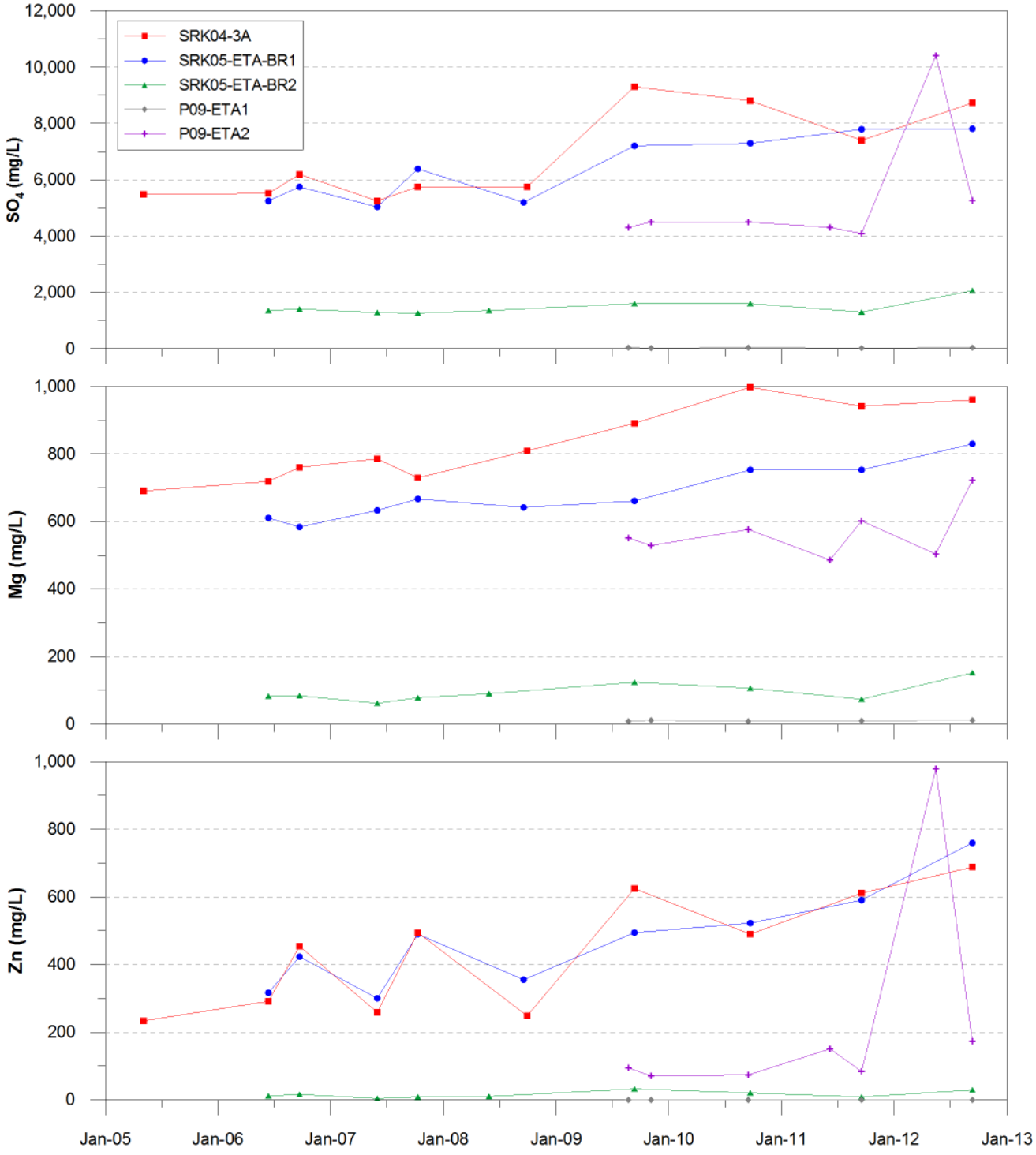


FIGURE 6G-1-7

Time Trends for SO_4, Mg, and Zn in SRK Wells in the ETA

Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

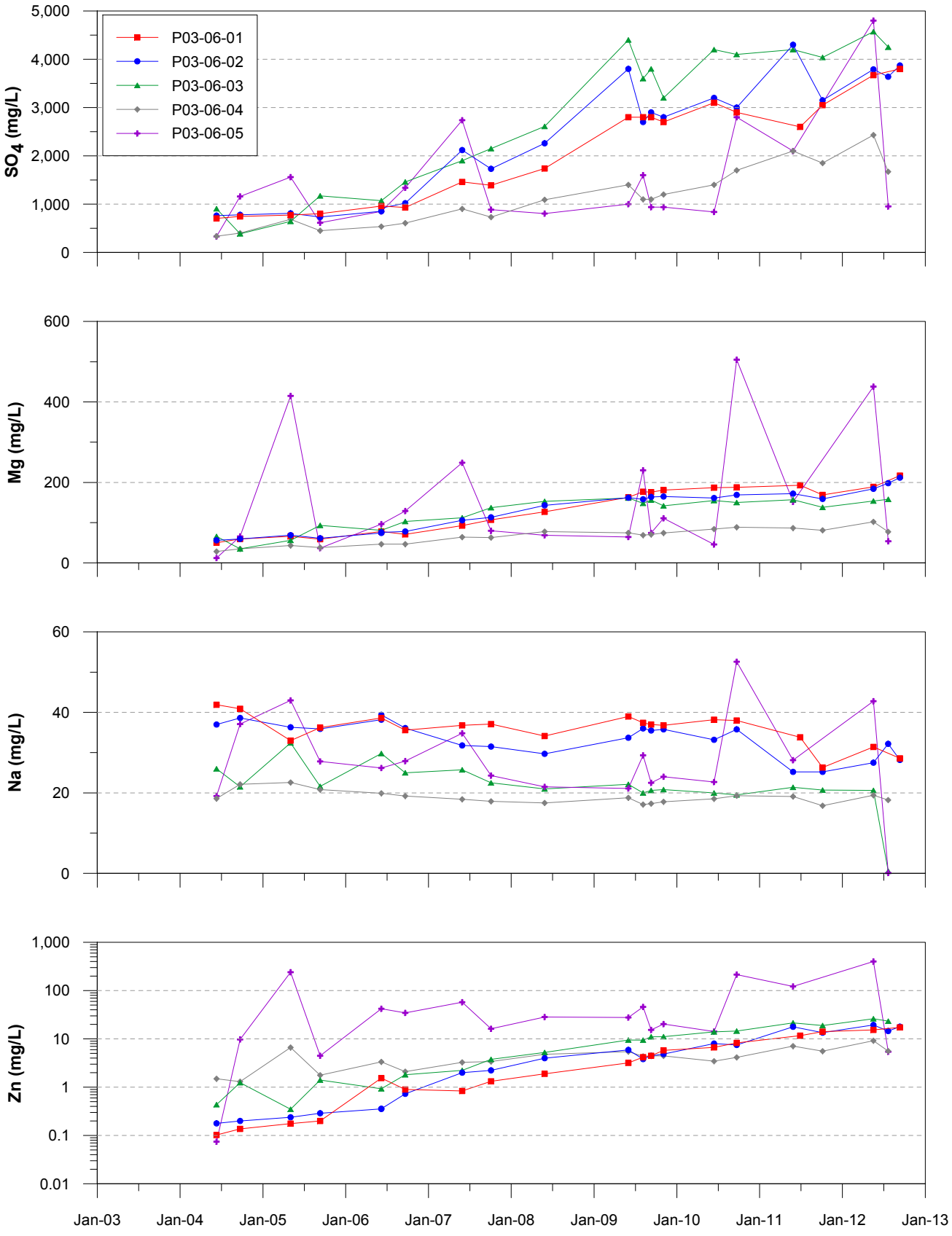


FIGURE 6G-1-8

Time Trends for SO_4, Mg, Na, and Zn in P03-06 at the Secondary Impoundment

Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

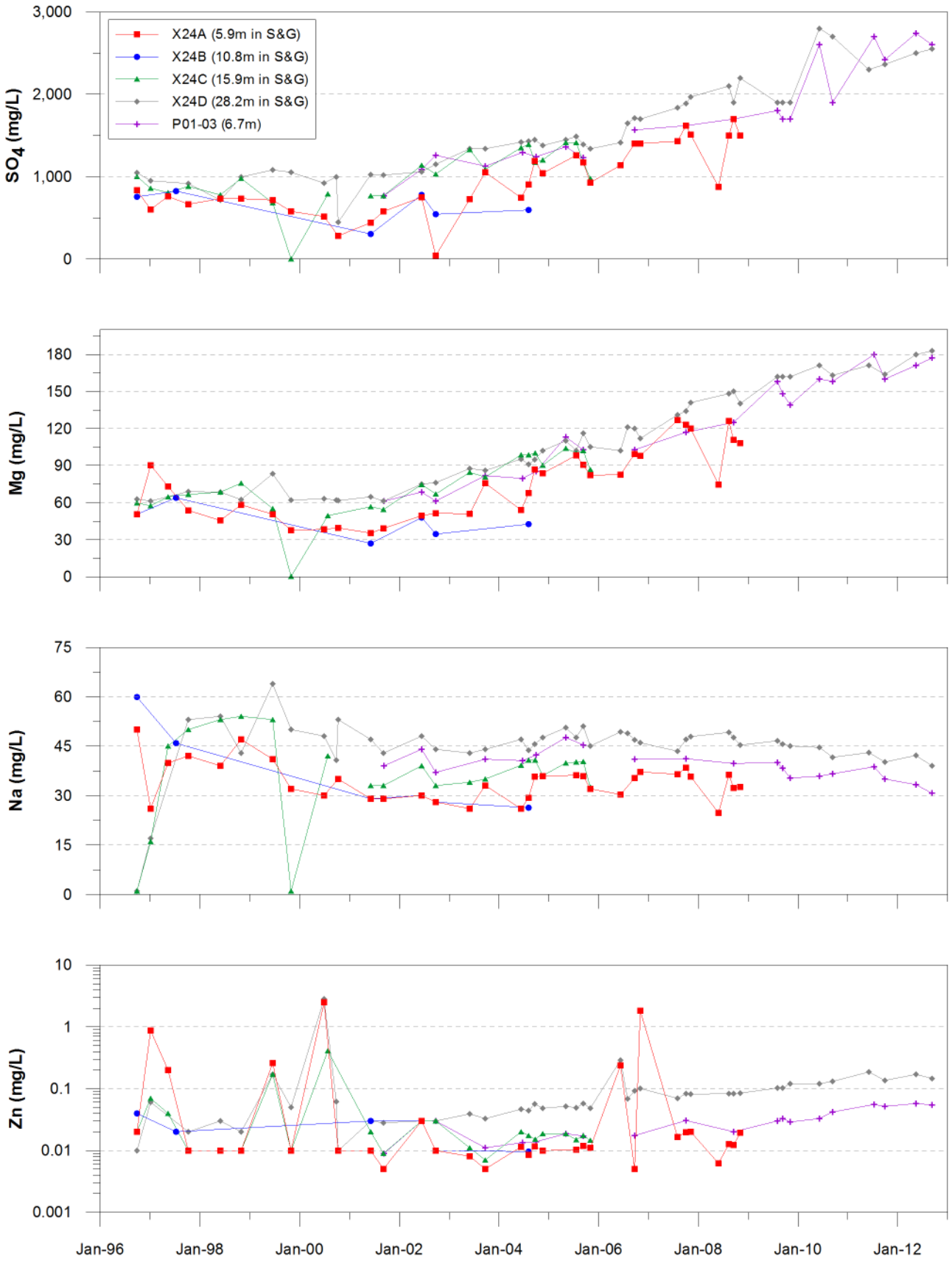


FIGURE 6G-1-9

Time Trends for SO_4, Mg, Na, and Zn in X24(96) and P01-03 at the Northern Side of the Intermediate Dam

Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

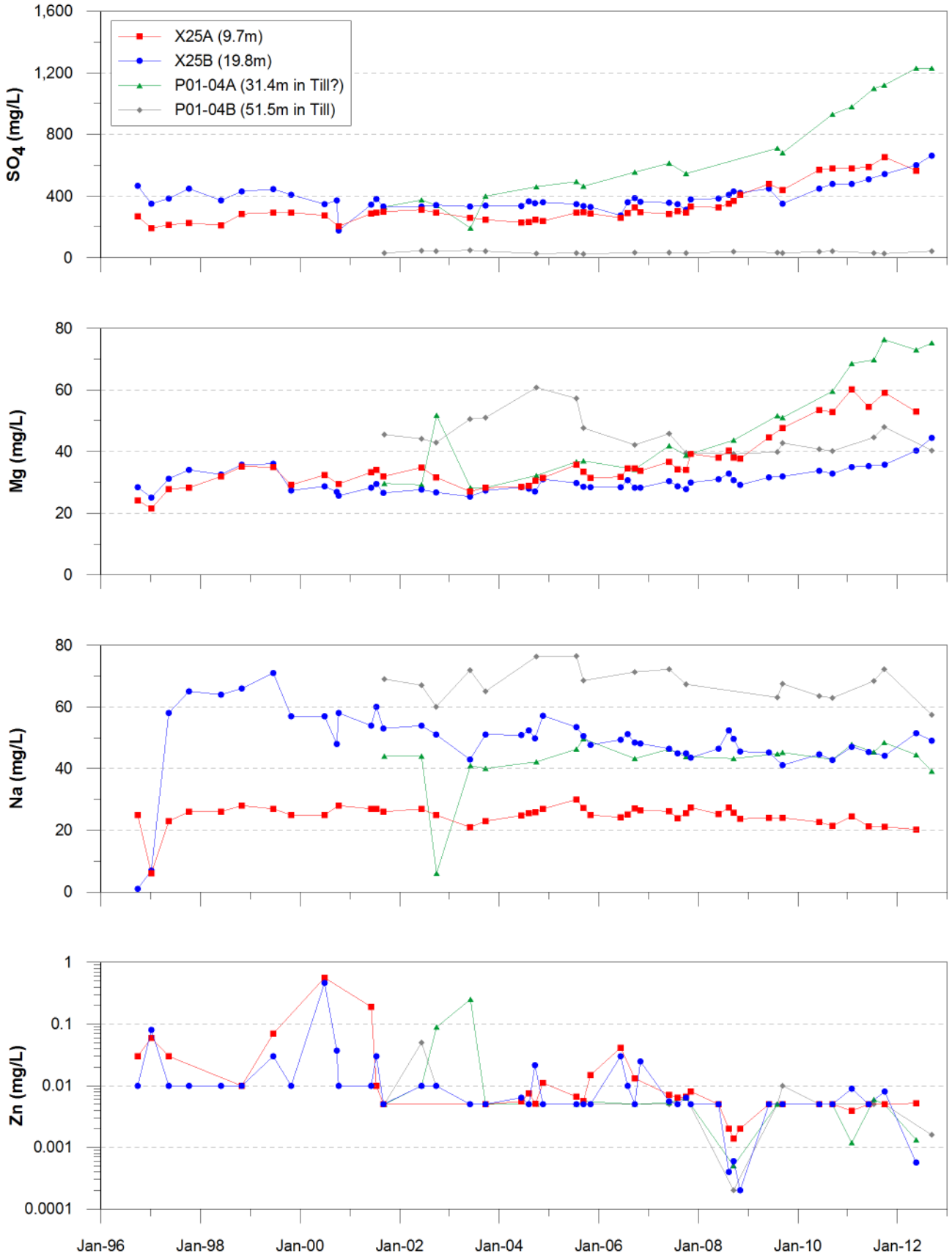


FIGURE 6G-1-10

Time Trends for SO_4, Mg, Na, and Zn in X25(96) and P01-04 at the Southern Side of the Intermediate Dam (North Side of Cross Valley Dam)

Faro Mine Remediation Project

Note:
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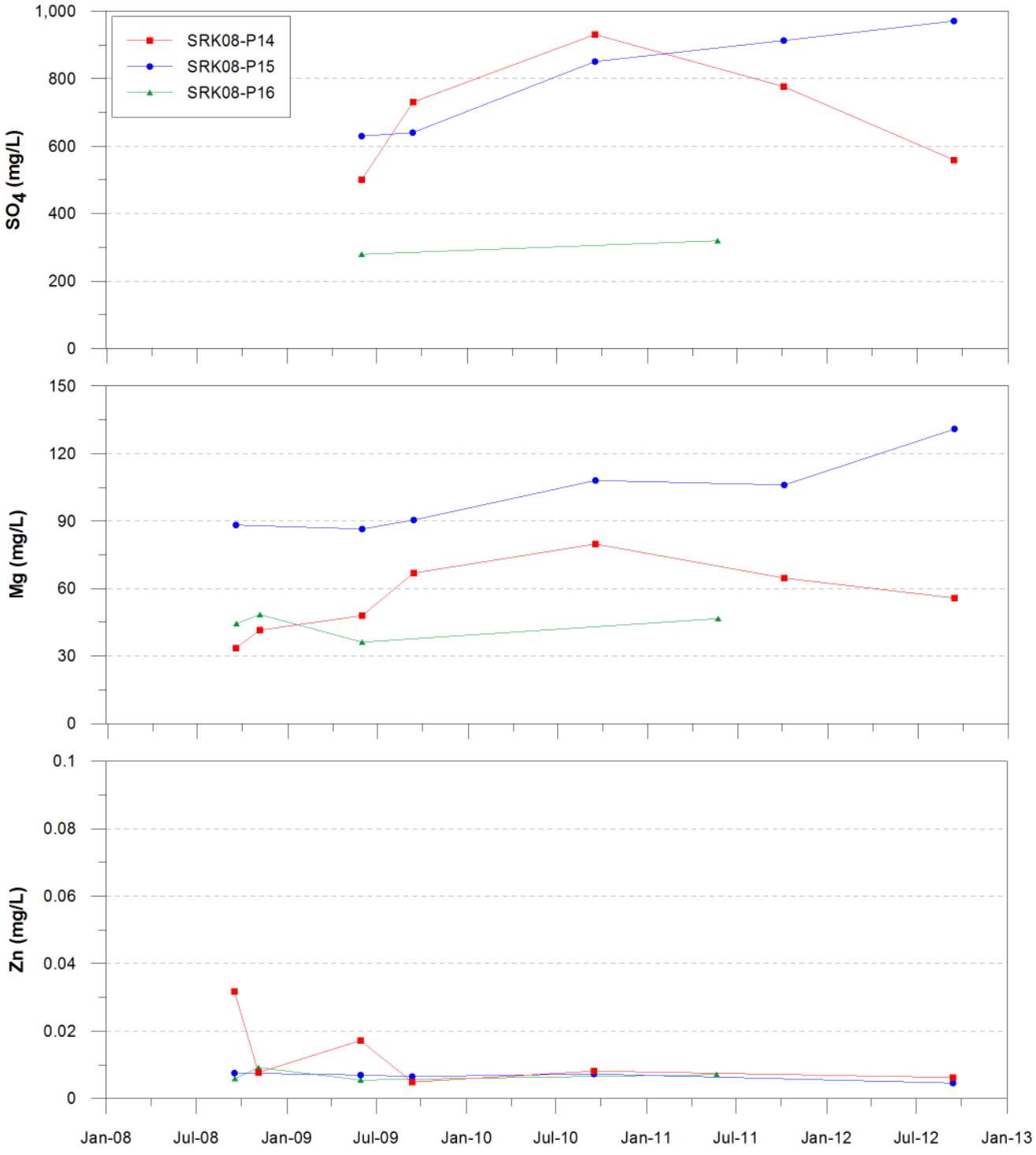

FIGURE 6G-1-11
Time Trends for SO_4, Mg, and Zn in SRK08 Wells Located Southwest of Grum Dump
Faro Mine Remediation Project

Note:
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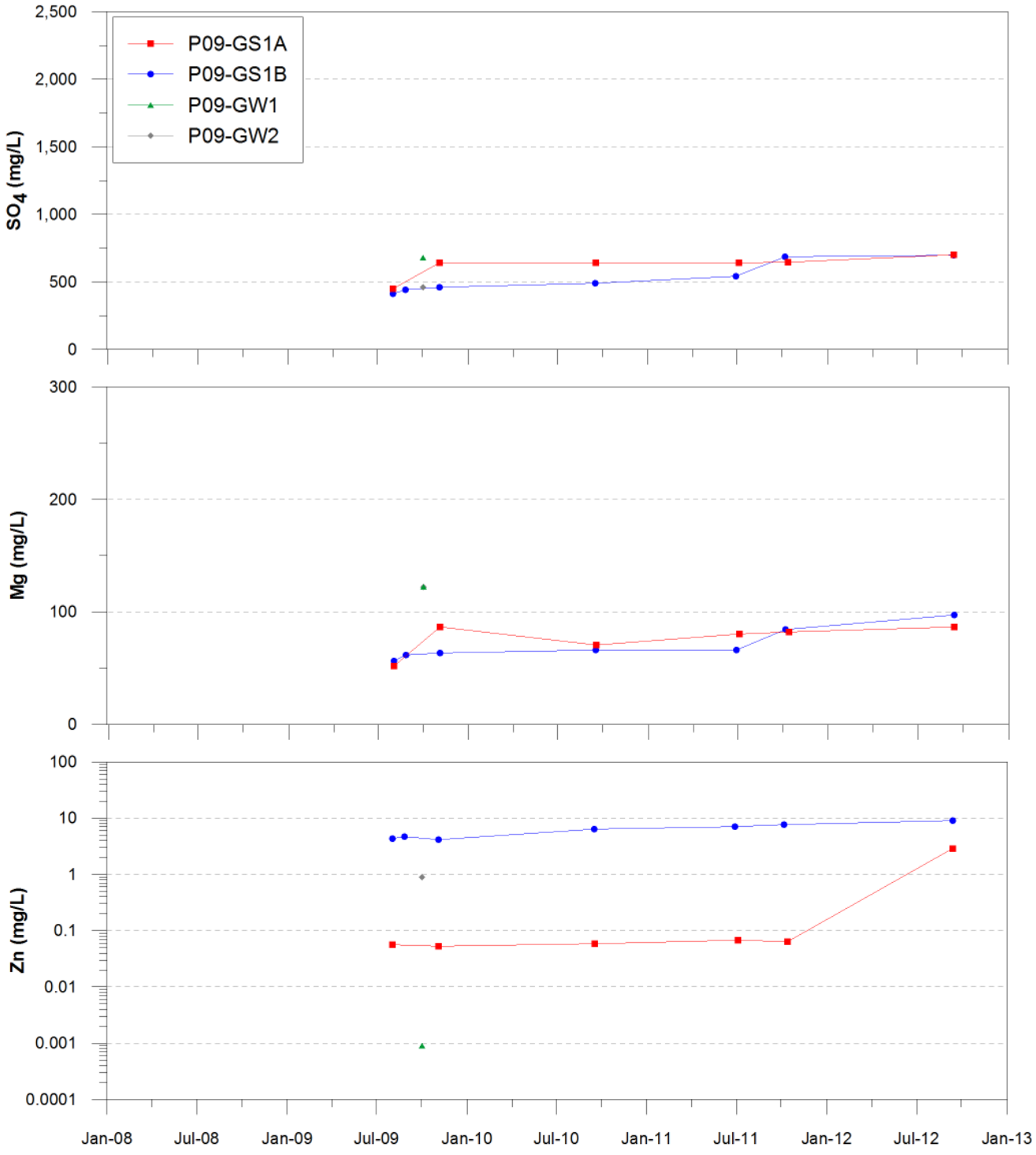

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

FIGURE 6G-1-12
Time Trends for SO_4, Mg, and Zn in Wells Located Near Grum Slot and West of Grum Dump
Faro Mine Remediation Project

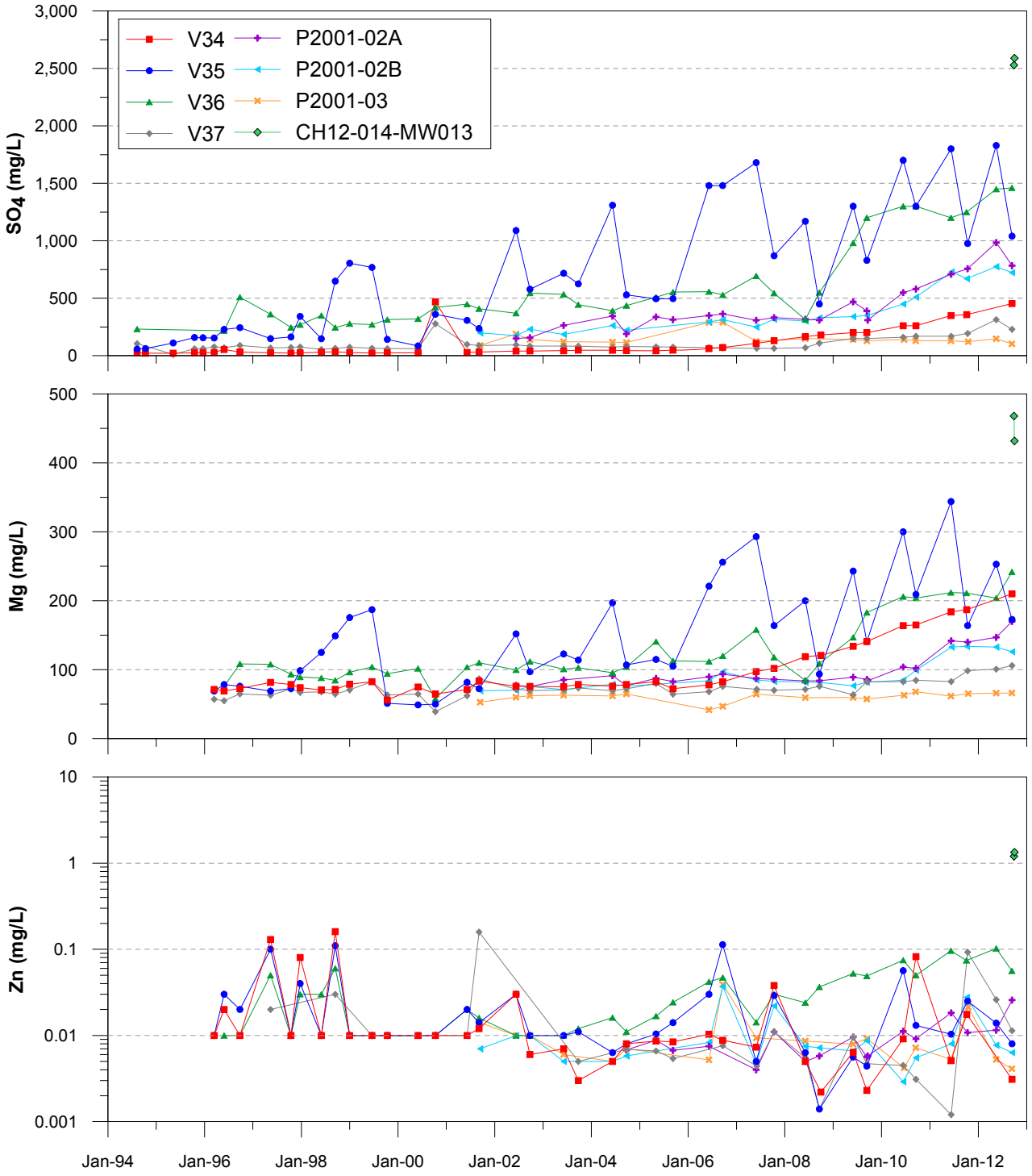

FIGURE 6G-1-13
Time Trends for SO_4, Mg, and Zn in Wells Downgradient of Vangorda Rock Dump
Faro Mine Remediation Project

Note:
Modified with permission from the Government of Yukon from Robertson GeoConsultants, Inc. 2013

Appendix 6H
Aquatic Environment Baseline Report (Minnow)



Aquatic Baseline Characterization, Faro Mine Interim Works (DRAFT)

Report Prepared For:
CH2M HILL

Prepared By:
Minnow Environmental Inc.
Georgetown, ON

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Aquatic Baseline Characterization
Faro Mine Interim Works
(DRAFT)

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EXECUTIVE SUMMARY

The Faro Mine Complex (FMC) was formerly owned by the Anvil Range Mining Corporation, which produced lead and zinc concentrates that were extracted for lead, zinc, silver, and gold. Mine operations were terminated in April 1998 and the site went into receivership. Site Care and Maintenance responsibilities are being managed by contractors acting on behalf of the Government of Yukon (YG), while efforts continue towards development of the final scope and implementation of the overall Faro Mine Remediation Plan (FMRP). In the meantime, YG seeks authorization for 10 years of interim site management and maintenance activities. This document has been prepared to support the assessment under the Yukon Environmental and Socio-economic Assessment Act (YESAA), specifically summarizing current surface water quality and aquatic ecosystem conditions.

Habitat

The FMC occupies portions of both the Rose Creek and Vangorda Creek watersheds. Both creeks are tributaries to the Pelly River, which is a major tributary to the Yukon River. Several physical alterations to stream courses have occurred over time around the FMC to accommodate mine features; these include several stream diversions and numerous road crossings, with some of the latter resulting in barriers to fish passage. Common features among most reaches of the Rose-Anvil Creek and lower Vangorda Creek systems include boulder and cobble substrate, with boulders and pools providing in-stream cover for fish.

Water Quality

Water quality data for the FMC from 2008 through 2012 indicate that concentrations of a variety of non-metals and metals are elevated in surface waters relative to the typical range of background (reference station) concentrations. Alkalinity, conductivity, hardness, sulphate, total dissolved solids, calcium, cobalt, magnesium, nickel, sodium, strontium, and zinc occur at concentrations above the background range in approximately half or more of samples collected downstream of the Vangorda/Grum Area (V8) and the Faro Mine Area (X14). Concentrations of non-metal analytes are below those expected to have adverse effects on aquatic biota.

Despite contaminant contributions from the Vangorda/Grum Area, and likely also the landslide across West Vangorda Creek, metal concentrations in lower Vangorda Creek

(V8) rarely (≤ 15% of samples) exceed guidelines for protection of aquatic life and median concentrations are usually less than half the guideline values. Water concentrations of several metals (cadmium, cobalt, iron, lead, manganese, zinc) are above guidelines in up to one-quarter of samples collected at NF1, on the North Fork Rose Creek (NFRC) upstream from the Haul Road, but zinc is the only mine-related metal that exceeds guidelines at stations between NF1 and Rose Creek station X14, just downstream of the Faro Mine Area. Cobalt and manganese are also found at concentrations above water quality guidelines for protection of aquatic life in up to 40% of samples collected at X14, but median concentrations for all metals other than zinc are below the guidelines. Water quality guidelines are infrequently exceeded at stations farther downstream in Rose Creek (R4) and Anvil Creek (A1) indicating that mine related effects on biota, if any, are likely localized around the Faro Mine Area. Mine-related effects on water quality do not extend into the Pelly River.

Sediment Quality

Arsenic, lead, manganese, and zinc concentrations tend to be elevated in sediment samples collected at mine-exposed areas relative to sediment quality guidelines. However, the survival and growth of the invertebrate *Hyalella azteca* were not affected in 14-day laboratory tests of sediments collected from mine-exposed areas. Mine-related contaminants tend to be associated with fine sediment particles; however the aquatic environments around and downstream from the FMC are typically moderately to swiftly flowing, with sediments composed of particles that are mainly sand-sized or larger. Therefore, sediment exposure to mine-related contaminants represents a relatively minor pathway for potential effects to aquatic biota to mine-related contaminants.

Periphyton

Periphyton communities were characterized in 2009 along the NFRC and the RCD. The group of photosynthetic bacteria known as Cyanophyta dominated the communities in the NFRC just downstream from the confluence with the Faro Creek Diversion, but a shift to diatom (Bacillariophyceae)-dominated communities occurred closer to the Haul Road and continued downstream throughout the RCD. *Achnanthes minutissima* made up roughly 44% (4 – 72%) of the diatom assemblage at all stations and was more abundant downstream than upstream of mine-related influences. *Achnanthes*, especially *A. minutissima*, is generally considered tolerant of a wide variety of environmental conditions and, in other studies, has been observed in streams affected by mining or metals. Data

regarding the tolerance to mine-related disturbance of diatom species other than *A. minutissima* are generally sparse or lacking in the published literature.

Benthic Invertebrate Communities

Benthic invertebrate surveys conducted annually between 2007 and 2010 indicated that communities are dominated by organisms in the mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) groups, as well as midges (chironomids). Most communities in streams adjacent to and downstream from mine-related disturbances at the FMC are similar to communities in local reference areas uninfluenced by mining. Exceptions are communities along lower NFRC and in Rose Creek immediately downstream from the Faro Mine Area where modest differences from reference communities have been evident in some studies.

Fish

Slimy sculpin (*Cottus cognatus*), Arctic grayling (*Thymallus arcticus*), Chinook salmon (*Oncorhynchus tshawytscha*), burbot (*Lota lota*), round whitefish (*Prosopium cylindraceum*) and longnose sucker (*Catostomus catostomus*) have been reported in surface waters around and downstream from the FMC. Within the Rose-Anvil Creek system, slimy sculpin tend to be most abundant, followed by Arctic grayling. Both species appear to utilize surface waters around the Faro Mine Area year-round, although some Arctic grayling migrate to the Pelly River for overwintering. Although juvenile Chinook salmon have occasionally been observed in the Rose Creek system near the FMC, the Rose-Anvil Creek system has been classified as having low to moderate suitability for Chinook salmon spawning and adults have rarely been observed in surface waters around the FMC. Blind Creek, to the east of Vangorda Creek, is a local stream that provides more important habitat for salmon. Downstream of the Vangorda/Grum Area, in lower Vangorda Creek, juvenile Chinook salmon are typically the most abundant fish because this area provides valuable rearing habitat for juveniles that move in from the Pelly River and other tributaries.

Culverts and rock drains associated with road crossings have isolated fish populations in upper NFRC and upper SFRC from populations in the rest of the Rose-Anvil Creek system. Also, a culvert on West Vangorda Creek and a waterfall on the main stem of Vangorda Creek have prevented upstream migration so that fish are only found in the lower reach of Vangorda Creek.

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LIST OF ACRONYMS

< – below

≤ – within or near

≥ – equal to or greater than

°C – degree Celsius

ANOVA – Analysis of Variance

BC – British Columbia

BCMOE – British Columbia Ministry of the Environment

BGBM – Background Benchmark - defined as the 95th [upper] and 5th [lower] percentiles for each variable based on the pooled reference station data set

CABIN – Canadian Aquatic Biomonitoring Network

CCME – Canadian Council of Ministers of the Environment

CCREM – Canadian Council of Resource and Environment Ministers

CH2M HILL – CH2M HILL Canada Limited

CI – Control-Impact

CSQG – Canadian Sediment Quality Guidelines

CWQG – Canadian Water Quality Guidelines

DL – Detection Limit

DOC – Dissolved organic carbon

EDI – Environmental Dynamics Inc.

EPT – Ephemeroptera-Plecoptera-Trichoptera

EQuIS – Environmental Quality Information System

FMC – Faro Mine Complex

FMIW – Faro Mine Interim Works

FMRP – Faro Mine Remediation Project

GLL – Gartner Lee Limited

ha – hectare

km – kilometre

km^2 – square kilometre

Laberge – Laberge Environmental Services

LSA – Local Study Area

m – metre

mg/L – milligram per litre

Minnow – Minnow Environmental Inc.

mm – millimetre

NFRC – North Fork Rose Creek
PEL – Probable Effect Level
RCD – Rose Creek Diversion
RCTA – Rose Creek Tailings Area
RGC – Robertson GeoConsultants Inc.
RSA – Regional Study Area
SFRC – South Fork Rose Creek
TDS – Total Dissolved Solids
TOC – Total Organic Carbon
TSS – Total suspended solids
WMEC – White Mountain Environmental Consulting
YESAA – Yukon Environmental and Socio-Economic Assessment Act
YG – Government of Yukon

1.0 INTRODUCTION

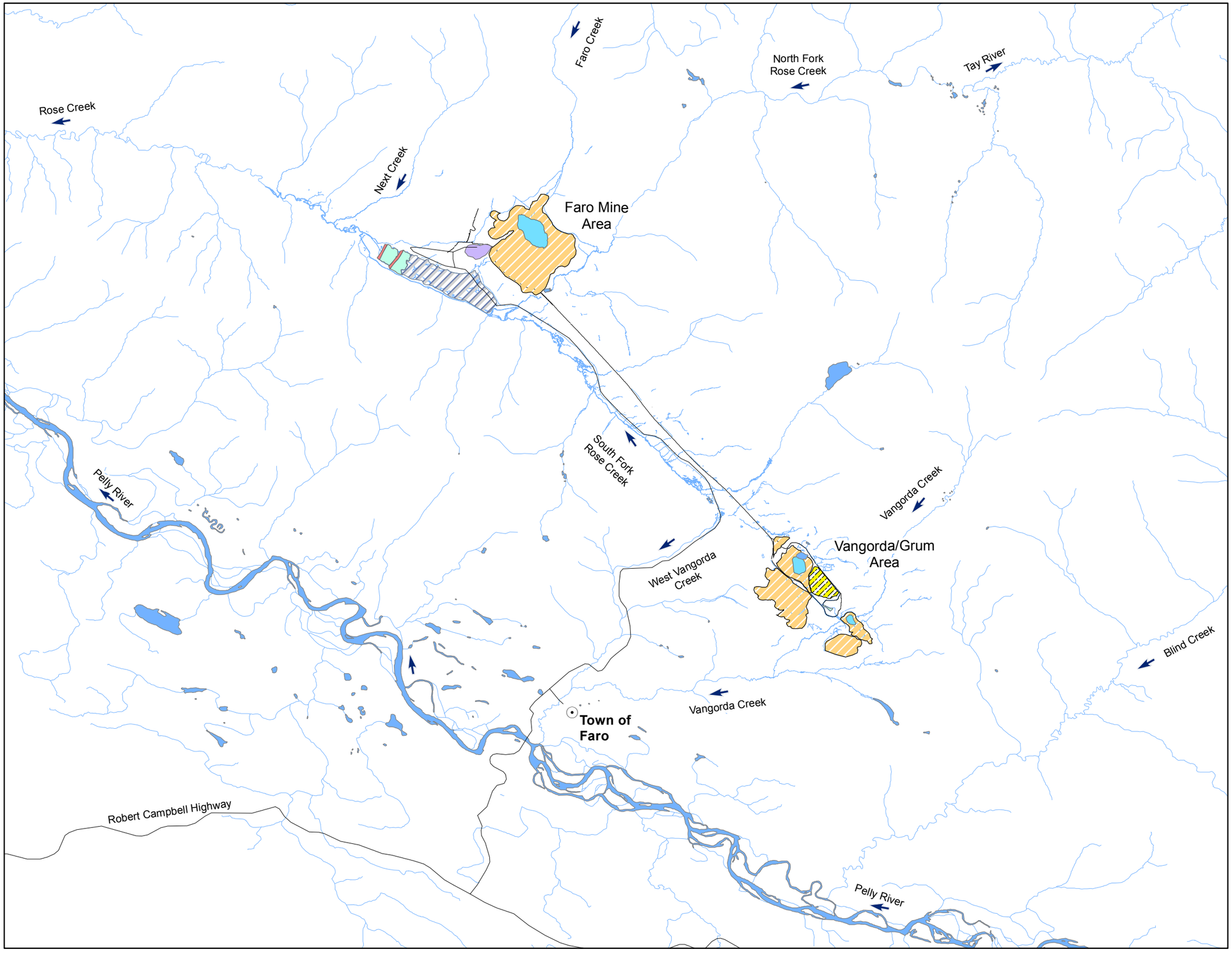
1.1 Background

The Faro Mine Complex (FMC), near Faro, Yukon, includes two areas of former mining activity: the Faro Mine and Mill (Faro Mine Area) and the Vangorda and Grum mines (Vangorda/Grum Area), which are located approximately 12 kilometres (km) apart (Figure 6H-1). The FMC was formerly owned by the Anvil Range Mining Corporation, which produced lead and zinc concentrates that were extracted for lead, zinc, silver, and gold. The Faro Mine Area was mined between 1969 and 1992, while the Vangorda/Grum Area was developed and mined between 1986 and 1998. Milling continued at the Faro Mine Area until April 1998, when all operations at the FMC were terminated due to poor economic circumstances and projections, and the site went into receivership. Until early 2009, management of the mine property was under the direction of Deloitte and Touche Inc., acting as the court appointed Interim Receiver. Site Care and Maintenance responsibilities were transferred in 2009 to Government of Yukon (YG).

While efforts continue towards development of the final scope and implementation of the overall Faro Mine Remediation Plan (FMRP), YG seeks authorization for 10 years of site management and maintenance activities. These activities are being collectively referred to as the Faro Mine Interim Works (FMIW) and will include the following:

- Site Operations, including operation of water management and water treatment facilities, and site maintenance activities;
- Site Investigations, including closure planning, monitoring and investigations;
- Down Valley Interim Hydraulic Upgrades; and
- Accessory Activities

A Project Proposal for the FMIW will be submitted under the *Yukon Environmental and Socio-economic Assessment Act* (YESAA). The Project Proposal will include a description of current (baseline) conditions. Minnow Environmental Inc. (Minnow) was retained by CH2M HILL Canada Limited (CH2M HILL), the company preparing the FMIW Project Proposal on behalf of the proponents (YG and Aboriginal Affairs and Northern Development Canada), to complete the characterization of baseline surface water quality and the aquatic ecosystem conditions, which is more simply referred to, herein, as the "Aquatic Baseline Characterization".



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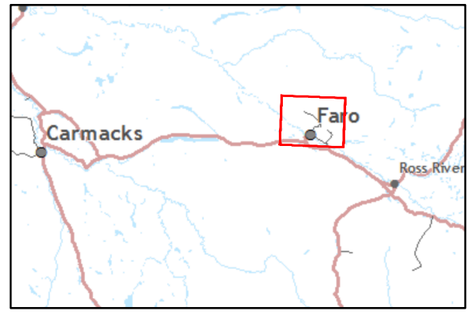

LEGEND

- Direction of Flow

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 0.5 1 2 km

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FIGURE 6H-1

Faro Mine and Vangorda/Grum Areas

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

CH2MHILL

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1.2 Report Organization

Methods associated with the gathering and evaluation of baseline information are described in Section 2.0. Sections 3.0 to 8.0 present the information for different aspects of the aquatic ecosystem near the FMC: habitat characteristics, water quality, sediment quality, periphyton, benthic invertebrates, and fish, respectively. A summary of the aquatic baseline conditions is presented in Section 9.0. References cited throughout the report are presented in Section 10.0

2.0 METHODS

2.1 Study Area

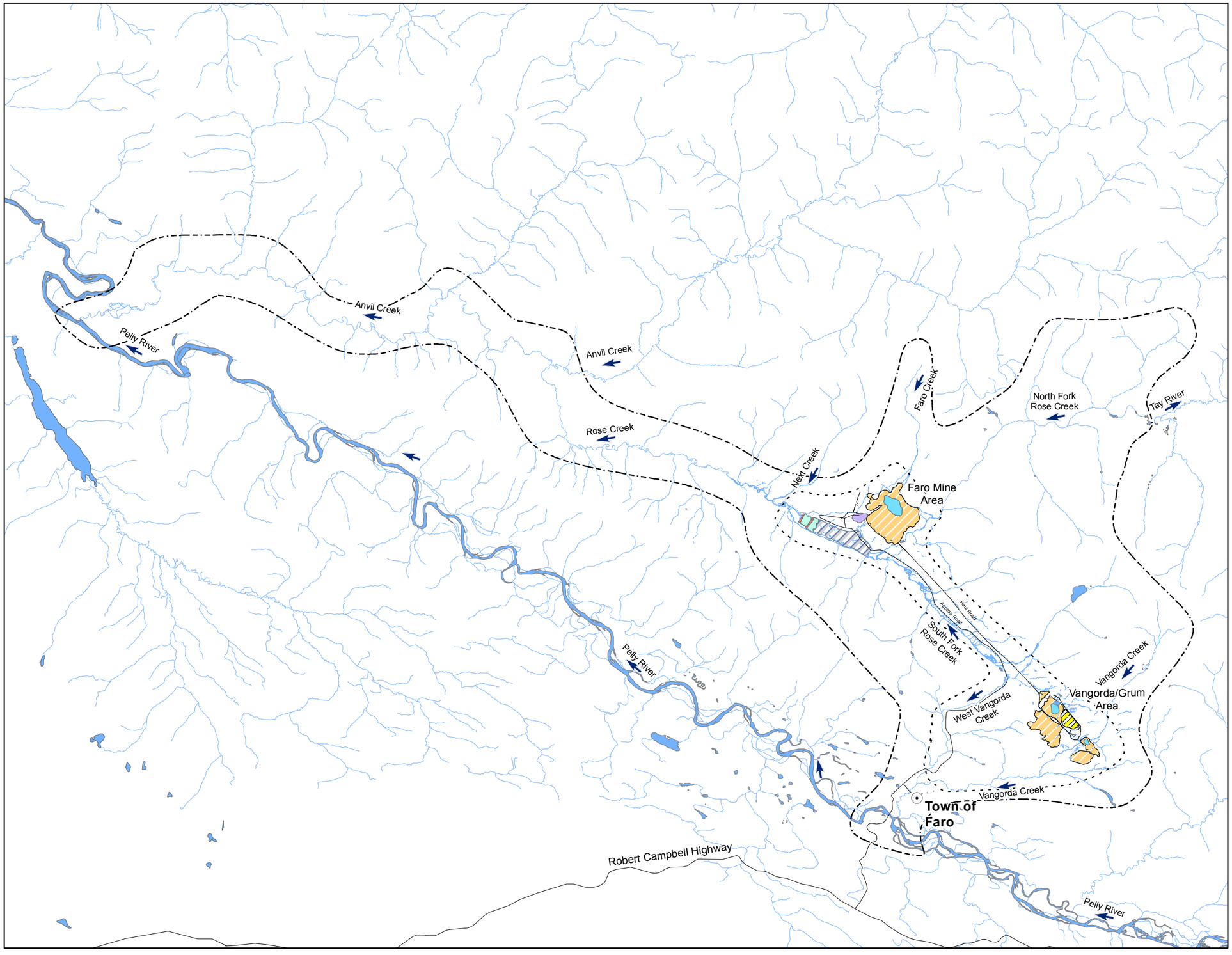
Both local and regional study areas are defined below for the FMIW aquatic baseline characterization, although, in the context of describing aquatic baseline conditions, these two areas are not functionally separate or distinct. Therefore, the aquatic baseline characterization refers to specific streams and locations within streams, where it is appropriate to do so, and otherwise considers local and regional study areas together as "the study area".

2.1.1 Local Study Area

The local study area (LSA) is the area within which the activities of the FMIW will take place and associated effects, if any, are most likely to be realized. For the surface water and aquatic ecology baseline characterization, the LSA encompasses the footprint of the former FMC operations and streams within approximately 500 metres (m) of the mine disturbance footprint (Figure 6H-2). The mine disturbance footprint includes the Faro Mine Area, to the west, and the Vangorda/Grum Area, to the east, as well as the area between the two in which the Access Road and the Haul Road are located. The western and middle portions of the LSA include portions of Faro Creek and the North and South Forks of Rose Creek, as well as the Rose Creek Diversion and Rose Creek immediately downstream from the tailings impoundment (Figure 6H-2). To the east, the LSA, associated with the Vangorda/Grum Area, includes portions of the west and main branches of Vangorda Creek.

2.1.2 Regional Study Area

The regional study area (RSA) for the surface water and aquatic ecology baseline characterization is defined as the maximum area over which there is potential for measureable project-related effects. For the purpose of the FMIW Project, the RSA has been defined as the drainages downstream from the LSA to the Pelly River, including the areas within the Pelly River immediately upstream and downstream of the mouths of Anvil and Vangorda creeks (Figure 6H-2).



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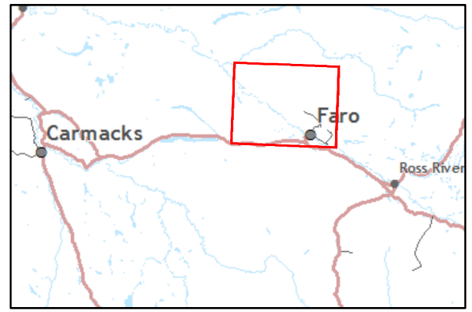

LEGEND

- Aquatic Local Study Area
- Aquatic Regional Study Area
- Direction of Flow

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 1 2 4 km

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FIGURE 6H-2

Aquatic Regional and Local Assessment Study Areas

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

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CH2MHILL

2.2 Sources of Data and Information

2.2.1 Water Quality

Data were provided by CH2M HILL for surface water stations and analytes requested by Minnow for the period 2008-2012, inclusive. This timeframe was selected to characterize baseline conditions using the most recent data available while also ensuring that the data represented a sufficient number of years to account for temporal variation.

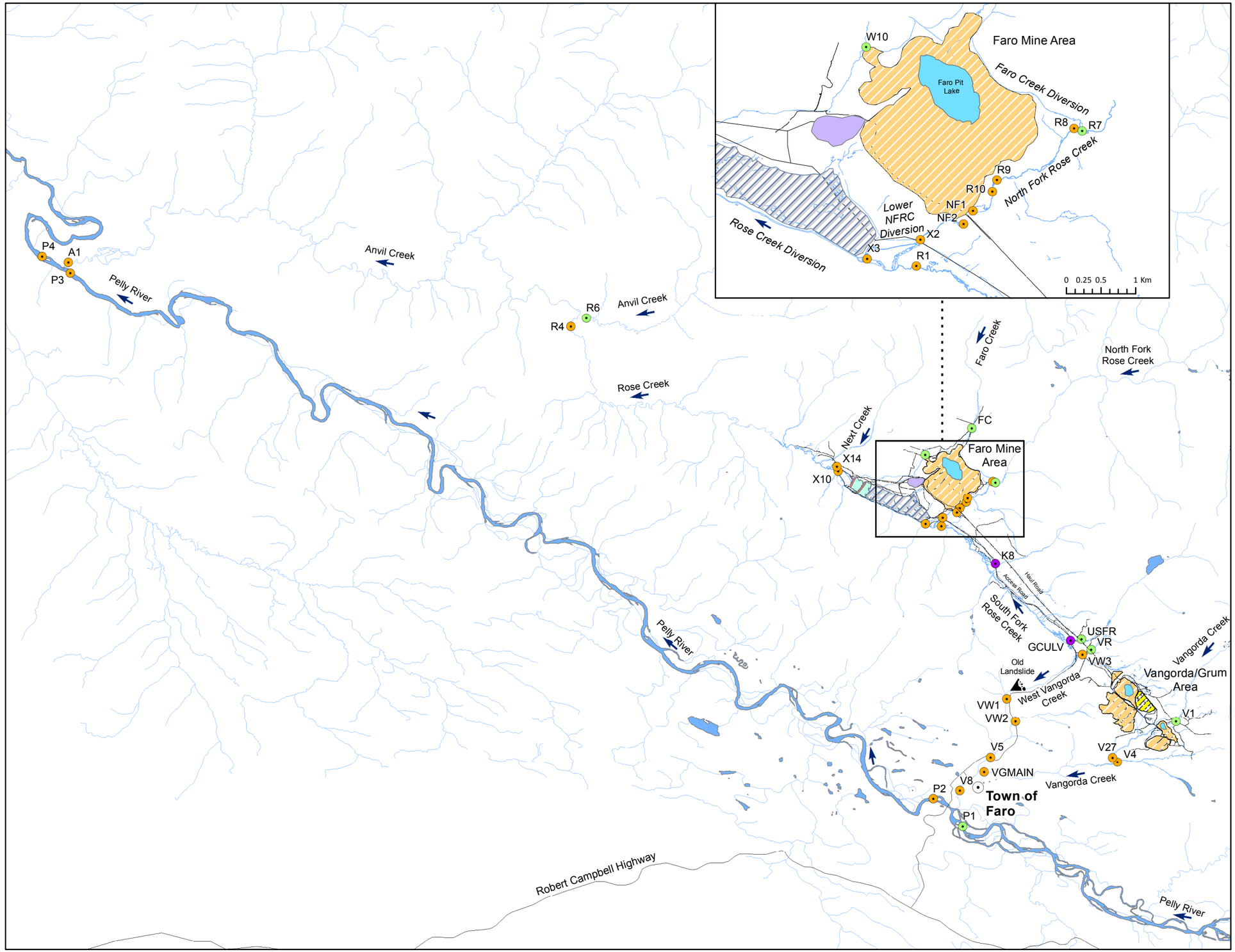
The stations for which water data were acquired included (Figure 6H-3):

- Reference stations: W10, FC, R7, USFR, V1, VR, R6;
- Mine-exposed stations: R8, R9, R10, NF1, NF2, X2, R1, X3, X10, X14, R4, A1/R11 (same location), V27, V4, VGMAIN, VW1, VW2, VW3, V5, V8;
- Pelly River stations: P1, P2, P3, P4; and
- First Nations traditional drinking water stations: GCULV, K8.

Acquired data pertained to analytes identified in past evaluations of surface water at the FMC to be most strongly indicative of mine-related influence on water quality (Minnow 2007, 2010) plus supporting variables that may contribute to water quality interpretation:

- Metals: cadmium, calcium, cobalt, iron, lead, magnesium, manganese, nickel, potassium, silver, sodium, strontium, uranium, zinc;
- Non metals: alkalinity, ammonia, hardness, nitrate, sulphate, total organic carbon (TOC), dissolved organic carbon (DOC), total dissolved solids (TDS), total suspended solids (TSS), turbidity; and
- Field measurements: conductivity, pH.

The data were extracted from an Environmental Quality Information System (EQuIS) that is currently being managed by CH2M HILL and were emailed to Minnow by CH2M HILL on October 9th, 2013. The data were received by Minnow in a Microsoft Excel spreadsheet matrix format organized by sample location and date (rows) versus analytes (columns). Additional data for 2004 through 2007 were requested for representative analytes (zinc, cadmium, sulphate, TSS, and turbidity) to provide a longer-term temporal perspective of water quality related to the FMC. Data collected prior to 2004 were not requested based on data quality concerns described by Minnow (2007) for some analytes.



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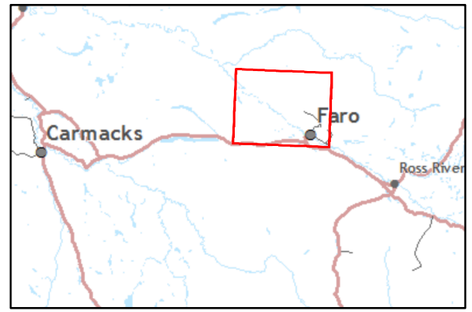

LEGEND

- Landslide
- Direction of Flow

Water Monitoring Station:

- Mine-Exposed
- Reference
- Historical First Nations Drinking Water Location

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 0.75 1.5 3 km

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FIGURE 6H-3

Locations of Reference and Mine-Exposed Water Monitoring Stations

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

2.2.2 Historical Reports and Data

Baseline information related to aquatic habitat characteristics, sediment quality, periphyton communities, benthic invertebrate communities, and fish communities in the vicinity of the FMC were compiled from past environmental reports, which are referenced in the appropriate sections of this report. Periphyton (primary producers), benthic invertebrates (consumers), and fish represent the various trophic levels within the aquatic ecosystem that may be impacted by changes in water and sediment quality. Aquatic habitat data were taken from reports dating as far back as the mid-1970s, based on the assumption that current physical habitat characteristics are likely comparable to past descriptions in areas that have not been physically altered by mine development. Also, individual studies of fish communities provide only a snap-shot in time of species composition and distribution, whereas compilation of data over time provides a more robust perspective of seasonal habitat utilization and abundance. Interpretation of historical habitat and fish community data considered that mine operations were active until 1998, and emphasis has been placed on information acquired in the years since mine operations ceased, particularly with respect to chemical concentrations in environmental media. Sediment quality and benthic invertebrate community data were compiled from studies conducted during the post-operational period, with emphasis on data collected since 2007.

2.3 Data Analyses

2.3.1 Water Quality

The data set was inspected for potential outliers that might confound summary statistics and data interpretation, focusing on identification of impossible or improbable values (e.g., values one or more orders of magnitude above all other values) and concentrations reported as being below the analytical detection limit (<DL) when the detection limit was problematically high (e.g., <DL value that was above the majority of quantified results or a water quality guideline). Decisions to include or exclude values from summary statistics were made on a case-by-case basis using professional judgement, although values were generally excluded only if their retention was likely to bias results or interpretation. All values flagged as potential outliers are highlighted in raw data tables in Attachment B (reference stations; Tables B.9 – B.16) and Attachment C (mine-exposed stations; Tables C.22 – C.48) with footnotes indicating how each value was ultimately handled.

2.3.1.1 Comparisons to Background Concentrations

All available data for reference stations monitored between 2008 and 2012 were pooled and used to compute summary statistics for each water quality analyte, including minimum, maximum, median, mean, standard deviation, and 5th and 95th percentiles. Raw data for the pooled data set and individual reference stations are presented in Attachment Tables B.9 to B.16. The 5th and 95th percentiles of the pooled reference data set were used to approximate the lower and upper range of background concentrations, respectively, for each analyte, and are referred to in this report as upper and lower "background benchmarks" (BGBM). Data for mine-exposed areas were compared to the BGBM for each analyte to identify locations and analytes with concentrations outside of the background concentration range (i.e., indicative of mine-related influence on water quality). In most cases, the upper BGBM was used as the basis of comparison, because mine influence on water quality would usually be expected to increase concentrations relative to background levels. In the cases of pH and alkalinity, it was relevant to also consider potential decreases in concentration due to the acid-generating potential of waste rock dumps and stored tailings. In addition, potential reductions in organic carbon concentrations downstream of mining were evaluated because such occurrences could limit the mitigation capacity of the receiving environment with respect to metal effects on biota (i.e., resulting from complexation of metals with organic carbon). Therefore, for pH, alkalinity, TOC and DOC, concentrations at mine-exposed stations were compared to the lower BGBM (reference 5th percentile), as well as the upper BGBM (reference 95th percentile).

Approximately 5% of concentrations of a given analyte at any station could be expected to naturally occur above the upper BGBM (95th percentile) and 5% could naturally occur below the lower BGBM (5th percentile). However, on a station-by-station basis, some variability could be expected in the specific percentage of samples naturally falling outside of the background range. For greater certainty in identifying locations and analytes with concentrations outside of the background range, analytes having at least 10% of samples above (all analytes) or 10% below (alkalinity, pH, TOC, DOC) the background range were considered to be indicative of mine influence.

In addition to determining the percentage of samples at each station having concentrations outside of the background range, the magnitude of current mine-related influence on water quality was evaluated by computing the ratio of the median concentration of each analyte at each station to the background benchmark.

2.3.1.2 Comparisons to Water Quality Guidelines

For most surface water stations, observed concentrations were compared to guidelines for protection of aquatic life. Canadian water quality guidelines (CWQG) were used if available (Canadian Council of Ministers of the Environment [CCME] 2014); otherwise, an alternative federal water quality criterion was used (e.g., Environment Canada 2013a, for cobalt). In the absence of a federal guideline, a guideline from British Columbia was selected, if available (Table 6H-1). An exception was that the newer British Columbia Ministry of the Environment (BCMOE) guideline (2008) for iron was used instead of the Canadian Council of Resource and Environment Ministers (CCREM) guideline (1987) because the former accounts for differences in toxicity associated with total versus dissolved iron forms.

Some water quality criteria vary on the basis of water hardness (sulphate, cadmium, lead, manganese, nickel, zinc) (Table 6H-2), so median hardness at each station was used to derive station-specific guidelines. This allowed for evaluation of samples for which hardness was not reported. Also, analyses were subsequently performed to verify that this approach did not result in overlooking guideline exceedances for samples with hardness less than the station median (i.e., instances where an analyte would have been flagged as exceeding the guideline, had the guideline been adjusted to the actual sample hardness rather than the median). Such instances were so rare that they had no influence on the overall patterns and interpretation of data. Water quality criteria for total alkalinity, DOC, TOC, TSS, and turbidity are expressed as a change relative to background means or medians; however, this resulted in guidelines that were well within the range of background concentrations. Therefore, the guidelines were modified by applying the incremental change specified by each guideline to the upper BGBM (and lower BGBM, if applicable) instead of to the mean or median (Table 6H-2).

The CWQG for ammonia is expressed on the basis of un-ionized ammonia, which comprises an increasing fraction of the total ammonia present in water as either water pH or temperature increase (or both). However, temperature and/or water pH data were not consistently reported among samples to support sample-specific calculation of the proportion of total ammonia present in the un-ionized form. Because the temperature and pH of surface waters near the FMC rarely rise above 15 degrees Celsius (°C) or 8.5, respectively, it was conservative to compare observed total ammonia concentrations at each station to the total ammonia concentration corresponding to an un-ionized concentration of 0.019 mg/L (the CWQG) at 15°C and pH 8.5 (Table 6H-2). This was calculated using the equation of Emerson et al. (1975):

Table 6H-1: Water quality guidelines for protection of aquatic life that were used to evaluate surface water quality data (selected value is shaded). See Table 6H-2 for site-specific adaptation of guidelines dependent on other water characteristics.

Variable		Units	Canadian Water Quality Guidelines (for protection of aquatic life), CCME 2014[a], unless otherwise footnoted	British Columbia Water Quality Guidelines (for protection of aquatic life), BCMOE 2006[b], 2013[c]
Non-Metals	Unionized ammonia (as NH_3-N)	mg/L	0.0156 (0.019 as whole ion)	guideline expressed as total ammonia[c]
	Nitrate (as NO_3-N)	mg/L	3 (13.0 as whole ion)	3 (13.0 as whole ion)[c]
	Dissolved organic carbon	mg/L	-	30-day median ± 20% of the median background concentration (approved)[c]
	Total organic carbon	mg/L	-	30-day median ± 20% of the median background concentration[c]
	pH	pH units	6.5-9.0	6.5 - 9.0[c]
	Sulphate	mg/L	-	128 - 429 mg/L[c] (hardness dependent)
	Total dissolved solids	mg/L	-	-
	Total suspended solids	mg/L	maximum average increase of 5 from background levels	mean of background plus 5 over 30 days if background is less than or equal to 25[c]
	Turbidity	NTU	maximum average increase of 2 from background levels	mean of background plus 2 over 30 days if background is ≤8 NTU[c]
Metals and Metalloids	Cadmium	mg/L	0.00004 - 0.00037 (hardness dependent)	0.00001 - 0.00006 (hardness dependent)[b]
	Cobalt	mg/L	0.0025[d]	0.004[c]
	Iron	mg/L	0.3	1 (total), 0.35 (dissolved)[c]
	Lead	mg/L	0.001 - 0.007 (hardness dependent)	0.004 - 0.016 (hardness dependent)[c]
	Magnesium	mg/L	-	-
	Manganese	mg/L	-	0.7 - 1.9 (hardness-dependent)[c]
	Nickel	mg/L	0.025 - 0.15 (hardness dependent)	0.025 - 0.15 (hardness dependent)[b]
	Potassium	mg/L	-	373[b]
	Silver	mg/L	0.0001	0.00005 - 0.0015 (hardness-dependent)[b]
	Uranium	mg/L	0.015	0.3[b]
	Zinc	mg/L	0.03	0.075 - 0.24 (hardness dependent)[c]

[a] CCME (Canadian Council for Ministers of the Environment). 2014. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Accessed at http://st-ts.ccme.ca/, February 2014.

[b] BCMOE (British Columbia Ministry of the Environment). 2006. A Compendium of Working Water Quality Guidelines for British Columbia. Environmental Protection Division, Victoria, British Columbia.

[c] BCMOE (British Columbia Ministry of the Environment). 2013. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia. Accessed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html, November 2013.

[d] Environment Canada. 2013a. Federal Environmental Quality Guidelines: Cobalt. February 2013.

Table 6H-2: Explanation of guidelines that depend on other water characteristics.

Variable		Guideline			Comment
		Value	Units	Source	
Non-metals	Total Ammonia (as NH3-N)	0.20	mg/L	CCME (2014)[b]	Guideline is specified as un-ionized ammonia (whole ion), which equals 0.0156 mg/L as un-ionized NH3-N. The equation of Emerson et al. (1975) was used to convert the guideline to total ammonia (as N) based on conservative assumptions of water pH of 8.5 and temperature of 15ºC, as explained in text.
	Organic carbon, dissolved	0.6 - 19.3	mg/L	BCMOE (2013)[a]	Guideline specified as ± 20% of background median concentration but this would not even encompass the range of background values. Instead, the guideline range was calculated by subtracting 20% from the 5th (0.8 mg/L) percentile and adding 20% to the 95th percentile (16.1 mg/L) of the pooled reference station data.
	Organic carbon, total	0.6 - 19.3	mg/L	BCMOE (2013)[a]	Guideline specified as ± 20% of background median but this would not even encompass the range of background values. The 5th (0.7 mg/L) and 95th (13.1 mg/L) percentiles were similar to those for dissolved organic carbon. Total organic carbon cannot be lower than dissolved organic carbon, so the guideline range derived for dissolved organic carbon was adopted for total organic carbon.
	Sulphate		mg/L	BCMOE (2013)[a]	Guidelines depends on water hardness: 0-30 mg/L hardness = 128 mg/L, 31-75 mg/L hardness = 218 mg/L, 76-180 mg/L hardness = 309 mg/L, 181-250 mg/L hardness = 429 mg/L. Median station hardness was used for guideline selection.
	Total suspended solids	25	mg/L	CCME (2014)[b]	Guideline is specified as mean of background TSS (lab) plus 5 mg/L. The mean (7.4 mg/L) of the pooled reference data plus 5 mg/L would result in a guideline of only 12.4 mg/L, which is much lower than the 95th percentile (20 mg/L) and maximum (400 mg/L) of pooled reference station data. Therefore the guideline was calculated as the 95th percentile plus 5 mg/L.
	Turbidity	4.23	NTU	CCME(2014)[b]	Guideline is specified as the mean of background turbidity (lab) plus 2 NTU. The mean (0.8 NTU) of the pooled reference data plus 2 NTU would result in a guideline of only 2.8 NTU, which is only marginally higher than the 95th percentile of background values (2.23 NTU) and much less than the background maximum (6.2 NTU). To maintain consistency with TSS, from which the turbidity guideline was derived (CCME 2002), the turbidity guideline was calculated as the 95th percentile (2.23 NTU) plus 2 NTU.
Metals	Cadmium		mg/L	CCME (2014)[b]	Guideline is hardness-dependent and expressed as ($10^{0.83(\log\{\text{hardness}\})-2.46}$)/1000 to an upper limit of 0.00037 mg/L for waters with hardness above 280 mg/L. Median station hardness was used for guideline derivation.
	Lead		mg/L	CCME (2014)[b]	Guideline is hardness-dependent and expressed as ($3.31 + e^{(1.273\ln(\text{mean hardness})-4.704)}$)/1000. Median station hardness was used for guideline derivation.
	Manganese		mg/L	BCMOE (2013)[a]	Guideline is hardness-dependent and expressed as (0.0044 x hardness) + 0.605. Median station hardness was used for guideline derivation.
	Nickel		mg/L	CCME (2014)[b]	Guideline is hardness-dependent and expressed as ($e^{(0.76\ln(\text{mean hardness})+1.06)}$)/1000. Median station hardness was used for guideline derivation.

[a] BCMOE (British Columbia Ministry of the Environment). 2013. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia. Accessed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html, November 2013.

[b] CCME (Canadian Council for Ministers of the Environment). 2014. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Accessed at http://st-ts.ccme.ca/, February 2014.

$$\text{Fraction UI-NH3} = 1/(1+10^{(pKa-pH)}), \text{ where } pKa = 0.09 + 2730/(273+T°C)$$

Exceptions to the above were stations GCULV and K8, which are locations of traditional drinking water used by local First Nations. For those stations, analyte concentrations were compared to Health Canada drinking water guidelines, if available, otherwise to provincial guidelines (Table 6H-3).

2.3.2 Sediment Quality

Historical sediment metal chemistry data were compiled for the Rose-Anvil and Vangorda creek systems. In cases where replicate samples were collected, mean values were calculated for each metal to facilitate comparisons of sediment quality among areas and over time. Concentrations in each area were evaluated relative to Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CSQG), which are numerical criteria that are designed to be protective of sediment-dwelling organisms based on long-term exposure (CCME 2013).

2.3.3 Periphyton, Benthic Invertebrates, and Fish

Characterization of periphyton, benthic invertebrates and fish relied primarily on critical review of, and compilation of information from, existing reports and data, as well as the overall conclusions presented in each report regarding existing mine-related influences on biota. Maps were prepared to depict sampling areas. Relevant data were summarized in tables and figures (presented in subsequent report sections).

For benthic invertebrate community evaluation, the results of studies conducted in 2008 (Minnow 2009) and 2010 (Laberge Environmental Services [Laberge] 2011) were re-evaluated by collating data for areas that were sampled using the same methods in both studies so results could be directly compared. Statistical methods were consistent with those reported by Minnow (2009) involving non-central t-tests (Kilgour et al. 1998) to determine if the community at each mine-exposed station was different from the reference condition defined by communities sampled in multiple reference areas.

Table 6H-3: Drinking water quality guidelines used to evaluate data for drinking water stations GCULV and K8 (selected value is shaded).

Variable		Units	Canadian Drinking Water Quality Guidelines, Health Canada (2010)[a]	British Columbia (Drinking Water), BCMOE 2006[b,c]	Ontario Drinking Water Quality Standards, Objectives and Guidelines, OMOE (2006)[d]
Non-Metals	Total Alkalinity	mg/L	-	-	30 -500 (operational guideline)
	Nitrate (as NO_3-N)	mg/L	10 (45 as whole ion)	10 (45 as whole ion)	10 (45 as whole ion) (maximum acceptable concentration)
	Dissolved organic carbon	mg/L	-	-	5 (aesthetic objective)
	Total organic carbon	mg/L	-	4 mg/L source water[c]	-
	pH	pH units	6.5-8.5 (aesthetic objective or operational guideline)	6.5 - 8.5 (aesthetic objective)[c]	6.5 - 8.5 (operational guideline)
	Sulphate	mg/L	500 (aesthetic objective or operational guideline)	500 (aesthetic objective)[c]	500 (aesthetic objective)
	Total dissolved solids	mg/L	500 (aesthetic objective or operational guideline)	500[c]	500 (aesthetic objective)
	Turbidity	NTU	0.1- 1.0 based on treatment type	mean of background plus1 if background ≤ 5; mean of background plus 5 if background ≤50; 10% of background if background >50[c]	5 (aesthetic objective)
Metals and Metalloids	Cadmium	mg/L	0.005 (maximum allowable concentration)	0.005 (maximum)[c]	0.005 (maximum acceptable concentration)
	Iron	mg/L	0.3 (aesthetic objective or operational guideline)	≤0.3 (aesthetic objective)[c]	0.3 (aesthetic objective)
	Lead	mg/L	0.01 (maximum allowable concentration)	0.01 (maximum)[c]	0.01 (maximum acceptable concentration)
	Magnesium	mg/L	-	100[c]	-
	Manganese	mg/L	0.05 (aesthetic objective or operational guideline)	≤0.05 (aesthetic objective)[c]	0.05 (aesthetic objective)
	Sodium	mg/L	200 (aesthetic objective or operational guideline)	-	200 (aesthetic objective) or 20 for individuals on sodium restricted diet
	Uranium	mg/L	0.02 (interim maximum allowable concentration)	0.02 (maximum)[c]	0.02 (maximum acceptable concentration)
	Zinc	mg/L	5 (aesthetic objective or operational guideline)	≤ 5 (aesthetic objective)[c]	5 (aesthetic objective)

[a] Health Canada. 2010. Guidelines for Canadian Drinking Water Quality

[b] BCMOE (British Columbia Ministry of the Environment). 2013. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia. Accessed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html, November 2013.

[c] BCMOE (British Columbia Ministry of the Environment). 2006. A Compendium of Working Water Quality Guidelines for British Columbia. Environmental Protection Division, Victoria, British Columbia.

[d] OMOE (Ontario Ministry of the Environment). 2006. Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines. PIBS 4449e01. June 2006.

3.0 HABITAT DESCRIPTION

3.1 Watershed Areas

The Rose-Anvil Creek and Vangorda Creek watersheds affected by the Faro Mine Complex have areas of 980 square kilometres (km^2) and 90 km^2 respectively and are tributaries to the Pelly River. By comparison, the Pelly River watershed has a total drainage area of 49,000 km^2, so the Rose-Anvil Creek and Vangorda Creek drainages represent approximately 2% and 0.2%, respectively, of the total Pelly River drainage area. The Pelly River is a major headwater of the Yukon River. With a total basin area of approximately 49,000 km^2, the Pelly River represents about 6% of the basin area and flow to the Yukon River.

Additional information regarding the hydrology of these systems is provided by CH2M HILL (2013).

3.2 Rose and Anvil Creeks

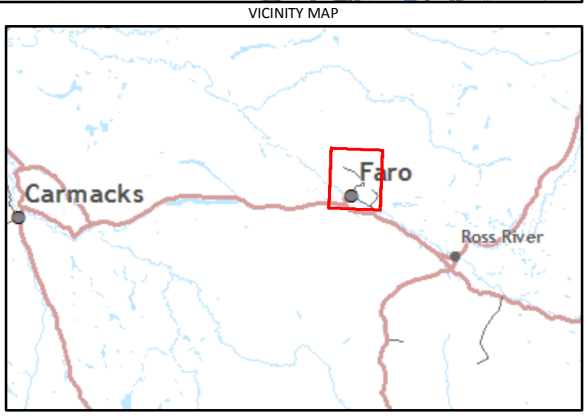
The upper portions of Rose Creek are divided into the North Fork (NFRC) and South Fork (SFRC) which converge just upstream of the Rose Creek Tailings Area (RCTA) (Figure 6H-4). Several physical alterations to stream courses have occurred over time to accommodate mine features, including the Faro Creek Diversion, the North Fork Rock Drain, the lower NFRC diversion, the constructed ground water recharge ponds along the lower NFRC, the creation of the Pumphouse Pond on SFRC, the creation and removal of the freshwater reservoir on the SFRC, the Rose Creek Diversion (RCD), and numerous road crossings (Figure 6H-5); these features are described, as applicable below. Natural aquatic habitat within the Rose Creek and Anvil Creek watersheds has been described in various past projects for the FMC, and this information has been summarized for key reaches (Table 6H-4, Figure 6H-6), and is discussed below. Common features among most reaches of the Rose-Anvil Creek system include boulder and cobble substrate, with boulders and pools providing in-stream cover for fish (Table 6H-4).

3.2.1 North Fork Rose Creek

Aquatic habitat in the upper reaches of the NFRC is relatively undisturbed (de Graff 2013). The creek originates in a wetland that also drains towards the Tay River (Figure 6H-4). Limited fish migration has been speculated to occur between the wetland and the Tay River system during high water events (White Mountain Environmental Consulting [WMEC] 2005b). The upper reach of the NFRC includes ponded areas, deep channels (2

Faro Creek
North Fork Rose Creek
Tay River
Steep Channel, Complete Barrier
North Fork Headwater Ponds
Next Creek
Faro Mine Area
Steep Channel, Partial Barrier
Rock Drain, Complete Barrier
Rose Creek Tailings Area
Culvert, Partial Barrier
Constructed Groundwater Recharge Ponds
Former Freshwater Supply Reservoir
Access Road
Haul Road
Dixon Lake
Mount Mye
South Fork Rose Creek
Culvert, Complete Barrier
Culvert, Complete Barrier
Vangorda Creek
Old Landslide
West Vangorda Creek
Vangorda/Grum Area
Culvert, Complete Barrier
Waterfall, Complete Barrier
Vangorda Creek
Town of Faro
Robert Campbell Highway
Pelly River

VICINITY MAP



LEGEND

- Barrier to Fish Migration
- Direction of Flow

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 0.5 1 2 km

Created by: J. Wilson

minnow environmental inc.

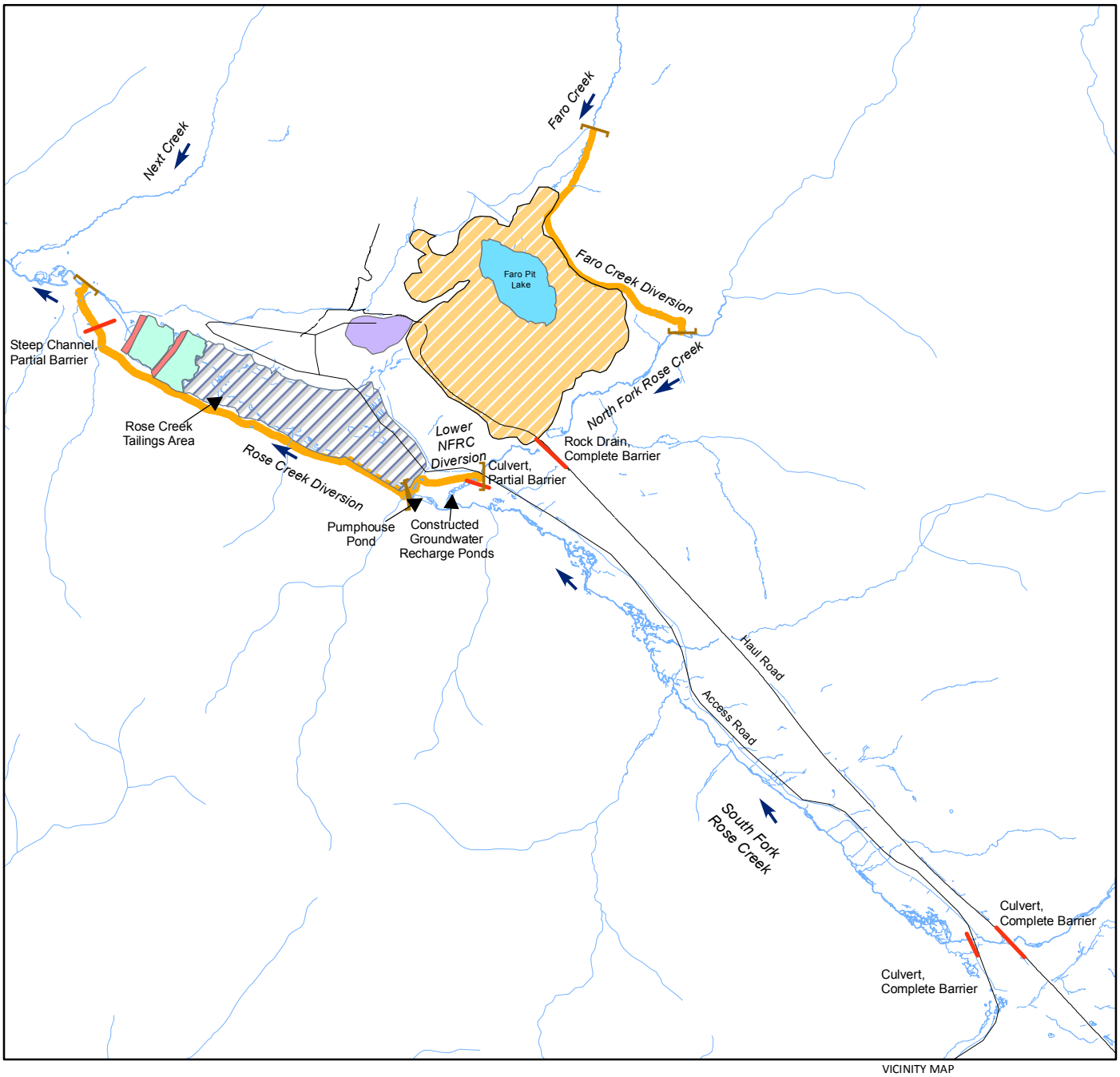
FIGURE 6H-4

Habitat Features of Rose and Vangorda Creeks

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

CH2MHILL



LEGEND

- Barrier to Fish Migration
- Direction of Flow
- Diversion Channels

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Tailings Pond
- Dam
- Mill Area

VICINITY MAP



N

0 0.5 1 km

Created by: J. Tester

minnow environmental inc.

FIGURE 6H-5

Faro Mine Area

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

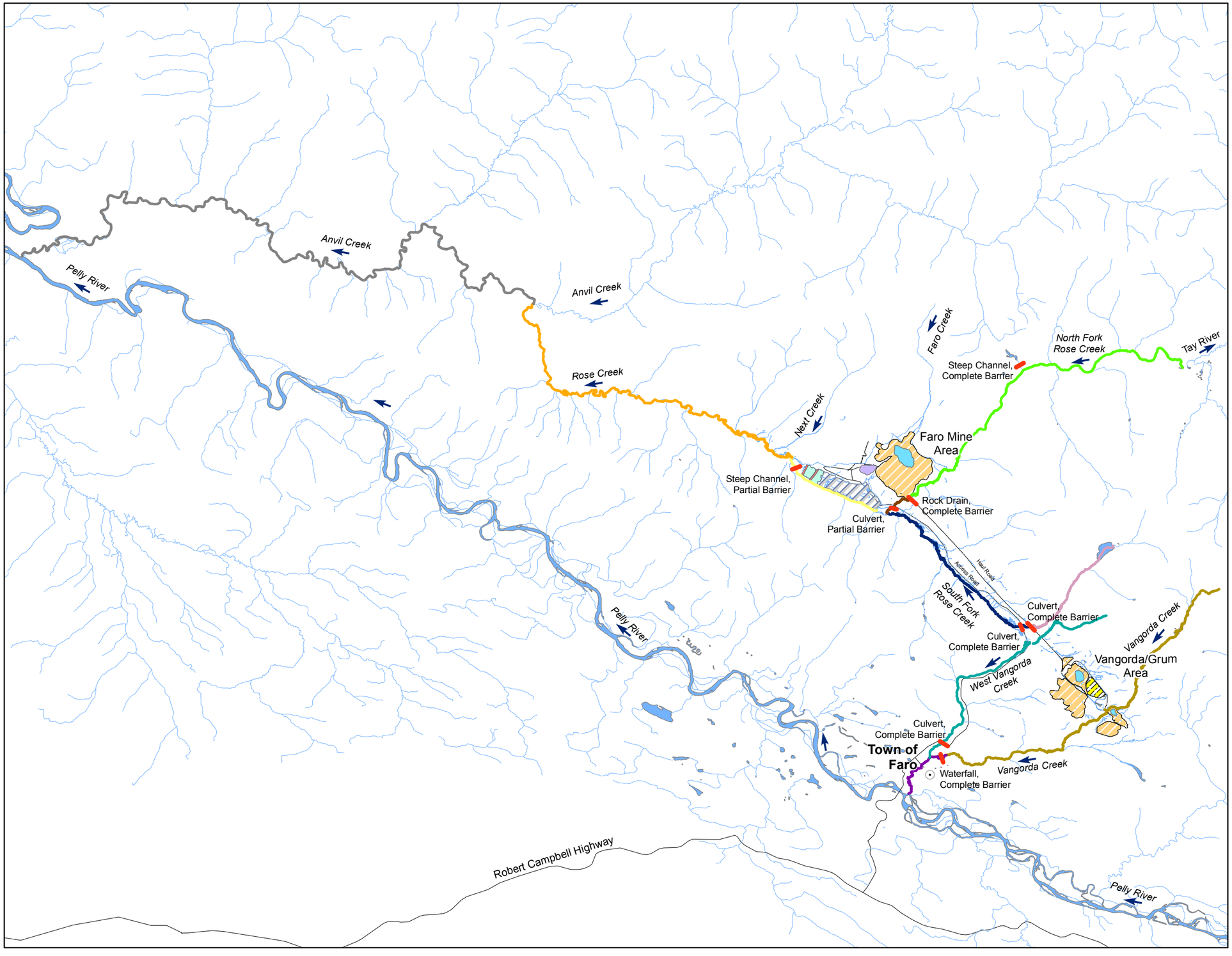
...\CH2M_FARO_8.5X11_PORTRAIT.MXD MWHITE5 11/29/2012 12:04:18 PM

CH2MHILL

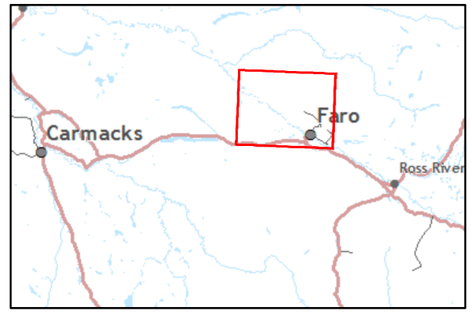
Table 6H-4: Habitat characteristics of creeks in the vicinity of the Faro Mine Complex[a].

Reach			Approximate Reach Length (km)	Channel Width (m)	Wetted Width (m)	Gradient (%)	Dominant Substrate	In-stream Cover (%)	Dominant In-stream Cover	Dominant Riparian Vegetation	Source(s)
Rose-Anvil Watershed	North Fork Rose Creek upstream from Haul Road	Reach 1	17	8 - 12	7.6	0.2 - 2	boulder/cobble	15	boulders, undercut banks, deep	shrubs	Roberston 1996 de Graff 2013
	North Fork Rose Creek downstream from Haul Road	Reach 2	2	8.3 - 8.4	6.5 - 6.8	0.4 - 1.6	boulder/cobble/ gravel	11	boulders, deep pools	shrubs	de Graff 2013
	South Fork Rose Creek upstream from Haul Road	Reach 3	5	8.6	7.7	4.8 - 20	boulder/cobble	70	boulder	willow	Minnow 2009 GLL 2003
	South Fork Rose Creek (Haul Road to confluence with North Fork)	Reach 4	10	4.9 - 10	4.2 - 6.9	0.2 - 2.5	boulder/cobble	16	boulders, pools	grasses, shrubs	Roberston 1996 AECOM 2009
	Rose Creek Diversion Channel	Reach 5	5	14 - 28	13 - 15	0.1 - 5.5	boulder	15	boulders	shrubs	de Graff 2013
	Rose Creek downstream from Faro Mine Complex	Reach 6	21	15 - 25	12 - 15	0.5 - 1.5	cobble/gravel	12	pools, boulder, undercut banks	shrubs, alder	Roberston 1996 WMEC 2008 Leberge 2011
	Anvil Creek downstream of Rose Creek	Reach 7	43	35 - 80	na	0.7 - 1.9	boulder/cobble	na	na	na	Roberston 1996
Vangorda Watershed	West Vangorda Creek	Reach 8	11	2 - 5.6	1.6 - 3.4	1.5 - 4.8	boulder/cobble/ gravel	15	boulder, woody debris	alder, willow	Harder 1987 Minnow 2009
	Upper Vangorda Creek (above falls)	Reach 9	15	4 - 7.4	4 - 4.7	3.5 - 6.8	boulder/cobble/ gravel	20	boulder	willow, grass	Harder 1987 Minnow 2009
	Lower Vangorda Creek (below falls)	Reach 10	3	7.8 - 10	5.2	1.5 - 3.9	boulder/cobble/ gravel	20	boulder	shrubs, alder	Harder 1987 Minnow 2009

[a] data compiled from relevant tables and figures in reports presented in Attachment A.
na - no data available



VICINITY MAP



LEGEND

- Barrier to Fish Migration
- Direction of Flow

Creek Reaches:

- Reach 1 North Fork Rose Creek upstream from Haul Road
- Reach 2 North Fork Rose Creek downstream from Haul Road
- Reach 3 South Fork Rose Creek upstream from Haul Road
- Reach 4 South Fork Rose Creek (Haul Road to confluence with North Fork)
- Reach 5 Rose Diversion Channel
- Reach 6 Rose Creek downstream from Faro Mine Complex
- Reach 7 Anvil Creek downstream from Rose Creek
- Reach 8 West Vangorda Creek
- Reach 9 Upper Vangorda Creek (above falls)
- Reach 10 Lower Vangorda Creek (below falls)

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 0.75 1.5 3 km

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minnow environmental inc.

FIGURE 6H-6

Stream Reaches for which Habitat Data have been Summarized

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

to 3 m deep and less than 5 m wide) with large boulder substrate, and wider flat glades with braiding and summer depths from 0.2 to 0.8 m (WMEC 2005b). A small lake located near the middle of the section of NFRC upstream from the Haul Road discharges to the NFRC though a steep creek that is impassable to fish (Figure 6H-4, WMEC 2005b). Immediately upstream of the Faro Creek Diversion, the channel is deep (2 m) and u-shaped, with finer substrate.

North of the Faro Mine Area, Faro Creek has been diverted from its original flow path so that it now flows around the northeast side of the Faro Pit and into the NFRC (Figure 6H-5). Farther downstream, the NFRC is divided by the rock drain at the Haul Road, which is impassible to fish (Figure 6H-5). In the NFRC reach between the confluence with the Faro Creek Diversion and the Haul Road, stream gradient ranges from 0.2 to 2%, with channel widths between 8 and 12 m (Table 6H-4). de Graff (2013) reported that the stream morphology within in this reach is riffle-pool, and that the channel is frequently confined. A pond located just upstream from the Haul Road was approximately 250 m long and 115 m wide during spring sampling (WMEC 2005a), but the surface area lessens following freshet as flows decrease. Depths also fluctuate depending on time of year and precipitation; average depth in the spring was greater than 4 m, but depth had declined to approximately 1 m when surveyed in August (WMEC 2005b).

Downstream from the Haul Road, the NFRC channel width is approximately 8.5 m, with gradient ranging from 0.4 to 1.6%. The channel is predominantly confined and morphology is mostly riffle-pool, with an area of cascade-pool (de Graff 2013).

Downstream from the Access Road, the NFRC splits into two separate channels (Figure 6H-5). The main channel contains remnants of the original streambed, flowing south to the confluence with the SFRC through five, small (<0.2 hectares [ha]), constructed ponds (de Graff 2013). The constructed ponds were intended to allow surface water to recharge groundwater wells nearby, which were utilized during the winter mine operations (prior to 1997) to augment the supply of process water (Gartner Lee Limited [GLL] 2002). There are culverts at the upper end of these ponds which may seasonally restrict fish movement, but the habitat upstream is accessible through a second channel that forks to the west (lower NFRC diversion, de Graff 2013). The second channel was constructed to divert sediment-laden water away from the Pumphouse Pond (Figure 6H-5) during spring freshet and to provide fish passage into the NFRC (GLL 2002).

3.2.2 South Fork Rose Creek

The SFRC originates just upstream from Dixon Lake (Figure 6H-4). Similar to the NFRC, fish habitat along the SFRC is divided with impassible culverts located at the Haul Road and the Access Road (Figure 6H-4). Aquatic habitat has not been well characterized for most of the reach upstream from the Haul Road. Immediately upstream from the Haul Road, the bankfull width is approximately 8.6 m, the gradient is 4.8%, and the morphology is predominantly riffle (Minnow 2009). A section with a gradient greater than 20% is also present upstream from the Haul Road (GLL 2003) and may present a natural barrier to upstream movement of fish. The reach downstream from the Haul Road to the confluence with the North Fork is approximately 10 km long, with bankfull widths ranging from about 5 to 10 m and gradient ranging from 0.2 to 2.5% (Table 6H-4). The upper portion of this reach (2.2 to 2.5%) is slightly steeper than the remainder, with boulder and cobble habitat (Harder 1991, AECOM 2009). Approximately 2.5 km upstream of the confluence with the NFRC is the location of the former Fresh Water Reservoir (Figure 6H-4), which was decommissioned in late 2003. The valley where the reservoir was located is relatively flat (0.2%) such that, after the reservoir dam was breached, the creek reverted to its original, meandering morphology, with substrate dominated by gravel and finer particles (AECOM 2009). Downstream from the former reservoir is another section of riffle habitat, followed by a wetland complex, and subsequently more riffle habitat downstream to the confluence with the NFRC (AECOM 2009). Boulders and pools provide instream cover for fish throughout most of the SFRC downstream from the Access Road. The SFRC receives some flow via the constructed ponds of the lower NFRC before flowing through the Pumphouse Pond, which is approximately 250 m by 40 m. The Pumphouse Pond was constructed as a water source for mill processing, with flows being augmented as required from the former reservoir. Thereafter, the creek receives flow from the lower NFRC diversion and the combined flow of the north and south forks is routed past the RCTA via the RCD.

3.2.3 Rose Creek Diversion

Downstream from the confluence of the NFRC and SFRC is the RCD, a channel that was constructed to divert water around the RCTA (Figure 6H-5). Generally, habitat and fish cover in the RCD is constrained by the lack of natural stream processes, homogenous substrates and sparse riparian vegetation (de Graff 2013). Wetted widths measured in late summer range from 13 to 15 m (de Graff 2013). In the upper two-thirds of the RCD, gradient is typically 0.5% or less, with predominantly boulder substrate, interspersed with

some cobble and gravel substrate. The lower third of the RCD has a gradient of equal to or greater than (≥) 5%, with predominantly boulder substrate (de Graff 2013). Despite the steep gradient, there are no significant drops along this section, and velocities, though fast, vary across the stream width, including slower-flowing refuges that allow fish with sufficient size and burst speed to migrate upstream during high flow (Environmental Dynamics Inc. [EDI] 2013b). The RCD rejoins the original Rose Creek channel several hundred metres downstream from the RCTA (Figure 6H-5).

3.2.4 Lower Rose Creek and Anvil Creek

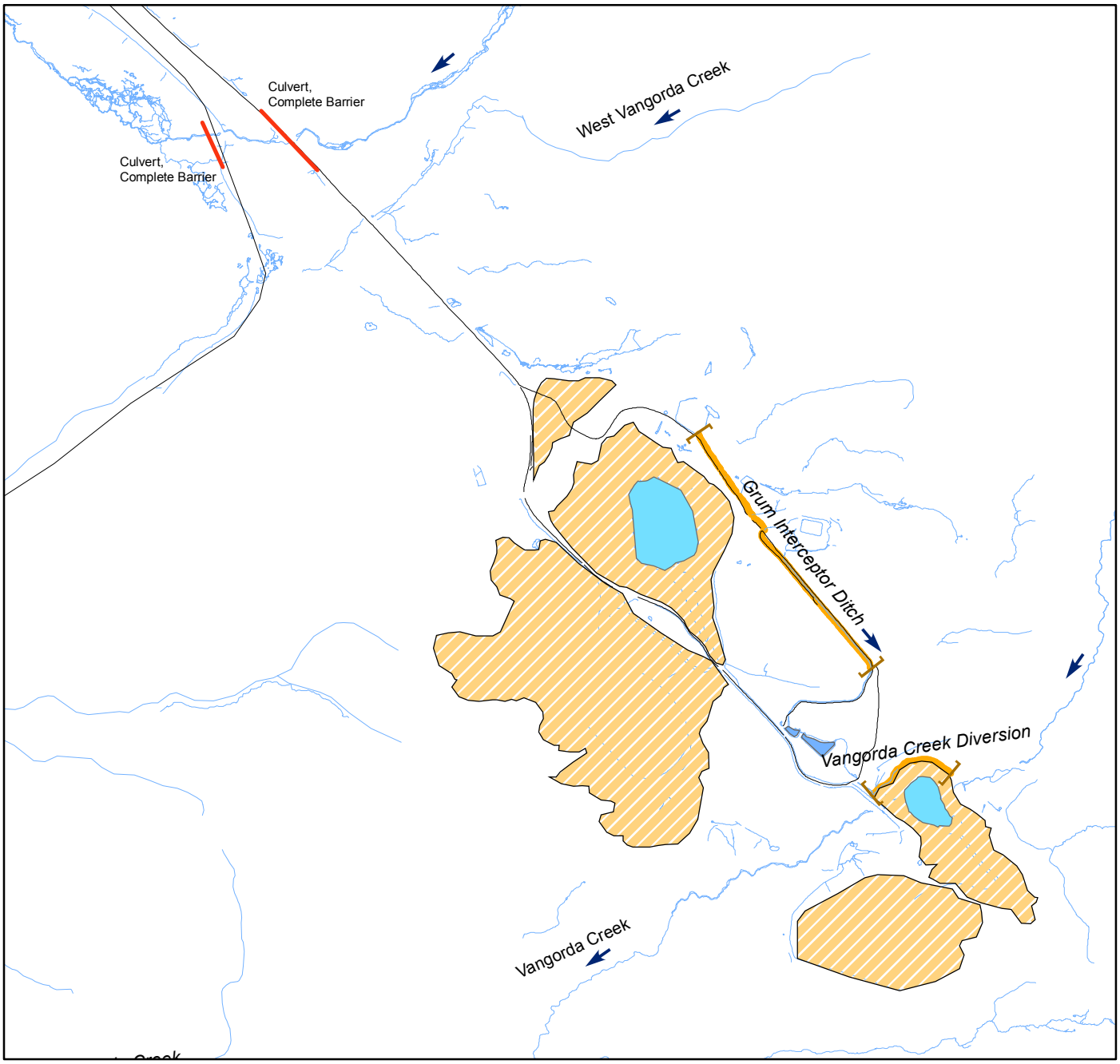
Downstream from the Faro Mine Area, Rose Creek flows approximately 20 km (river, not straight line, distance) to its confluence with Anvil Creek. The substrate of this portion of Rose Creek is predominately cobble/gravel, with gradients from 0.5 to 1.5% (Table 6H-4). Channel widths range from 15 to 25 m. Instream cover is provided by pools, boulders and undercut banks (WMEC 2008).

Thereafter, Rose Creek converges with Anvil Creek, which flows another 40 km (river distance) to the Pelly River, with creek width ranging from 35 to 80 m, and gradients from 0.7 to 1.9% (Table 6H-4). Substrate is predominantly boulder and cobble.

3.3 Vangorda Creek

Vangorda Creek originates approximately 7 km upstream of the Vangorda/Grum Area near the top of Mount Mye. Portions of upper Vangorda Creek have been diverted around pits and rock piles, including a section that flows through a large, metal half-culvert (Figure 6H-7). The main stem of upper Vangorda Creek has a channel width of 4 to 7.4 m, gradients ranging from 3.5 to 6.8%, and substrate dominated by boulder, cobble and gravel (Table 6H-4). Below the Vangorda/Grum Area, the confined channel consists mostly of gravel/cobble/boulder substrate and has a slope of approximately 4% (Robertson GeoConsultants Inc. [RGC] 1996). An 8-m waterfall, which represents a barrier to upstream fish migration, is located on the main stem just upstream from the confluence with West Fork Vangorda Creek (Figure 6H-4).

The West Fork Vangorda Creek originates approximately 3 km upstream from the Haul Road. It has channel widths from 2 to 5.6 m, gradients from 1.5 to 4.8%, and boulder, cobble and gravel substrates. The culvert under the Access Road, near the Town of Faro, presents an impassible barrier to fish migration at its downstream end (Figure 6H-4, GLL 2002).



LEGEND

- Barrier to Fish Migration
- Direction of Flow
- Diversion Channels

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Tailings Pond
- Dam
- Mill Area

VICINITY MAP



N

0 0.3 0.6 km

Created by: J. Tester

minnow environmental inc.

FIGURE 6H-7
Vangorda/Grum Area
Faro Mine Interim Works
Minnow Project No.: 2499 Date: February 2014

...\CH2M_FARO_8.5X11_PORTRAIT.MXD MWHITE5 11/29/2012 12:04:18 PM

CH2MHILL

Downstream from the confluence of the main stem and west fork, Vangorda Creek has channel widths of 7.8 to 10 m and gradients of 1.5 to 3.9% (Table 6H-4). The section from the waterfall to Campbell Street, at the Town of Faro, has a steeper gradient and more boulder substrate, compared to the reach downstream from Campbell Street to the Pelly River, which has a shallower gradient and more cobble and gravel substrate (Harder 1987).

4.0 WATER QUALITY

Characterization of baseline water quality focused on substances identified in previous studies as being elevated in surface waters downstream from the FMC (Minnow 2007, 2010) or having the potential to be elevated in the future based on concentrations in sources such as pit water and waste rock seeps (Minnow 2010) (see methods in Section 2.0). Concentrations of other water quality analytes were shown to be within the range of background surface water concentrations and are therefore not discussed.

Data for reference areas were compiled for relevant analytes and compared to concentrations measured at stations downstream of mine disturbances to identify the locations, frequency, and magnitude of measurable mine-related effects on water quality (Section 4.1). Concentrations measured at stations downstream of mine disturbances were then compared to water quality guidelines for protection of aquatic life to determine the extent to which biota may currently be affected by historical mine operations (Section 4.2).

4.1 Background Water Quality

Background water quality was characterized using data from reference stations located upstream of the FMC on Guardhouse Creek (W10), Faro Creek (FC), North Fork Rose Creek (R7), South Fork Rose Creek (USFR), West Vangorda Creek (VR), and Vangorda Creek (V1), as well as at Anvil Creek upstream of the confluence with Rose Creek (R6) (Figure 6H-3). As described in Section 2.3.1, the data for all reference stations were pooled so the data set would reflect the range of water concentrations naturally occurring among streams in the area. The 5th and 95th percentiles of the pooled data set were used to define the lower and upper range of background concentrations, respectively (Table 6H-5).

Summary statistics for the pooled data set indicate that reference streams tend to be slightly basic, with median pH of 7.7 (range 5.2-9.15). Water hardness is relatively low (median 48 mg/L as $CaCO_3$), but can range up to 251 mg/L. Organic carbon content is also low (median TOC of 2.4 mg/L) and is mainly in dissolved form (i.e., dissolved and total carbon concentrations are approximately equal). Total suspended solids and turbidity also tend to be low (<1 mg/L and 0.5 Nephelometric Tubidity Units [NTU], respectively) but can range up to 400 mg/L and 6.2 NTU, respectively, with highest concentrations typically being associated with spring snow melt and/or large rain events. Metal concentrations are also variable (Table 6H-5).

Table 6H-5: Water quality summary statistics for pooled reference station data (V1, VR, USFR, R7, FC, R6, W10)[a], Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [b]	Standard deviation [b]	Lower Background Benchmark (5th percentile)	Upper Background Benchmark (95th percentile)
Non-Metals	Alkalinity, Total	mg/L	209	5.1	160	40.1	55.1	43.3	10.0	150
	Ammonia-N	mg/L	225	<0.005	0.36	0.01	0.018	0.033	-	0.054
	Conductivity, Field	µS/cm	164	4.4	620	110	137	101	-	292
	Hardness, Total ($CaCO_3$)	mg/L	237	8.2	251	48.0	64.2	48.4	-	159
	Nitrate-N	mg/L	166	<0.002	0.24	0.04	0.06	0.06	-	0.20
	Organic carbon, Dissolved	mg/L	149	<0.5	30.3	2.4	4.4	5.8	0.8	19.0
	Organic carbon, Total	mg/L	151	<0.5	27.8	2.3	4.2	5.4	0.7	15.0
	pH, Field	pH units	184	5.23	9.15	7.73	7.65	0.56	6.6	8.4
	Sulfate	mg/L	234	0.3	25	7.4	8.0	6.0	-	21.5
	Total dissolved solids	mg/L	202	16	300	64	82	50	-	180
	Total suspended solids	mg/L	227	<1	400	<1	7	32	-	20
	Turbidity, Lab	NTU	67	<0.1	6.2	0.53	0.77	1.02	-	2.23
Metals	Cadmium, Total	mg/L	212	<0.000005	0.000348	0.0000120	0.0000256	0.0000396	-	0.000107
	Calcium, Total	mg/L	230	2.47	74.6	14.9	19.0	13.8	-	45.7
	Cobalt, Total	mg/L	207	0.000006	0.00127	0.0000300	0.0000756	0.000168	-	0.000248
	Iron, Total	mg/L	227	<0.001	3.15	0.082	0.15	0.31	-	0.46
	Lead, Total	mg/L	228	<0.000005	0.017	0.000215	0.000600	0.00152	-	0.00203
	Magnesium, Total	mg/L	228	0.27	15.8	2.52	3.86	3.37	-	11.0
	Manganese, Total	mg/L	229	<0.00005	0.212	0.00609	0.0126	0.0230	-	0.0378
	Nickel, Total	mg/L	230	0.00015	0.0107	0.00034	0.00052	0.00092	-	0.0011
	Potassium, Total	mg/L	221	<0.05	2.18	0.55	0.67	0.41	-	1.39
	Sodium, Total	mg/L	226	<0.05	4.9	1.84	1.86	0.66	-	3.08
	Strontium, Total	mg/L	222	0.0168	0.251	0.0681	0.0781	0.0466	-	0.175
	Uranium, Total	mg/L	225	<0.000002	0.00619	0.000683	0.000975	0.000907	-	0.00251
	Zinc, Total	mg/L	230	<0.0001	0.0389	0.0021	0.0039	0.0057	-	0.014

[a] Data for individual reference stations are summarized in Attachment Tables B.2 - B.8.

[b] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

4.2 Downstream Water Quality Relative to Background Levels

Water concentrations measured in mine-exposed areas were compared to background levels. For substances having the potential to be reduced by mine-related disturbances, such as pH and organic carbon, monitoring data indicated that concentrations at mine-exposed stations are rarely below the lower (5th percentile) background benchmark (Attachment Tables B.22 to B.46); therefore, the comparisons subsequently focused on identifying locations and analytes having concentrations above the 95th percentile of background concentrations (i.e., above the upper BGBM). Stations where more than 10% of samples contained analyte concentrations above the corresponding BGBM are shown in Table 6H-6. All substances previously identified as having concentrations that were elevated relative to background levels (Minnow 2010) continued to be elevated in more than 10% of samples collected at one or more stations downstream of mine disturbances in 2008 to 2012, inclusive (Table 6H-6).

Table 6H-7 presents the median concentrations measured at mine-exposed stations compared to the median and upper range of background concentrations, with shading used to highlight locations and analytes having median concentrations above the BGBM. Median concentrations of most analytes are above background levels at most stations located on Vangorda Creek. Such occurrences are less common in the Rose-Anvil Creek system, upstream of X14; however, concentrations at X14 are often more than double those observed at upstream stations. Elevated median hardness, sulphate, manganese, and potassium concentrations persist to A1, at the mouth of Anvil Creek (Table 6H-7)[1].

Monitoring of additional stations on West Vangorda Creek (VW1-VW3) began in 2009 based on recommendations made by Minnow (2010). While there are limited data for the period evaluated (flagged as "ID" in Table 6H-6), the data help to characterize inputs originating from the west side of the Vangorda/Grum Area relative to the effects of a historical landslide that crossed the creek between VW1 and VW3 (Figure 6H-3). Few analytes are elevated at VW3 compared to background concentrations (Table 6H-6, Attachment Table C.25). Data for VW1, farther downstream, provide some evidence that water quality is affected at that location though not many samples were collected over the period assessed (Table 6H-7). Data for a small tributary south of the Vangorda waste rock pile (VW2) suggest that water quality of West Vangorda Creek is influenced by this source as well (Table 6H-7). The effect on water quality from mine sources relative to the

[1] Although median turbidity is also elevated above background levels at A1, relatively lower concentrations at stations closer to the FMC indicate that there is a source of suspended solids between R4 and A1 that is not mine-related.

Table 6H-6: Analytes with concentrations above the corresponding upper background benchmark (95th percentile of reference data) in more than 10% of samples[a] at mine-exposed stations, 2008 - 2012. Blank cells represent variables for which <10% of samples were elevated relative to the upper background benchmark.

	Analyte	Percent of Samples > Background Benchmark																			
		Vangorda Creek Stations								Rose-Anvil Creek Stations											
		V27	V4	VGMAIN	VW3	VW1	VW2	V5	V8	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-metals	Alkalinity, Total		95%	35%	ID	50%	ID	80%	51%										23%		
	Ammonia-N		25%		ID	30%	ID	14%						12%		21%	15%		72%		
	Conductivity, Field	79%	97%	ID	ID	ID	ID	91%	91%			14%	17%	21%		24%	18%	23%	83%	73%	35%
	Hardness, Total (CaCO3)	74%	91%	75%	ID	ID	ID	91%	82%				25%		15%		17%	29%	72%	46%	50%
	Nitrate-N	71%		ID	ID		ID	15%	42%		28%	30%	ID	44%	32%		29%	37%		30%	29%
	Organic carbon, Dissolved			ID	ID	ID	ID									ID				ID	
	Organic carbon, Total			ID	ID	ID	ID		11%												18%
	pH, Field				ID	ID	ID	15%	13%												
	Sulfate	100%	96%	100%	ID	100%	ID	100%	100%				12%	11%	41%	38%	46%	57%	99%	100%	86%
	Total dissolved solids	79%	95%	ID	ID	ID	ID	88%	88%				21%		14%	21%		27%	84%	60%	44%
	Total suspended solids				ID	30%	ID	50%	32%							15%					25%
	Turbidity, Lab		11%		ID	ID	ID	67%	41%				ID		11%	ID			40%	ID	ID
Metals	Cadmium, Total	24%		83%	ID	ID	ID	35%	43%				23%					19%	28%		12%
	Calcium, Total	71%	87%	67%	ID	50%	ID	82%	76%				29%		12%	16%	11%	24%	73%	46%	44%
	Cobalt, Total	11%		89%	ID	ID	ID	59%	46%			29%	75%	14%	28%	24%			100%	63%	27%
	Iron, Total		12%		ID	ID	ID	40%	22%				18%			38%		12%	26%		27%
	Lead, Total			16%	ID	ID	ID	26%	20%		10%		44%	16%	22%	14%			12%	13%	12%
	Magnesium, Total	80%	94%	83%	ID	ID	ID	98%	97%				13%		15%		12%	28%	66%	40%	33%
	Manganese, Total		66%	20%	ID	70%	ID	48%	25%				81%	36%	64%	63%	67%	45%	100%	77%	56%
	Nickel, Total	14%	19%	63%	ID	ID	ID	98%	92%				25%	11%	23%	17%	13%	20%	97%	69%	46%
	Potassium, Total			20%	ID	20%	ID	31%	19%						13%	32%	10%		49%	38%	62%
	Sodium, Total	51%	57%	43%	ID	50%	ID	61%	57%	18%	19%	23%	29%	25%	27%	27%	31%	19%	74%	58%	41%
	Strontium, Total	65%	93%	63%	ID	ID	ID	88%	75%	13%	27%	27%	31%	31%	30%	41%	39%	44%	68%	42%	30%
	Uranium, Total	56%	91%	68%	ID	60%	ID	83%	81%	11%	18%	24%	20%	27%	24%	25%	27%	28%	26%	20%	19%
	Zinc, Total	94%		86%	ID	20%	ID	33%	48%			14%	59%	37%	73%	17%	50%	86%	97%	48%	10%

ID - insufficient data (n<10 samples)

[a] And station median was above background median.

Table 6H-7: Median analyte concentrations at mine-exposed stations compared to the upper background benchmark (2008-2012). Shaded values indicate median concentration was greater than the upper background benchmark (95th percentile of reference stations).

	Analyte	Units	Reference		Vangorda Creek							
			Median	95th Percentile	V27	V4	VGMAIN	VW3	VW1	VW2	V5	V8
Non-metals	Alkalinity, Total	mg/L	40	150	83.5	280	134	56[a]	152	305[a]	200	152
	Ammonia-N	mg/L	0.010	0.054	0.010	0.031	0.011	0.018[a]	0.018	0.005[a]	0.022	0.020
	Conductivity, Field	µS/cm	110	292	513	545	325[a]		267[a]	422[a]	501	552
	Hardness, Total (CaCO3)	mg/L	48	159	270	336	235	72[a]	197[a]	391[a]	274	301
	Nitrate-N	mg/L	0.04	0.20	0.60	0.07	0.23[a]	0.17[a]	0.12	0.16[a]	0.09	0.15
	Organic carbon, Dissolved	mg/L	2.4	19.0	1.6	4.3	12.6[a]				4.3	2.9
	Organic carbon, Total	mg/L	2.3	15.0	1.7	4.5	8.73[a]	10.7[a]	10.6[a]	6.97[a]	3.7	2.85
	pH, Field	pH units	7.7	8.4	8.1	8.0	8.1		8.0[a]	8.2[a]	8.2	8.0
	Sulfate	mg/L	7.4	21.5	163.0	56.8	130.0	33.5[a]	46.2[a]	95.6[a]	80.5	121.5
	Total dissolved solids	mg/L	64	180	340	372	255[a]	120[a]	220	430[a]	325	360
	Total suspended solids	mg/L	<1	20	1.0	2.0	1.0	11.2[a]	7.5[a]	2.0[a]	22.8	4.1
	Turbidity, Lab	NTU	0.53	2.2	0.3	1.6	0.3	4.0[a]		0.6[a]	5.6	1.5
Metals	Cadmium, Total	mg/L	0.000012	0.000107	0.000066	0.000022	0.000200	0.000209[a]	0.000015	0.000115[a]	0.000071	0.000078
	Calcium, Total	mg/L	14.9	45.7	65.0	83.0	64.8	19.5[a]	47.0	96.3[a]	65.5	69.5
	Cobalt, Total	mg/L	0.000030	0.000248	0.00003	0.00007	0.00100	0.00029[a]	0.00011	0.00002[a]	0.00041	0.00020
	Iron, Total	mg/L	0.082	0.46	0.04	0.24	0.07	0.23[a]	0.13	0.01[a]	0.24	0.12
	Lead, Total	mg/L	0.00022	0.00203	0.00039	0.00022	0.00100	0.00128[a]	0.00022	0.00006[a]	0.00109	0.00100
	Magnesium, Total	mg/L	2.52	11.0	24	30.2	20.2	5.86[a]	17.3	36.1[a]	24.85	24.9
	Manganese, Total	mg/L	0.00609	0.0378	0.0037	0.0454	0.0080	0.0132[a]	0.0689	0.0004[a]	0.0362	0.0160
	Nickel, Total	mg/L	0.00034	0.0011	0.0008	0.0008	0.0016		0.0006	0.0012[a]	0.0023	0.0020
	Potassium, Total	mg/L	0.55	1.39	0.86	1.06	1.04	0.56[a]	0.89	1.04[a]	1.20	1.09
	Sodium, Total	mg/L	1.84	3.08	3.1	3.2	2.7	1.0[a]	3.2	2.5[a]	3.5	3.5
	Strontium, Total	mg/L	0.0681	0.175	0.230	0.337	0.259	0.091[a]	0.203	0.327[a]	0.264	0.275
	Uranium, Total	mg/L	0.000683	0.00251	0.0034	0.0099	0.0036	0.0011[a]	0.0026	0.0072[a]	0.0038	0.0041
	Zinc, Total	mg/L	0.0021	0.014	0.0309	0.0036	0.0230	0.2383[a]	0.0034	0.0048[a]	0.0089	0.0141

	Analyte	Units	Reference		Rose Creek / Anvil Creek											
			Median	95th Percentile	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-metals	Alkalinity, Total	mg/L	40	150	93	97	98	83	96	94	89	97	109	97	113	120
	Ammonia-N	mg/L	0.010	0.054	0.020	0.021	0.020	0.020	0.014	0.015	0.018	0.030	0.020	0.078	0.010	0.005
	Conductivity, Field	µS/cm	110	292	179	202	207	187	221	204	198	222	216	500	411	243
	Hardness, Total (CaCO3)	mg/L	48	159	97	108	104	91	109	108	97	115	130	217	156	161
	Nitrate-N	mg/L	0.04	0.20	0.08	0.13	0.13		0.19	0.14	0.07	0.15	0.16	0.06	0.12	0.10
	Organic carbon, Dissolved	mg/L	2.4	19.0	2.2	2.1	2.3	3.2	2.2	2.3	3.9[a]	2.3	2.2	2.6	1.7[a]	3.6
	Organic carbon, Total	mg/L	2.3	15.0	2.2	2	2.35	3.2	2.1	2.29	2.76	2.24	2.4	2.6	2.7	3.92
	pH, Field	pH units	7.7	8.4	7.8	7.7	7.7	7.5	7.5	7.6	7.8	7.7	7.8	7.9	7.4	7.9
	Sulfate	mg/L	7.4	21.5	8.1	13.3	12.8	12.0	15.8	17.1	20.0	20.0	23.2	130.0	56.0	43.0
	Total dissolved solids	mg/L	64	180	114	130	129	120	137	130	140	132	148	310	247	180
	Total suspended solids	mg/L	<1	20	1.0	1.0	1.0	4.0	1.0	1.4	3.0	1.0	1.0	2.0	1.0	3.5
	Turbidity, Lab	NTU	0.53	2.2	0.8	0.7	0.8		0.8	0.9	2.9[a]	0.8	0.9	1.8	0.5[a]	13.9
Metals	Cadmium, Total	mg/L	0.000012	0.000107	0.000009	0.000011	0.000014	0.000043	0.000024	0.000026	0.000021	0.000018	0.000020	0.000060	0.000032	0.000030
	Calcium, Total	mg/L	14.9	45.7	29.6	33.6	31.8	30.6	30.1	30.8	28.0	33.5	36.3	61.2	45.0	43.2
	Cobalt, Total	mg/L	0.000030	0.000248	0.00004	0.00004	0.00006	0.00040	0.00012	0.00017	0.00010	0.00010	0.00008	0.00171	0.00034	0.00013
	Iron, Total	mg/L	0.082	0.46	0.14	0.14	0.14	0.30	0.16	0.19	0.38	0.17	0.24	0.38	0.15	0.15
	Lead, Total	mg/L	0.00022	0.00203	0.00049	0.00052	0.00039	0.00188	0.00093	0.00100	0.00039	0.00060	0.00048	0.00078	0.00038	0.00030
	Magnesium, Total	mg/L	2.52	11.0	5.73	6.61	6.11	5.22	6.72	6.47	5.69	7.17	8.74	14.45	9.72	10.4
	Manganese, Total	mg/L	0.00609	0.0378	0.0164	0.0176	0.0181	0.0722	0.0286	0.0623	0.0607	0.0505	0.0353	1.2700	0.3135	0.0468
	Nickel, Total	mg/L	0.00034	0.0011	0.0004	0.0004	0.0005	0.0009	0.0006	0.0009	0.0006	0.0006	0.0008	0.0032	0.0015	0.0010
	Potassium, Total	mg/L	0.55	1.39	0.79	0.84	0.81	0.76	0.86	0.90	0.95	1.00	1.00	1.38	1.28	1.42
	Sodium, Total	mg/L	1.84	3.08	2.2	2.2	2.3	2.1	2.5	2.2	2.3	2.4	2.4	4.3	3.4	2.8
	Strontium, Total	mg/L	0.0681	0.175	0.120	0.133	0.133	0.110	0.142	0.124	0.151	0.157	0.164	0.224	0.157	0.154
	Uranium, Total	mg/L	0.000683	0.00251	0.0014	0.0015	0.0015	0.0009	0.0015	0.0013	0.0017	0.0017	0.0017	0.0014	0.0011	0.0018
	Zinc, Total	mg/L	0.0021	0.014	0.0025	0.0038	0.0068	0.0190	0.0106	0.0240	0.0050	0.0143	0.0287	0.0493	0.0140	0.0048

[a] limited data (n<10)

landslide cannot be conclusively determined from the available data. Concentrations of many analytes remain elevated above background levels to the mouth of Vangorda Creek at V8 (Table 6H-7).

For most variables, the ratio of the station median to the upper BGBM is less than three (Table 6H-8), indicating a relatively modest magnitude of mine-related influence on water quality relative to background concentrations.

4.3 Comparisons to Water Quality Guidelines

Water quality data from mine-exposed stations in the Rose-Anvil and Vangorda drainages were also compared to water quality guidelines for protection of aquatic life. The percent of samples at each station having concentrations above the respective guidelines is shown in Table 6H-9, to indicate frequencies of guideline exceedances, while the ratio of the median concentration to the guideline is shown in Table 6H-10 to indicate relative magnitudes of guideline exceedances among stations and analytes.

4.3.1 Non-metals

Approximately 16% of samples at X14 over the 2008 - 2012 period had concentrations of ammonia that were above the guideline (Section 2.3.1.2, Table 6H-9), which resulted from using conservative assumptions of temperature and pH to convert the guideline for un-ionized ammonia to a total ammonia guideline (Table 6H-2). This was done because temperature and pH values, which are needed to estimate the proportion of total ammonia present in the un-ionized form, were not consistently reported for samples. However, pH was available for most samples and using these values with a conservatively high temperature of 15ºC results in estimates of un-ionized ammonia at X14 that are consistently below the water quality guideline for protection of aquatic life of 0.0156 mg/L un-ionized NH3-N. Therefore, ammonia concentrations do not appear to be of concern in surface waters downstream of the FMC.

Sulphate concentrations were above background concentrations at mine-exposed stations in Vangorda Creek and at X14 in Rose Creek (Table 6H-8), but were consistently below the guideline for protection of aquatic life (Table 6H-9).

Of other non-metal analytes that had elevated concentrations relative to guidelines downstream of mine sources (Table 6H-9), TOC, DOC, TSS and turbidity all have guidelines that are derived as a specified magnitude or proportional increment from background concentrations (Tables 6H-1, 6H-2). Such guidelines would typically be

Table 6H-8: Ratio of median analyte values at mine-exposed stations to the upper background benchmark (95th percentile of reference data) [a]. Highlighted values indicate median concentrations that were at least 3 times higher than the upper background benchmark, to accentuate stations and variables reflecting greatest mine-related influence.

	Analyte	Vangorda Stations								Rose-Anvil Stations											
		V27	V4	VGMAIN	VW3	VW1	VW2	V5	V8	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-Metals	Alkalinity, Total	0.6	1.9	0.9	0.4 [b]	1.0	2.0 [b]	1.3	1.0	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.8	0.8
	Ammonia-N	0.2	0.6	0.2	0.3 [b]	0.3	0.1 [b]	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.6	0.4	1.4	0.2	0.1
	Conductivity, Field	1.8	1.9	1.1 [b]	no data	0.9 [b]	1.4 [b]	1.7	1.9	0.6	0.7	0.7	0.6	0.8	0.7	0.7	0.8	0.7	1.7	1.4	0.8
	Hardness, Total (CaCO3)	1.7	2.1	1.5	0.5 [b]	1.2 [b]	2.5 [b]	1.7	1.9	0.6	0.7	0.7	0.6	0.7	0.7	0.6	0.7	0.8	1.4	1.0	1.0
	Nitrate-N	3.0	0.4	1.2 [b]	0.9 [b]	0.6	0.8 [b]	0.5	0.8	0.4	0.7	0.7	no data	1.0	0.7	0.4	0.8	0.8	0.3	0.6	0.5
	Organic Carbon, Dissolved	0.1	0.2	0.7 [b]	no data	no data	no data	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2 [b]	0.1	0.1	0.1	0.1 [b]	0.2
	Organic Carbon, Total	0.1	0.3	0.6 [b]	0.7 [b]	0.7 [b]	0.5 [b]	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.3
	pH, Field	1.0	1.0	1.0	no data	1.0 [b]	1.0 [b]	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	Sulfate	7.6	2.6	6.0	1.6 [b]	2.1 [b]	4.4 [b]	3.7	5.6	0.4	0.6	0.6	0.6	0.7	0.8	0.9	0.9	1.1	6.0	2.6	2.0
	Total dissolved solids	1.9	2.1	1.4 [b]	0.7 [b]	1.2	2.4 [b]	1.8	2.0	0.6	0.7	0.7	0.7	0.8	0.7	0.8	0.7	0.8	1.7	1.4	1.0
	Total suspended solids	0.1	0.1	0.1	0.6 [b]	0.4 [b]	0.1 [b]	1.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2
	Turbidity, Lab	0.1	0.7	0.1	1.8 [b]	no data	0.3 [b]	2.5	0.7	0.3	0.3	0.4	no data	0.4	0.4	1.3 [b]	0.4	0.4	0.8	0.2 [b]	6.2
Metals	Cadmium, Total	0.6	0.2	1.9	1.9 [b]	0.1 [b]	1.1 [b]	0.7	0.7	0.1	0.1	0.1	0.4	0.2	0.2	0.2	0.2	0.2	0.6	0.3	0.3
	Calcium, Total	1.4	1.8	1.4	0.4 [b]	1.0	2.1 [b]	1.4	1.5	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.8	1.3	1.0	0.9
	Cobalt, Total	0.1	0.3	4.0	1.2 [b]	0.4 [b]	0.1 [b]	1.6	0.8	0.1	0.2	0.2	1.6	0.5	0.7	0.4	0.4	0.3	6.9	1.4	0.5
	Iron, Total	0.1	0.5	0.2	0.5 [b]	0.3 [b]	0.0 [b]	0.5	0.3	0.3	0.3	0.3	0.6	0.3	0.4	0.8	0.4	0.5	0.8	0.3	0.3
	Lead, Total	0.2	0.1	0.5	0.6 [b]	0.1 [b]	0.0 [b]	0.5	0.5	0.2	0.3	0.2	0.9	0.5	0.5	0.2	0.3	0.2	0.4	0.2	0.2
	Magnesium, Total	2.2	2.8	1.8	0.5 [b]	1.6 [b]	3.3 [b]	2.3	2.3	0.5	0.6	0.6	0.5	0.6	0.6	0.5	0.7	0.8	1.3	0.9	0.9
	Manganese, Total	0.1	1.2	0.2	0.3 [b]	1.8	0.0 [b]	1.0	0.4	0.4	0.5	0.5	1.9	0.8	1.6	1.6	1.3	0.9	33.6	8.3	1.2
	Nickel, Total	0.7	0.8	1.5	no data	0.5 [b]	1.1 [b]	2.1	1.8	0.3	0.4	0.4	0.8	0.5	0.8	0.5	0.6	0.7	3.0	1.4	0.9
	Potassium, Total	0.6	0.8	0.7	0.4 [b]	0.6	0.7 [b]	0.9	0.8	0.6	0.6	0.6	0.5	0.6	0.6	0.7	0.7	0.7	1.0	0.9	1.0
	Sodium, Total	1.0	1.0	0.9	0.3 [b]	1.0	0.8 [b]	1.1	1.2	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.8	0.8	1.4	1.1	0.9
	Strontium, Total	1.3	1.9	1.5	0.5 [b]	1.2 [b]	1.9 [b]	1.5	1.6	0.7	0.8	0.8	0.6	0.8	0.7	0.9	0.9	0.9	1.3	0.9	0.9
	Uranium, Total	1.4	4.0	1.4	0.4 [b]	1.0	2.9 [b]	1.5	1.6	0.6	0.6	0.6	0.4	0.6	0.5	0.7	0.7	0.7	0.6	0.5	0.7
	Zinc, Total	2.1	0.2	1.6	16.5 [b]	0.2	0.3 [b]	0.6	1.0	0.2	0.3	0.5	1.3	0.7	1.7	0.3	1.0	2.0	3.4	1.0	0.3

[a] Median values that were reported as less than the detection limit (DL) were used at the DL for calculation

[b] limited data (n<10)

Table 6H-9: Percentage of samples collected from mine-exposed stations with analyte values above water quality criteria. Highlighted values indicate more than 10% of samples had analyte concentrations above the guideline.

	Analyte	Vangorda stations								Rose-Anvil stations											
		V27	V4	VGMAIN	VW3	VW1	VW2	V5	V8	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-metals	Ammonia-N	0%	5%	0%	0%[a]	0%	0%[a]	4%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	16%	0%	0%
	Nitrate-N	0%	0%	0%[a]	0%[a]	0%	0%[a]	0%	0%	0%	0%	0%	no data	0%	0%	0%	0%	0%	0%	0%	0%
	Organic carbon, Dissolved	0%	0%	25%[a]	100%[a]	no data	100%[a]	8%	9%	2%	2%	0%	0%	0%	2%	11%[a]	0%	0%	1%	11%[a]	9%
	Organic carbon, Total	0%	0%	71%[a]	33%[a]	33%[a]	33%[a]	5%	7%	2%	3%	0%	0%	0%	0%	10%	0%	0%	0%	8%	9%
	pH, Field	0%	0%	0%	0%[a]	0%[a]	0%[a]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Sulfate	0%	0%	0%	0%[a]	0%	0%[a]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	0%	0%
	Total suspended solids	2%	9%	16%	25%[a]	30%	14%[a]	50%	26%	6%	4%	2%	7%	0%	2%	15%	0%	3%	2%	8%	25%
	Turbidity, Lab	0%	0%	19%	33%[a]	50%[a]	33%[a]	55%	26%	0%	0%	0%	no data	0%	2%	25%[a]	0%	0%	12%	20%[a]	67%[a]
Metals	Cadmium, Total	6%	0%	11%	50%[a]	0%[a]	11%[a]	8%	3%	0%	0%	0%	23%	0%	4%	4%	2%	4%	0%	0%	0%
	Cobalt, Total	2%	0%	5%	0%[a]	11%[a]	0%[a]	10%	5%	0%	0%	0%	13%	0%	0%	0%	0%	0%	31%	4%	0%
	Iron, Total	2%	5%	10%	25%[a]	22%[a]	17%[a]	27%	15%	2%	2%	2%	12%	0%	0%	12%	0%	0%	4%	4%	12%
	Lead, Total	2%	5%	5%	25%[a]	11%[a]	0%[a]	9%	8%	2%	2%	2%	13%	4%	3%	4%	0%	1%	2%	9%	0%
	Manganese, Total	0%	0%	0%	0%[a]	0%	0%[a]	0%	0%	0%	0%	0%	13%[a]	0%	0%	0%	0%	0%	40%	4%	0%
	Nickel, Total	2%	0%	0%	0%[a]	0%[a]	0%[a]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Potassium, Total	0%	0%	0%	0%[a]	0%	0%[a]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Uranium, Total	0%	13%	0%	0%[a]	0%	0%[a]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Zinc, Total	51%	2%	14%	50%[a]	20%	13%[a]	13%	15%	0%	0%	4%	24%	15%	34%	3%	23%	47%	73%	16%	3%

[a] sample size of n < 10

Table 6H-10: Ratio of median analyte values at mine-exposed stations to water quality guideline values [a,b]. Highlighted values indicate median concentrations that were above the respective water quality guideline (ratio >1).

	Analyte	Units	Vangorda Stations								Rose-Anvil Stations											
			V27	V4	VGMAIN	VW3	VW1	VW2	V5	V8	R8	R9	R10	NF1	NF2	X2	R1	X3	X10	X14	R4	A1
Non-metals	Ammonia-N	mg/L	0.1	0.2	0.1	0.1 [c]	0.1	0.0 [c]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.4	0.1	0.0
	Nitrate-N	mg/L	0.2	0.0	0.1	0.1 [c]	0.0	0.1 [c]	0.0	0.1	0.0	0.0	0.0	no data	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0
	Organic carbon, Dissolved	mg/L	0.1	0.2	0.7	no data	no data	no data	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2
	Organic carbon, Total	mg/L	0.1	0.2	0.5	0.6 [c]	0.5 [c]	0.4 [c]	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
	pH, Field	pH units	0.9	0.9	0.9	no data	0.9 [c]	0.9 [c]	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.9
	Sulfate	mg/L	0.4	0.1	0.3	0.2 [c]	0.1 [c]	0.2 [c]	0.2	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.2	0.1
	Total suspended solids	mg/L	0.0	0.1	0.0	0.4 [c]	0.3	0.1 [c]	0.9	0.2	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.1
	Turbidity, Lab	NTU	0.1	0.4	0.1	1.0 [c]	no data	0.1 [c]	1.3	0.4	0.2	0.2	0.2	no data	0.2	0.2	0.7	0.2	0.2	0.4	0.1	3.3
Metals	Cadmium, Total	mg/L	0.2	0.1	0.6	1.7 [c]	0.1 [c]	0.3 [c]	0.2	0.2	0.1	0.1	0.1	0.3	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1
	Cobalt, Total	mg/L	0.0	0.0	0.4	0.1 [c]	0.0 [c]	0.0 [c]	0.2	0.1	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.7	0.1	0.1
	Iron, Total	mg/L	0.0	0.2	0.1	0.2 [c]	0.1 [c]	0.0 [c]	0.2	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.4	0.2	0.2	0.4	0.1	0.2
	Lead, Total	mg/L	0.1	0.0	0.1	0.3 [c]	0.0 [c]	0.0 [c]	0.2	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
	Manganese, Total	mg/L	0.0	0.0	0.0	0.0 [c]	0.0	0.0 [c]	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.8	0.2	0.0
	Nickel, Total	mg/L	0.0	0.0	0.0	no data	0.0 [c]	0.0 [c]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Potassium, Total	mg/L	0.0	0.0	0.0	0.0 [c]	0.0	0.0 [c]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Silver, Total	mg/L	0.1	0.1	0.1	0.1 [c]	0.1	0.1 [c]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Uranium, Total	mg/L	0.2	0.7	0.2	0.1 [c]	0.2	0.5 [c]	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Zinc, Total	mg/L	1.0	0.1	0.8	7.9 [c]	0.1	0.2 [c]	0.3	0.5	0.1	0.1	0.2	0.6	0.4	0.8	0.2	0.5	1.0	1.6	0.5	0.2

[a] In cases where the guideline covers a range of values (alkalinity, total organic carbon, and pH), the upper value of the range was used to calculate the ratio
[b] Median values that were reported as less than the detection limit (DL) were used at the DL for calculation
[c] Limited data (n<10 samples)

derived on a location-specific basis and take into account seasonal variation in background concentrations; however, to facilitate evaluation of data across numerous stations, a single guideline was derived for each substance, using a modified approach that took into account natural background variability (Section 2.3.2.1, Table 6H-2). Water monitoring data for 2008 – 2012 show that concentrations of organic carbon are generally within the guidelines except at stations in mid to upper Vangorda Creek (VGMAIN, VW1-VW3), and at stations R1 and R4 where sample sizes were limited. Table 6H-7 shows that median organic carbon concentrations are within the range of background concentrations at all stations; suggesting that even the modified guideline derivation process used for these variables is too conservative. Overall, the data indicate limited mine-related effect on organic carbon concentrations.

Although concentrations of both TSS and turbidity were elevated in some samples collected in the Vangorda Creek and Rose-Anvil Creek drainages (Table 6H-9), median station concentrations are usually below the modified guideline[2], as indicated by ratios <1 in Table 6H-10. This means that most samples had concentrations within or only slightly above the range of background concentrations. Also, median and maximum concentrations at most mine-exposed stations were comparable to or less than those measured at background (reference) stations (Table 6H-11).

Furthermore, it appears that elevated concentrations of TSS and turbidity are contributed by sources other than the FMC. For example, elevated TSS and turbidity concentrations along West Vangorda Creek are likely at least partially attributable to the landslide that crossed the creek between VW3 and VW1 (Figure 6H-3). Also TSS and turbidity were more often elevated (Table 6H-9), and to a greater degree (Table 6H-10) at the most downstream Anvil Creek station (A1) than at stations closer to the FMC (e.g., X14). TSS and turbidity levels were also sometimes elevated at minimally-mine-affected station R1 (SFRC) (Table 6H-9). Stations R1 and A1 have larger catchment areas than the majority of reference stations monitored at the FMC, and thus could be expected to reflect higher TSS and turbidity levels (Moeller et al. 1979; Stein and Yoon 2007). TSS and turbidity levels of as low as 270 mg/L and 25 NTUs, respectively, have been associated with effects on aquatic biota (CCME 2002) but such concentrations were rarely exceeded in surface waters around the FMC that are accessible to fish (i.e., at V8 and stations in the Rose-Anvil drainage; Table 6H-11; Figure 6H-8; also see detailed data in Attachment Tables C.29 to C.42).

[2] The modified guideline being a small specified increase above the background concentration range as described in Table 6H-3.

Table 6H-11: Median and maximum concentrations of total suspended solids and turbidity for mine exposed stations compared to reference stations, 2008 - 2012.

Station	Total Suspended Solids (mg/L)		Turbidity (NTU)	
	Median	Maximum	Median	Maximum
Pooled Reference Stations	<1	400	0.53	6.2
V27	<1	61	0.3	1.3
V4	1.95	120	1.6	3.1
VGMAIN	<1	190	0.3	80.0
VW3	11.2	39	4.0	12.8
VW1	7.5	1,500	-	756
VW2	2	130	0.6	24.6
V5	23	1,730	5.6	730
V8	4.1	1,500	1.5	683
R8	<1	69	0.8	2.1
R9	<1	440	0.7	2.5
R10	<1	73	0.8	2.7
NF1	<4	26	-	-
NF2	<1	12	0.8	2.6
X2	1	30	0.9	5.3
R1	3	210	2.9	5.0
X3	<1	13	0.8	3.5
X10	<1	27	0.9	3.0
W8	<1	4	-	-
X14	2	55	1.8	12.0
R4	<1	71	0.5	6.0
A1	4	180	13.9	18.4

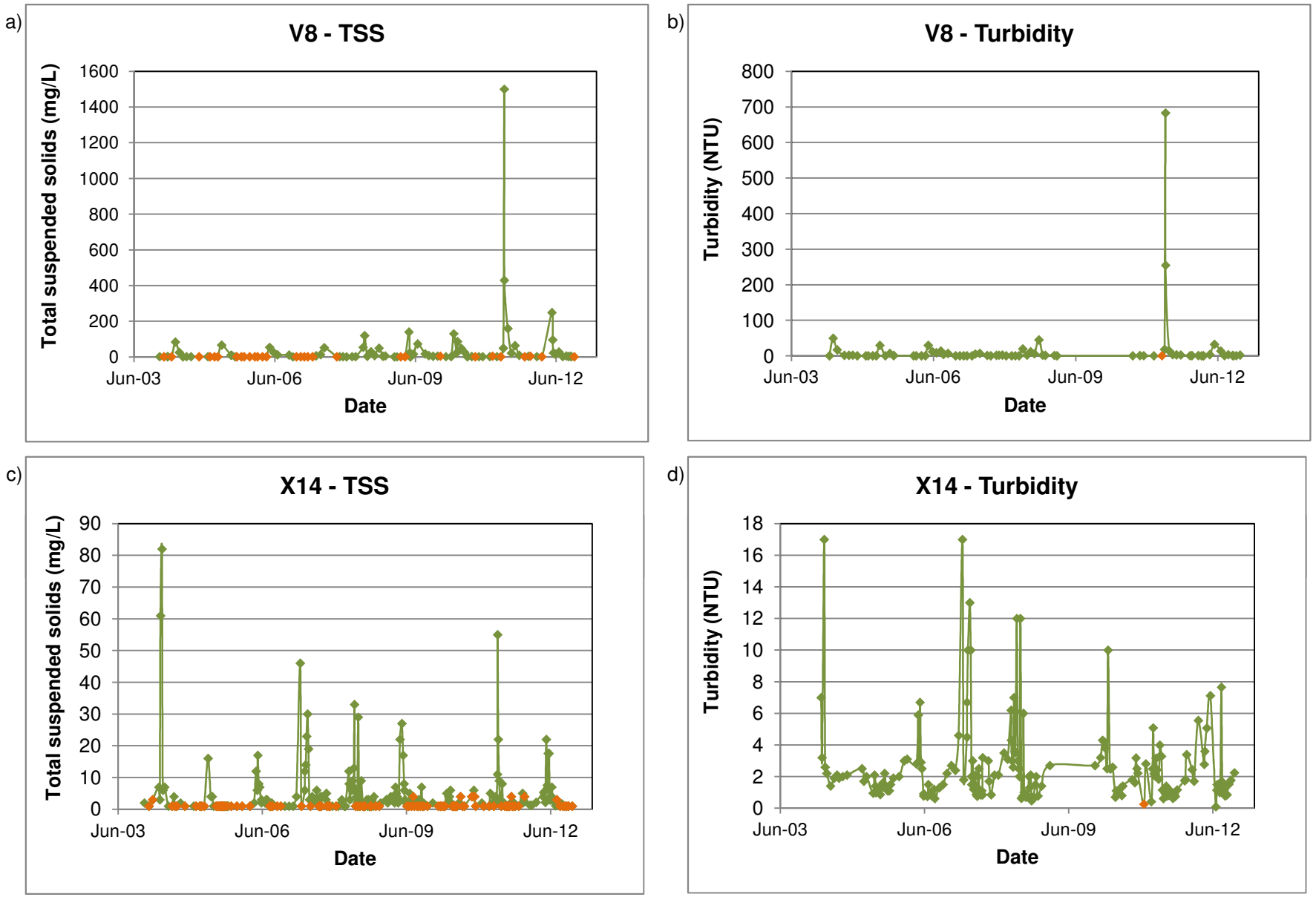


Figure 6H-8: Surface water concentrations of total suspended solids and turbidity at mine-exposed stations V8 and X14, 2004 to 2012. Orange points indicate values reported as less than the detection limit.

The above information indicates that non-metal variables discharged by the FMC currently pose little risk of effects to aquatic biota.

4.3.2 Metals

Concentrations of mine-related metals that were measured at stations downstream of the FMC were also compared to guidelines for protection of aquatic life. Cadmium, cobalt, iron, lead, manganese, uranium, and zinc concentrations were above guidelines in more than 10% of samples collected at one or more stations downstream of mine disturbances (Table 6H-9). Of these, the relatively more frequent elevations of iron at R1, which is relatively undisturbed, and at A1, well downstream of the Faro Mine Area, indicate sources other than the FMC; Figure 6H-9 shows that iron concentrations are positively related to TSS concentrations at these stations, with elevated levels of both likely being associated with mobilization of particulate matter during snowmelt and rain events. The pattern of data for West Fork Vangorda Creek also suggests that at least some of the iron measured at stations farther downstream (V5 and V8) originates from the landslide.

Furthermore, most of the total iron measured at V8 is in particulate, not dissolved; form (Attachment Figure C.1). Of the remaining mine-related metals, zinc was most often measured at concentrations above the guideline for protection of aquatic life at stations located downstream from FMC sources (Table 6H-9). Despite contributions from the Vangorda/Grum Area, and likely also the landslide across West Vangorda Creek, metal concentrations at V8 rarely (≤ 15% of samples) exceeded guidelines for protection of aquatic life (Table 6H-9) and median concentrations were ≤ half the guideline values (Table 6H-10).

Station NF1, located on NFRC immediately upstream of the Haul Road, had cadmium, cobalt, iron, lead, manganese, and zinc that were above guidelines in up to one-quarter of samples collected from 2008 - 2012, but the guidelines were less often exceeded at the next downstream station NF2 (Table 6H-9), suggesting a localized source near NF1. At station X14, concentrations of cobalt (31% of samples), manganese (40%), and zinc (73%) were sometimes also above guidelines (Table 6H-9; Figure 6H-10). However, guidelines were infrequently exceeded at stations farther downstream in Rose Creek (R4) and Anvil Creek (A1) (Table 6H-9).

Metal concentrations in Vangorda Creek and in Rose Creek downstream of the FMC (V8 and X14, respectively) have been relatively stable over the past decade (Figure 6H-11).

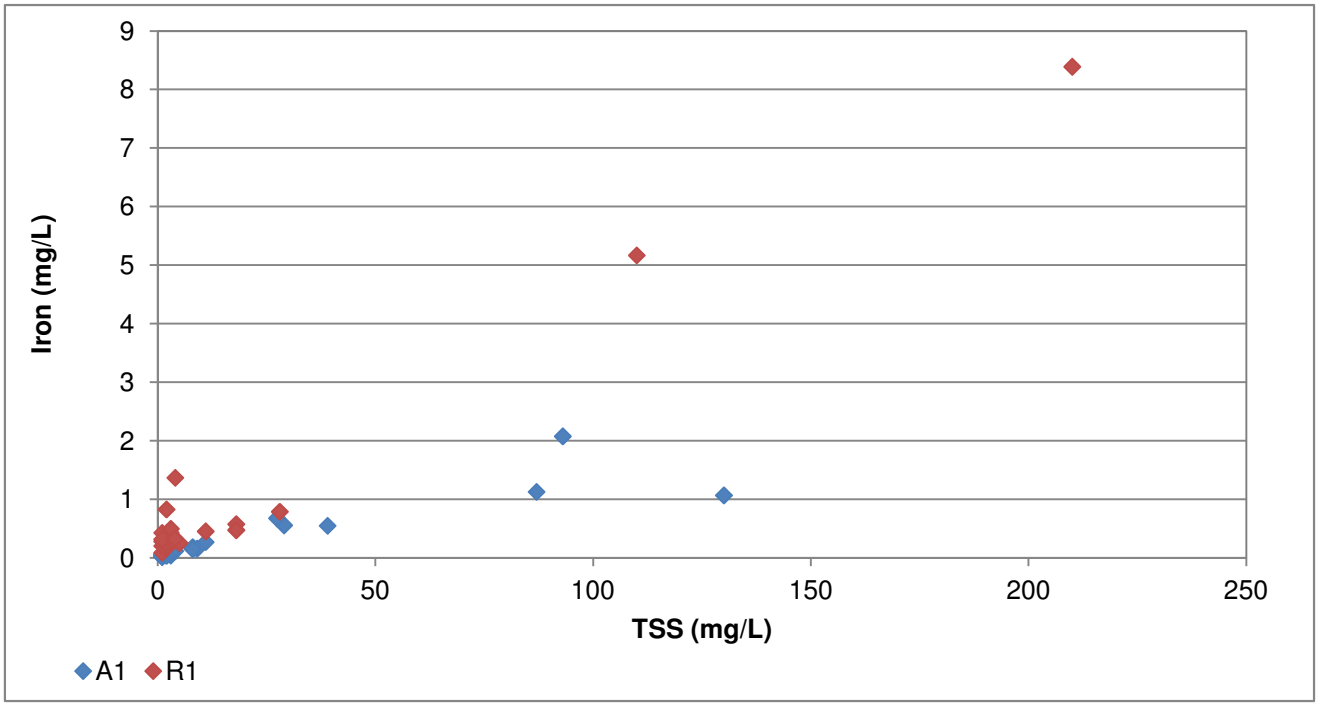


Figure 6H-9: Water concentrations of iron relative to TSS at relatively undisturbed station R1 (South Fork Rose Creek) and at station A1 (the mouth of Anvil Creek).

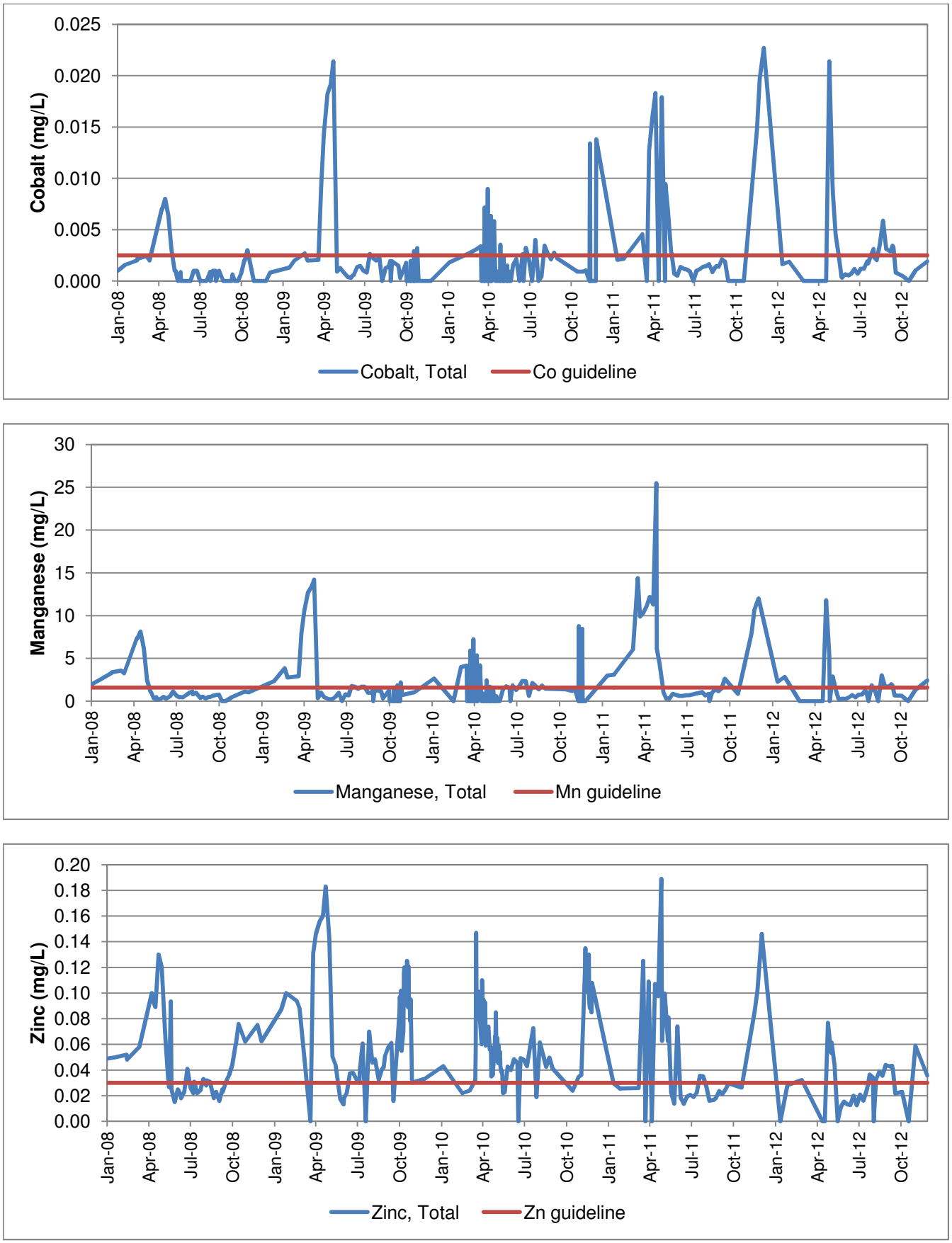


Figure 6H-10: Cobalt, manganese and zinc concentrations at X14 relative to water quality guidelines (2008 - 2012).

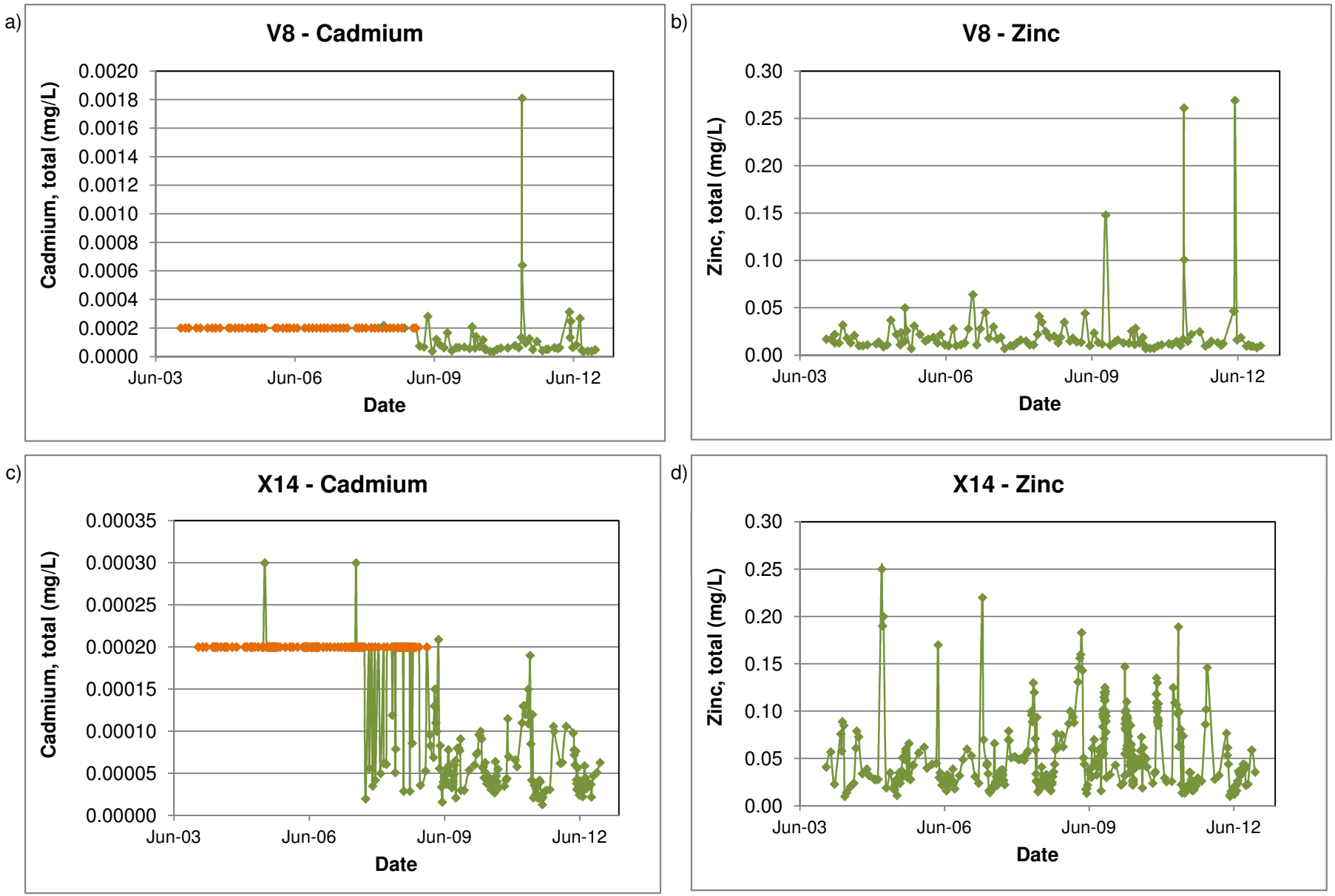


Figure 6H-11: Surface water concentrations of total cadmium and zinc at mine-exposed stations V8 and X14, 2004 to 2012. Orange points indicate values reported as less than the detection limit.

4.4 Pelly River

Water concentrations were compared among stations on the Pelly River upstream and downstream of Vangorda Creek (P1 and P2) and Anvil Creek (P3 and P4; Table 6H-12, Figure 6H-3). The comparison focused on selected analytes considered to be good indicators of mine-related disturbance on water quality (alkalinity, sulphate, manganese and zinc). There were no significant differences ($p<0.05$) in mean concentrations of alkalinity, sulphate, or zinc at P2-P4 compared to P1, based on ANOVA followed by post-hoc tests (Table 6H-12). Mean manganese concentrations at P2 and P3 were lower than those at P1. The data indicate that mine-related influences on surface water quality do not currently extend into the Pelly River.

4.5 Traditional Drinking Water Stations

Two water monitoring stations are traditional locations of drinking water taking by First Nations: GCULV (Grum culvert) and K8 (Figure 6H-3). Water quality at these stations was compared to drinking water quality guidelines. Organic carbon, turbidity, iron, and/or manganese concentrations were occasionally above the guidelines between 2008 and 2012 (Table 6H-13).

4.6 Summary

Water quality data for the FMC from 2008 through 2012 indicate that concentrations of a variety of non-metals and metals are elevated in surface waters relative to the typical range of background (reference station) concentrations. Alkalinity, conductivity, hardness, sulphate, total dissolved solids, calcium, cobalt, magnesium, nickel, sodium, strontium, and zinc occur at concentrations above the background range in approximately half or more of samples collected downstream of the Vangorda/Grum Area (V8) and the Faro Mine Area (X14). Concentrations of non-metal analytes are below those expected to have adverse effects on aquatic biota.

Metal concentrations in lower Vangorda Creek (V8) rarely (≤ 15% of samples) exceed guidelines for protection of aquatic life and median concentrations are usually less than half the guideline values. Water concentrations of several metals (cadmium, cobalt, iron, lead, manganese, zinc) are above guidelines in up to one-quarter of samples collected at NF1, on the North Fork Rose Creek (NFRC) upstream from the Haul Road, but zinc is the only mine-related metal that exceeds guidelines at stations between NF1 and Rose Creek station X14, just downstream of the Faro Mine Area. Cobalt and manganese are also found at concentrations above water quality guidelines for protection of aquatic life in up to

Table 6H-12: Statistical comparisons of water quality at Pelly River exposure stations (P2 - P4) compared to the upstream reference station (P1). Highlighted values indicate concentration at exposure stations that differed significantly from the P1 reference station based on ANOVA followed by post-hoc tests (p<0.05).

Analytes[a]	Units	Pelly River Reference (P1) Median	Pelly River Mine-Exposed Station Medians		
			P2	P3	P4
Alkalinity, total	mg/L	110	120	120	110
Sulphate	mg/L	62	52	50	48
Manganese, total	mg/L	0.029	0.017	0.014	0.035
Zinc, total	mg/L	0.0146	0.0153	0.0060	0.0127

[a] Representative mine-related variables

Table 6H-13: Water quality summary statistics and the percentage of samples exceeding current drinking water quality guidelines for drinking water stations GCULV and K8, Faro Mine, Yukon.

	Analyte	Units	Drinking water quality criterion [a]	GCULV							K8						
				n	Minimum	Maximum	Median	Mean [b]	Standard deviation [b]	% > current drinking water quality criterion	n	Minimum	Maximum	Median	Mean [b]	Standard deviation [b]	% > current drinking water quality criterion
Non-Metals	Alkalinity, Total	mg/L	30 - 500	15	12.9	60.2	26.0	30.8	15.4	0%	17	<0.5	71.9	47.5	45.2	18.5	0%
	Nitrate-N	mg/L	10	4	0.0213	0.04	0.03	0.03	0.01	0%	3	0.05	0.12	0.06	0.08	0.04	0%
	Organic carbon, Dissolved	mg/L	5	1	-	-	24	24	-	100%	2	1.9	17.7	9.8	9.8	11.2	50%
	Organic carbon, Total	mg/L	4	3	2.47	25	7.2	11.6	11.9	67%	3	2.1	15.7	8.3	8.7	6.8	67%
	pH, Field	pH units	6.5 - 8.5	14	6.99	8.5	8.1	8.1	0.4	0%	16	7.4	8.4	8.0	8.0	0.3	0%
	Sulfate	mg/L	500	14	<0.5	8.43	6.0	5.3	2.2	0%	19	2.43	19.8	12.0	11.2	4.0	0%
	Total dissolved solids	mg/L	500	4	30	64	44	46	16	0%	5	62	88	78	78	10	0%
	Turbidity, Lab	NTU	0.1 - 1.0	15	0.18	2.32	0.45	0.76	0.74	27%	14	0.11	2.23	0.18	0.42	0.56	7%
Metals	Cadmium, Total	mg/L	0.005	16	<0.000005	0.0003	<0.0002	0.000094	0.000065	0%	16	0.000006	0.0003	<0.0002	0.000090	0.000067	0%
	Iron, Total	mg/L	0.3	15	<0.05	0.645	0.08	0.15	0.18	20%	16	0.006	0.553	<0.05	0.07	0.13	6%
	Lead, Total	mg/L	0.01	15	0.00003	0.00136	<0.001	0.00050	0.00028	0%	19	0.000052	0.00543	<0.001	0.00075	0.0011	0%
	Magnesium, Total	mg/L	100	16	0.74	3.48	1.30	1.69	0.88	0%	17	0.79	4.16	2.58	2.44	0.99	0%
	Manganese, Total	mg/L	0.05	16	<0.001	0.12	0.0070	0.019	0.030	6%	17	0.00023	0.0166	<0.001	0.0018	0.0039	0%
	Sodium, Total	mg/L	200	15	0.73	2.87	1.75	1.78	0.65	0%	19	1.13	3.06	1.89	1.95	0.53	0%
	Uranium, Total	mg/L	0.02	15	<0.0005	0.0018	0.00055	0.00068	0.00050	0%	19	<0.0005	0.0053	0.00214	0.00222	0.00158	0%
	Zinc, Total	mg/L	5	15	0.001	0.011	<0.005	0.004	0.003	0%	19	0.0006	0.017	<0.005	0.004	0.005	0%

[a] Refer to Table 6H-3 for information regarding the source of drinking water quality guidelines

[b] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

40% of samples collected at X14, but median concentrations for all metals but zinc are below the guidelines. Water quality guidelines are infrequently exceeded at stations farther downstream in Rose Creek (R4) and Anvil Creek (A1) indicating that mine related effects on biota, if any, are likely localized around the Faro Mine Area. Mine-related effects on water quality do not extend into the Pelly River.

5.0 SEDIMENT QUALITY

5.1 Historical Studies

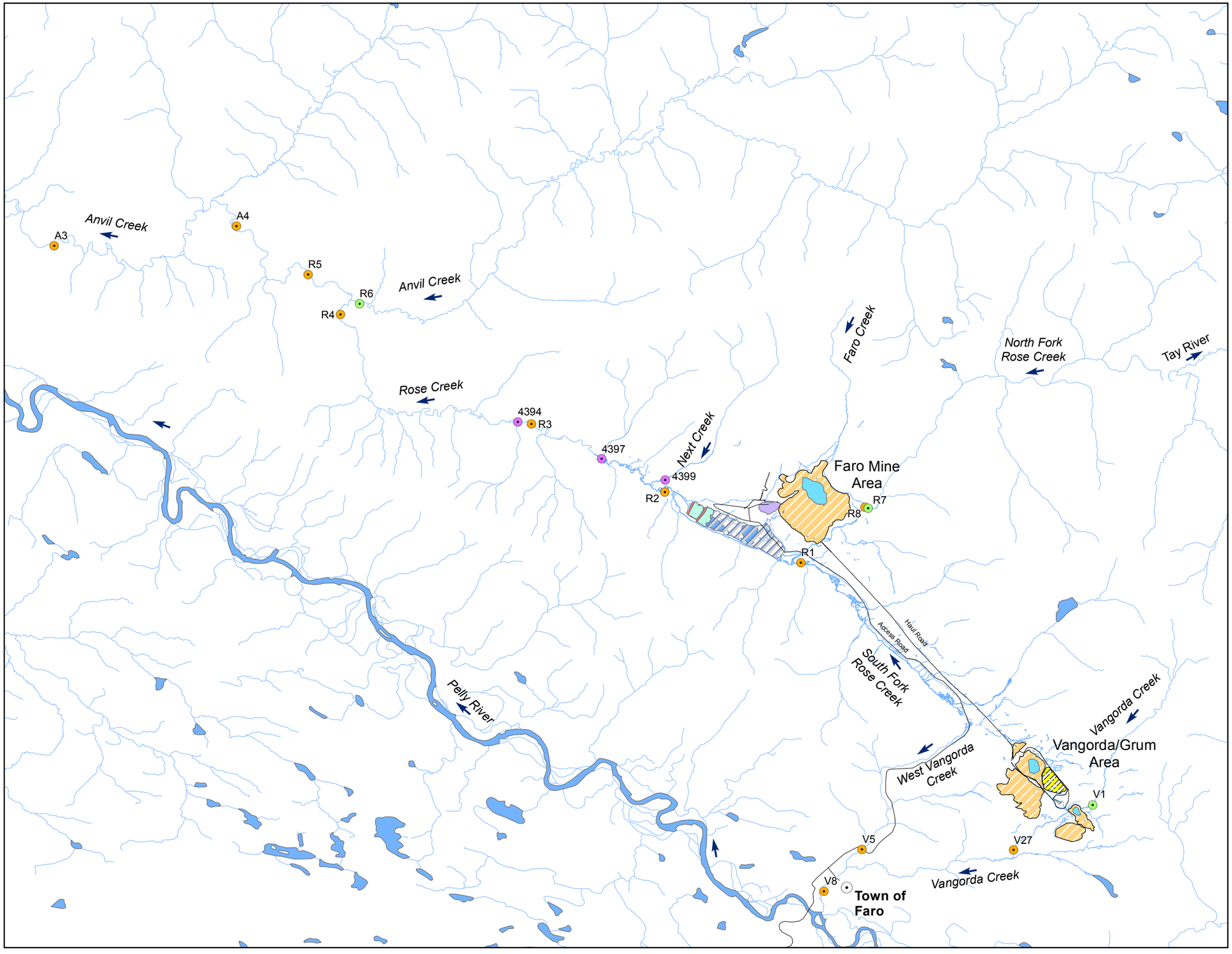
Sediment quality has been monitored in the Rose-Anvil Creek and Vangorda Creek systems since as early as 1973 and 1991, respectively (Figure 6H-12, Attachment Tables D.1 and D.2), and the results available to 2006 were summarized by Minnow (2007). There was some study-to-study variability in terms of precise sampling station locations, laboratory equipment/techniques, and the metal concentrations reported. However, sampling methods were similar among most studies; typically fine-grained sediment samples were collected in triplicate from streambed deposits using a trowel or shovel, then placed into glass jars, refrigerated, and shipped to a laboratory for analysis of metal content. Because fine sediment deposits were sparse in some areas, samples were sometimes collected from areas that were, or are sometimes, dry (i.e., soils above the water surface, not necessarily accessible to aquatic biota). Metals analyses were usually performed on the fraction of sediment samples that passed through a 100-mesh sieve (0.15 millimetres [mm]).

Metal concentrations were elevated in the fine fraction of sediment samples collected downstream of the FMC compared to reference areas (Figures 6H-13 and 6H-14). In particular, arsenic, lead, and zinc concentrations were above CSQG Probable Effect Levels (PEL) (CCME 2013). However, whole sediment concentrations, on which CSQG are based, were not measured except by Hoos and Holman (1973) and Minnow (2009). Samples collected in 2007 and 2008 (Minnow 2009) represent the most recent characterization of sediment quality and are discussed in more detail below.

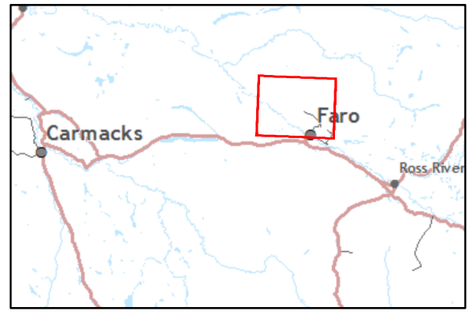
5.2 Recent Surveys (2007-2008)

Sediment data collected in 2007 and 2008 (at stations V1, V27, R7, R2 and X2, Figure 6H-12) are considered representative of current conditions because water quality has been relatively stable in the interim (Figures 6H-8 and 6H-11). The grain size analysis results presented in Table 6H-14 demonstrate that sediments are composed mainly of sand and gravel, typical of fast-flowing, upper perennial creek habitats (Cowardin, et. al. 1979). Of the samples collected, combined silt and clay fractions represented <5% of the whole sediment samples, except in the case of X2, where silt and clay represented 25% and 6.5%, respectively. TOC content was also low (<4%) in all samples (Table 6H-14).

Sediment metal concentrations at reference areas V1 and R7 did not exceed sediment quality guidelines in either whole sediment samples (<1 mm) or the fine fraction (<0.15



VICINITY MAP



LEGEND

- Direction of Flow

Sediment Station:

- Mine-Exposed
- Reference
- 1999 Yukon Government Sampling Station

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 0.75 1.5 3 km

Created by: J. Wilson

minnow environmental inc.

FIGURE 6H-12

Location of Reference and Mine-Exposed Sediment Monitoring Stations from Past Studies

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

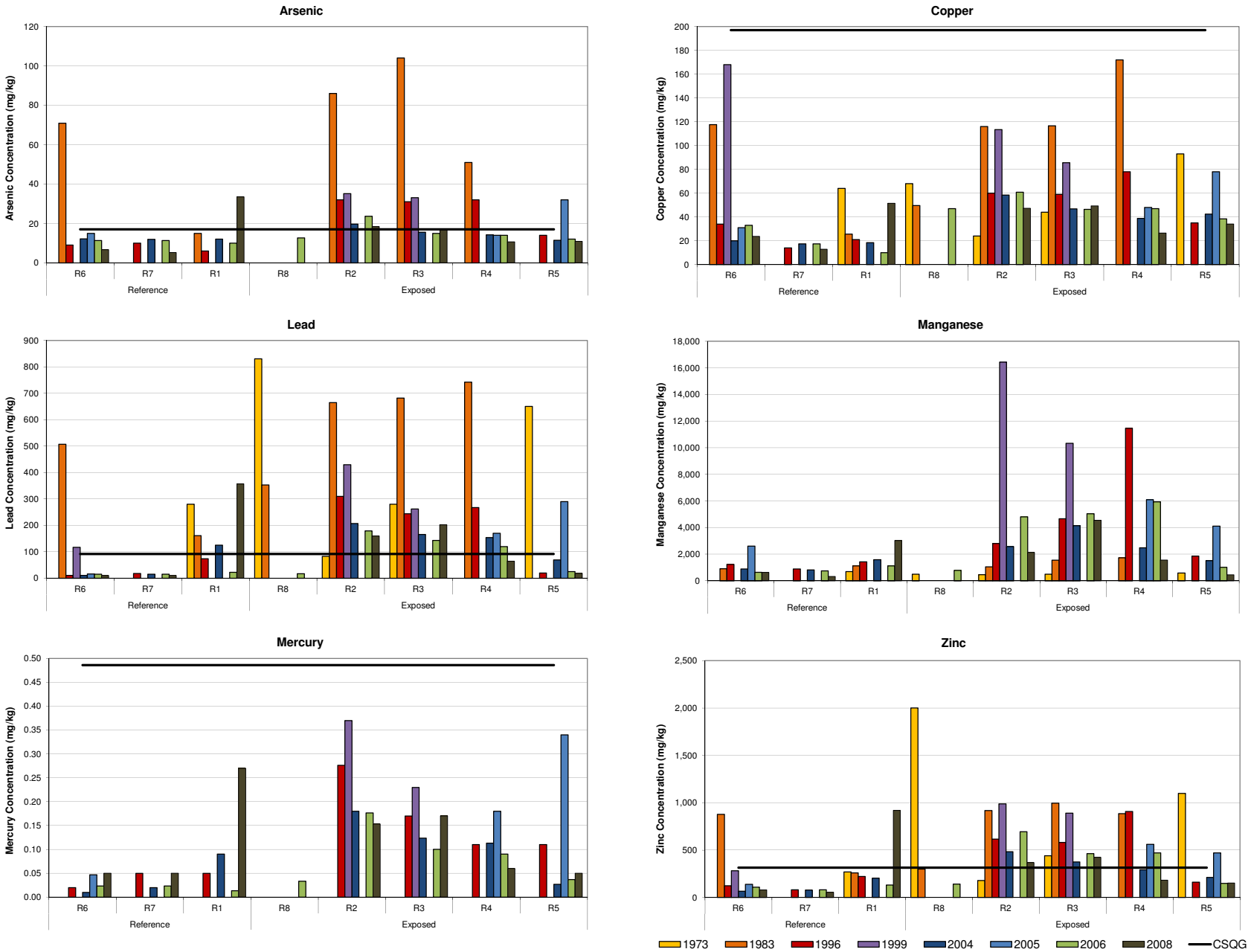


Figure 6H-13: Temporal comparison of mean sediment metal concentrations (0.15 mm fraction) for mine-related variables relative to Canadian Sediment Quality Guideline (CCME 2013b) probable effect levels at Rose-Anvil Creek monitoring stations, 1973 to 2008. Note that CSQG apply to whole sediments, not just the fine fraction, butare presented here for context. (Sources: Hoos and Holman 1973; Godin and Osler 1985; Laberge 1997, 2004, 2006, 2009; YTG [unpub.] 1999; Access et al. 2006).

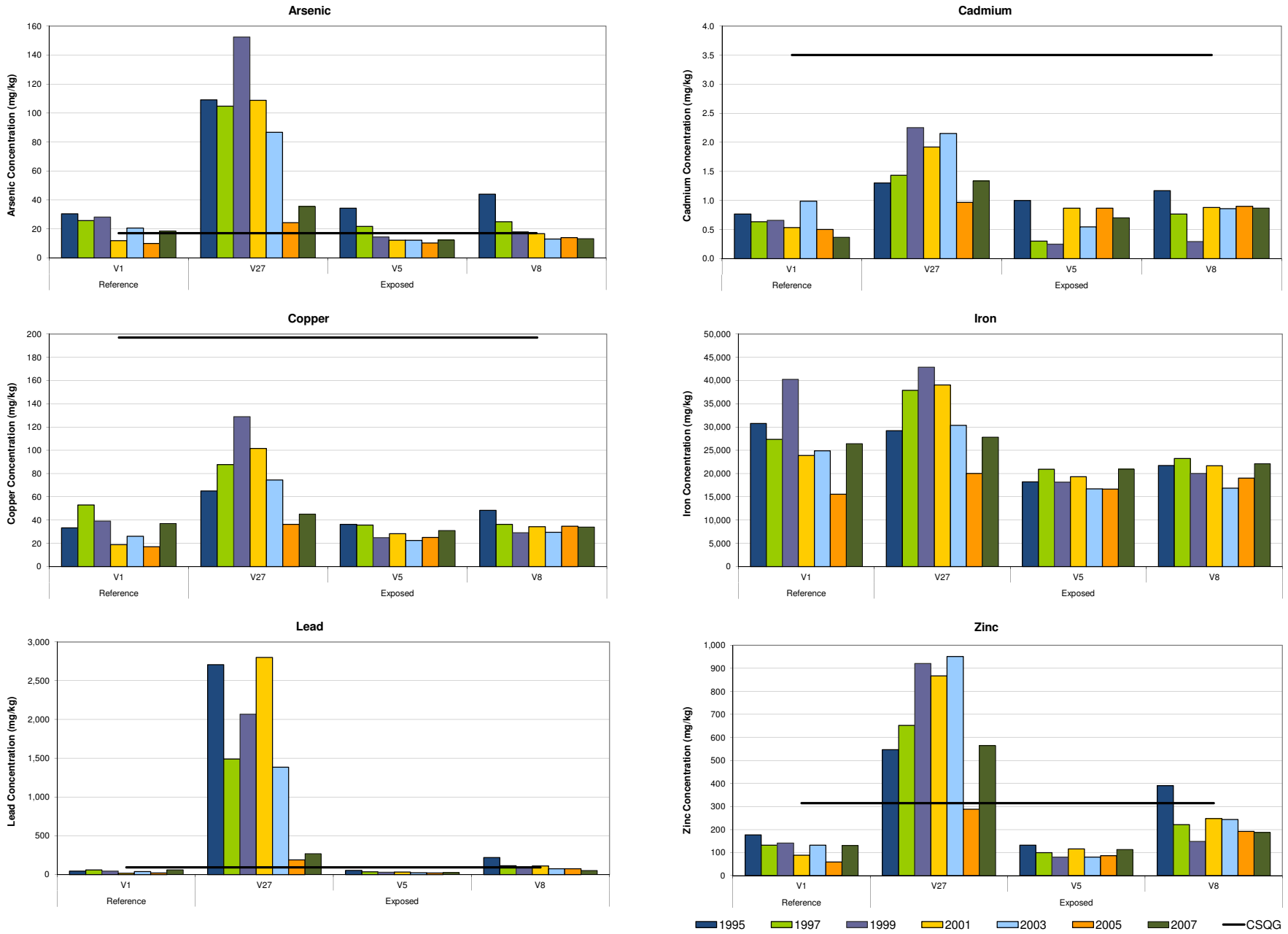


Figure 6H-14: Temporal comparison of mean sediment metal concentrations (0.15 mm fraction) for mine-related variables relative to Canadian Sediment Quality Guideline (CCME 2013b) probable effect levels at Vangorda Creek monitoring stations, 1995 to 2007. Note that CSQG apply to whole sediments, not just the fine fraction, but are presented here for context. (Source data: Laberge 1996, 1998, 2000, 2002a, 2003, 2005, 2007).

Table 6H-14: Summary sediment quality in Vangorda and Rose Creeks, Faro Mine Complex, August 2007 and 2008. Shading indicates the guideline used in the evaluation and measured values above guidelines (Minnow 2009).

	Parameter	Units	MDL[a]	Sediment Quality Guidelines						Vangorda Creek - 2007								Rose Creek - 2008					
				Canadian[b]		British Columbia[c]		Ontario[f]		V1 (reference)		V27-A		V27-B		V27-C		R7 (reference)		R2		X2	
										Aug. 28		Aug. 28		Aug. 28		Aug. 28		Aug. 21		Aug. 20		Aug. 21	
				ISQG[d]	PEL[e]	ISQG[d]	PEL[e]	LEL[g]	SEL[h]	whole[i]	<0.15mm	whole[i]	<0.15mm	whole[i]	<0.15mm	whole[i]	<0.15mm	whole[i]	< 0.15 mm	whole[i]	< 0.15 mm	whole[i]	< 0.15 mm
Grain Size	Gravel (> 2 mm)	%	0.1							82		48		41		29		0.2		32		<0.1	
	Sand (0.0625 - 2 mm)	%	0.1							17		51		58		70		97		67		69	
	Silt (0.0039 - 0.0625 mm)	%	0.1							0.1		0.3		0.4		0.4		1.9		0.4		24	
	Clay (<0.0039)	%	0.1							1.0		0.9		1.2		1.1		1.2		0.6		6.5	
Non-Metals	Available (KCl) Ammonia (N)	mg/kg	0.5															13		4.6		18	
	Nitrite (N)	mg/kg	0.5							<0.5		<0.5		<0.5		<0.5							
	Nitrate plus Nitrite (N)	mg/kg	2							<2		<2		<2		<2							
	Total Kjeldahl Nitrogen (TKN)	mg/kg	3					550	4,800	0.9		0.7		0.8		0.8		150		36		1,500	
	Available (KCl) Orthophosphate (P)	mg/kg	50							4.9		3.6		2.8		3.2		<50		<50		<50	
	Total Organic Carbon (TOC)	%	0.2					1	10	0.13		3.7		0.3		0.24		0.25		0.2		1.2	
	Soluble (2:1) pH	pH Units	0.01															6.96		7.64		7.52	
Metals and Metalloids	Aluminum (Al)	mg/kg	100							8,020	16,100	8,180	14,800	8,700	14,300	9,630	13,200	9,180	10,400	8,150	18,000	13,600	13,400
	Antimony (Sb)	mg/kg	0.1							0.2	0.3	0.7	2	0.5	2.2	0.8	2	0.6	0.6	0.8	2.0	1.3	1.3
	Arsenic (As)	mg/kg	0.2	5.9	17	5.9	17	6	33	6.9	16.2	19.9	48.7	16.8	46	24.7	39.8	10.1	8.6	9.0	20.2	20.7	21.6
	Barium (Ba)	mg/kg	0.1							64.3	130	73.5	338	88	265	116	209	125	192	107	404	211	258
	Beryllium (Be)	mg/kg	0.1							0.3	0.6	0.2	0.5	0.2	0.5	0.3	0.5	0.2	0.4	0.2	0.8	0.7	0.7
	Bismuth (Bi)	mg/kg	0.1							0.2	0.7	0.1	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.1	0.4	0.8	0.8
	Boron (B)	mg/kg	5							<5	<5	<5	<5	<5	<5	<5	<5						
	Cadmium (Cd)	mg/kg	0.05	0.6	3.5	0.6	3.5	0.6	10	0.35	0.52	0.82	2.47	0.92	2.35	1.05	2.26	0.17	0.23	0.24	0.86	0.85	0.97
	Chromium (Cr)	mg/kg	1	37.3	90	37.3	90	26	110	14	26	25	48	22	43	24	42	17	19	20	53	32	31
	Cobalt (Co)	mg/kg	0.3							7.4	17.2	11.2	24.1	11.8	23.4	13.6	23.5	7.1	8.0	10.9	29.4	15.4	14.6
	Copper (Cu)	mg/kg	0.5	35.7	197	35.7	197	16	110	14.7	28.4	21.7	57.9	21.2	55.2	25.1	52.1	9.0	13.0	15.2	45.0	36.5	36.9
	Iron (Fe)	mg/kg	100			21,200	43,766	20,000	40,000	18,500	34,100	19,200	35,600	20,600	36,900	23,000	32,700	22,100	22,400	19,200	43,400	34,600	32,000
	Lead (Pb)	mg/kg	0.1	35.0	91.3	35	91	31	250	10.2	25.2	146	352	123	362	152	313	16.6	12.7	42.8	134	273	286
	Magnesium (Mg)	mg/kg	100															3,790	3,690	4,810	10,300	5,970	5,500
	Manganese (Mn)	mg/kg	0.2					460	1,100	378	736	830	2,320	941	2,290	1,070	2,290	393	576	2,200	9,620	1,340	1,600
	Mercury (Hg)	mg/kg	0.05	0.170	0.486	0.170	0.486	0.2	2	<0.05	<0.05	0.11	0.27	0.19	0.24	0.09	0.22	<0.05	<0.05	<0.05	0.07	0.20	0.21
	Molybdenum (Mo)	mg/kg	0.1							0.4	0.8	0.7	1.9	0.9	1.8	1.2	1.9	0.8	0.8	1.0	2.7	1.2	1.3
	Nickel (Ni)	mg/kg	0.8			16	75	16	75	16.2	32.7	28.1	55.6	26.8	54.7	30.3	52.5	16.0	17.9	23.7	63.5	36.3	36.9
	Phosphorus (P)	mg/kg	10					600	2,000									549	741	556	793	774	827
	Potassium (K)	mg/kg	100															1040	1360	740	1640	1750	1660
	Selenium (Se)	mg/kg	0.5			2				<0.5	0.6	0.6	1.3	0.6	1.1	0.6	1.2	<0.5	0.5	0.5	<0.5	0.8	<0.5
	Silver (Ag)	mg/kg	0.05							0.09	0.14	0.16	0.68	0.3	0.63	0.29	0.73	0.07	0.10	0.09	0.28	0.56	0.66
	Sodium (Na)	mg/kg	100															101	148	106	329	183	200
	Strontium (Sr)	mg/kg	0.1							15.5	21	39.9	58	40.7	48.7	40.3	47.3	20.4	29.2	25.2	57.8	31.9	34.6
	Thallium (Tl)	mg/kg	0.05							<0.05	0.06	0.19	0.29	0.13	0.32	0.16	0.29	0.09	0.15	0.11	0.34	0.31	0.27
	Tin (Sn)	mg/kg	0.1							0.3	0.5	0.3	0.4	0.2	0.4	0.3	0.3	0.5	0.7	0.3	3.8	1.0	1.0
	Titanium (Ti)	mg/kg	1							116	247	95	176	104	174	133	151	302	396	149	361	442	390
	Uranium (U)	mg/kg	0.05							1.59	3.71	0.89	1.93	0.85	1.99	1.04	1.87						
	Vanadium (V)	mg/kg	2							14	25	17	31	18	25	18	24	21	24	18	39	35	34
	Zinc (Zn)	mg/kg	1	123	315	123	315	120	820	53	108	290	709	338	806	385	733	57	63	175	546	456	491
	Zirconium (Zr)	mg/kg	0.5															0.9	0.9	0.9	2.0	1.1	1.0

[a] MDL = Method Detection Limit.
[b] CCME (Canadian Council of Ministers of the Environment). 2013. Sediment Quality Guidelines for Protection of Aquatic Life. Accessed at http://st-ts.ccme.ca/, November 2013.
[c] BCMOE (British Columbia Ministry of Environment). 2006b. A Compendium of Working Water Quality Guidelines for British Columbia. (Updated August 2006)
[d] Interim sediment quality guideline
[e] Probable effect level
[f] OMOE (Ontario Ministry of Environment). 1993. Guidelines For The Protection and Management Of Aquatic Sediment Quality In Ontario. August 1993, Reprinted October, 1996. MOE (1993).
[g] Lowest effect level.
[h] Severe effect level.
[i] Samples for metal analysis were pre-screened to 2 mm to remove large particles that could bias sample results.

mm; Table 6H-14). Arsenic, lead, manganese, and zinc were elevated relative to sediment quality guidelines in samples collected at mine-exposed areas. Metal concentrations were typically about three times higher in the fine fraction than whole sediment (Table 6H-14), as would be expected in coarse sediments (Horowitz 1991). The exception was at X2, where the sediment sample contained more fines and concentrations were similar between the whole and fractioned sample (Table 6H-14). Thus, a large proportion of sediment metals is associated with fine sediment particles, which usually represents a small proportion of the total sediment composition.

Tests were conducted to determine if elevated sediment metal concentrations were associated with toxicity to aquatic biota. Samples from Rose Creek (X2 and R2) and Vangorda Creek (V1 and V27) were tested for potential effects on survival and growth of *Hyalella azteca* over a 14-day exposure period (Environment Canada 1997), with results expressed as percent survival and organism dry weight (Table 6H-15). No effects were observed among the organisms exposed to sediments collected from mine-exposed areas (V27, X2, R2) compared to those exposed to reference area (V1) or lab control sediment (Table 6H-15).

Table 6H-15: Results of 14-d survival and growth tests using *Hyallela azteca* for sediment samples collected near the Faro Mine Complex. Organisms were not significantly affected in mine-exposed sediment samples compared to lab controls (p>0.05 Tukey multiple comparison test) .

Sample	Sample Date	Mean Survival (%)	Mean Dry Weight (mg)
Lab Control	Aug-07	100	0.297
V1 (Reference)	Aug-07	100	0.410
V27-A	Aug-07	100	0.357
V27-B	Aug-07	100	0.307
V27-C	Aug-07	100	0.275
Lab Control	Aug-08	88	0.203
X2	Aug-08	90	0.186
R2	Aug-08	86	0.236

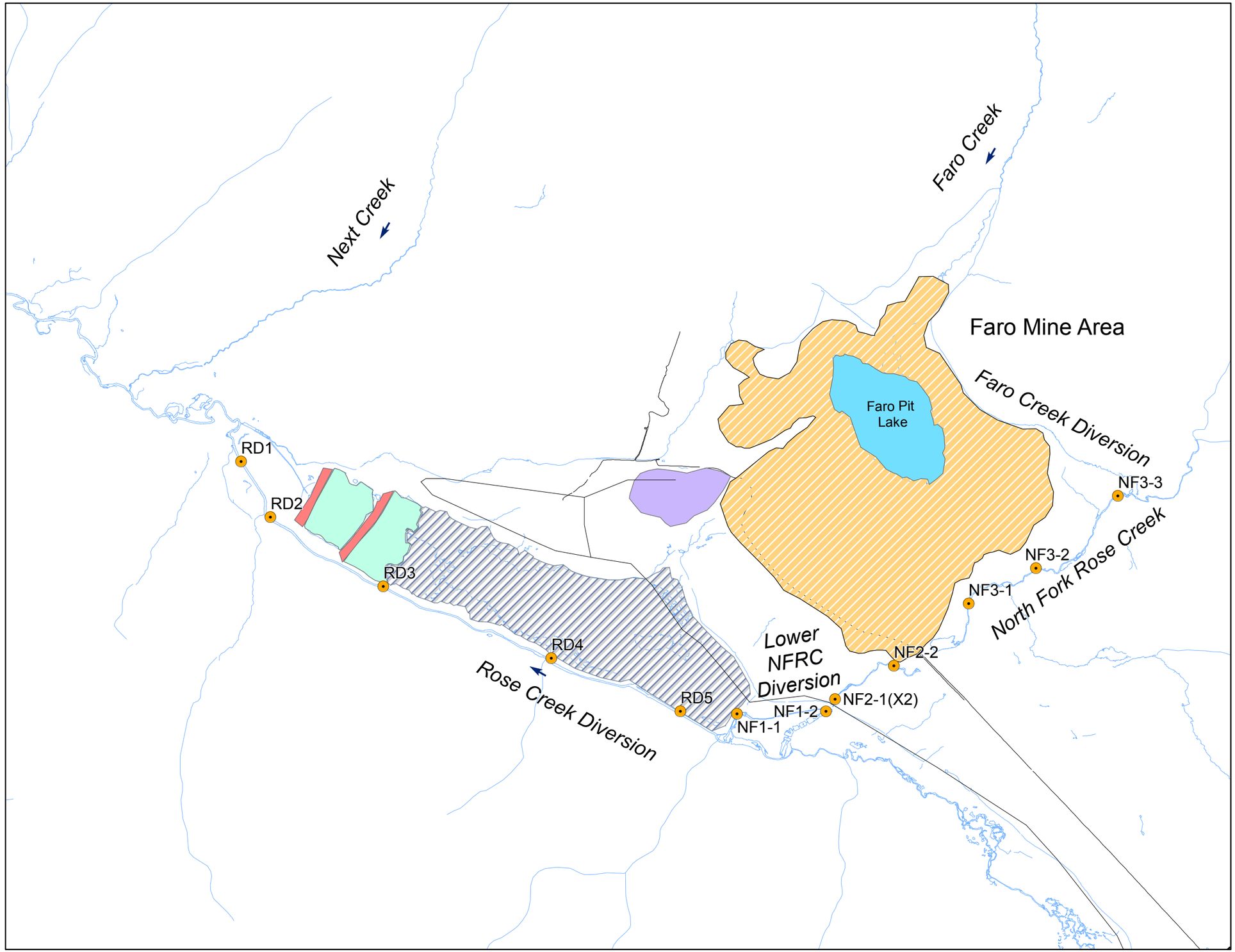
6.0 PERIPHYTON

Periphyton communities were characterized in 2009 along the NFRC and the RCD (de Graff 2013). The locations of investigations are illustrated on Figure 6H-15. The group of photosynthetic bacteria known as Cyanophyta dominated the communities in the NFRC just downstream from the confluence with the Faro Creek Diversion, but a shift to diatom (Bacillariophyceae)-dominated communities occurred closer to the Haul Road and continued downstream throughout the RCD (Figure 6H-16). Richness and Simpson's Evenness values were highly variable among sampling areas; however, diatom richness was elevated at downstream stations compared to the most upstream station (Attachment Table E.4).

The cyanophytes, *Chamaesiphon spp*., *Homoeothrix varians*, and *Clastidium setigerum,* were most abundant at station NF3-3 just downstream of the confluence of the NFRC with the Faro Creek Diversion, where mine influence is minimal, and were less abundant among stations farther downstream (Figure 6H-17). *Chamaesiphon spp*. have been shown to be both tolerant (Genter and Lehman 2000) and intolerant (Bray et al. 2008) to acid mine drainage, depending on the species. The 2009 data suggest that these three species are all intolerant of mine-related disturbances and may serve as future indicators of changes to aquatic health around the FMC.

The highest periphyton densities were observed in the NFRC just downstream of the Access Road (NF1-2) (Figure 6H-16a), where the diatom *Achnanthes minutissima* was most abundant (Figure 6H-17). In fact, *A. minutissima* made up roughly 44% (4 – 72%) of the diatom assemblage at all stations and was more abundant downstream than upstream of mine-related influences (Figure 6H-18). *Achnanthes*, especially *A. minutissima*, has previously been reported as the dominant diatom in streams affected by mining (Deniseger et al. 1986; Hill et al. 2000; Luis et al. 2009; Verb and Vis 2000). *A. minutissima* is generally considered tolerant of a wide variety of environmental conditions and is typically the only reported *Achnanthes* species in streams affected by acid mine drainage (Ponader and Potapova 2007). It also has been observed in higher relative abundance in areas with elevated levels of copper, lead, and zinc (Yoshiaki et al. 2004). As a result, its presence is frequently considered indicative of disturbed conditions (Sabater et al. 1998; Sabater 2000). Therefore, *A. minutissima* is likely indicative of the mine-related disturbances around the FMC.

The diatoms *Cymbella minuta*, *Fragilaria vaucheria*, and *Synedra ulna* showed a pattern similar to *A. minutissima* with respect to relative abundance among stations, while



VICINITY MAP



LEGEND

Direction of Flow

Sample Stations:

Periphyton & Benthic Invertebrate Stations

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Tailings Pond
- Dam
- Mill Area

N

0 0.15 0.3 0.6 km

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FIGURE 6H-15

Location of Stations Sampled by de Graff (2013)

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

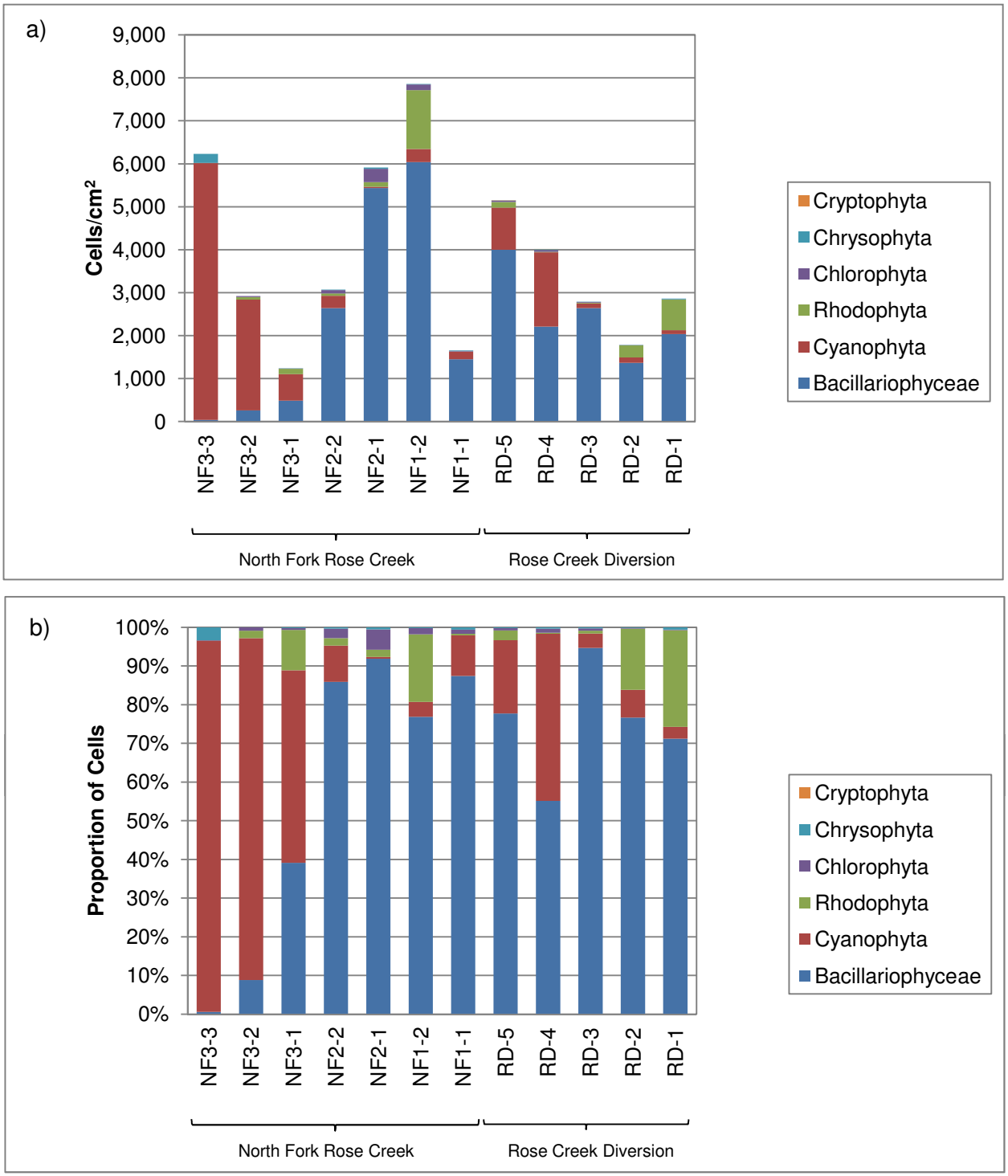

Figure 6H-16: Periphyton phylum a) abundance and b) proportion in the North Fork Rose Creek and Rose Creek Diversion, 2009. Data obtained from de Graff (2013).

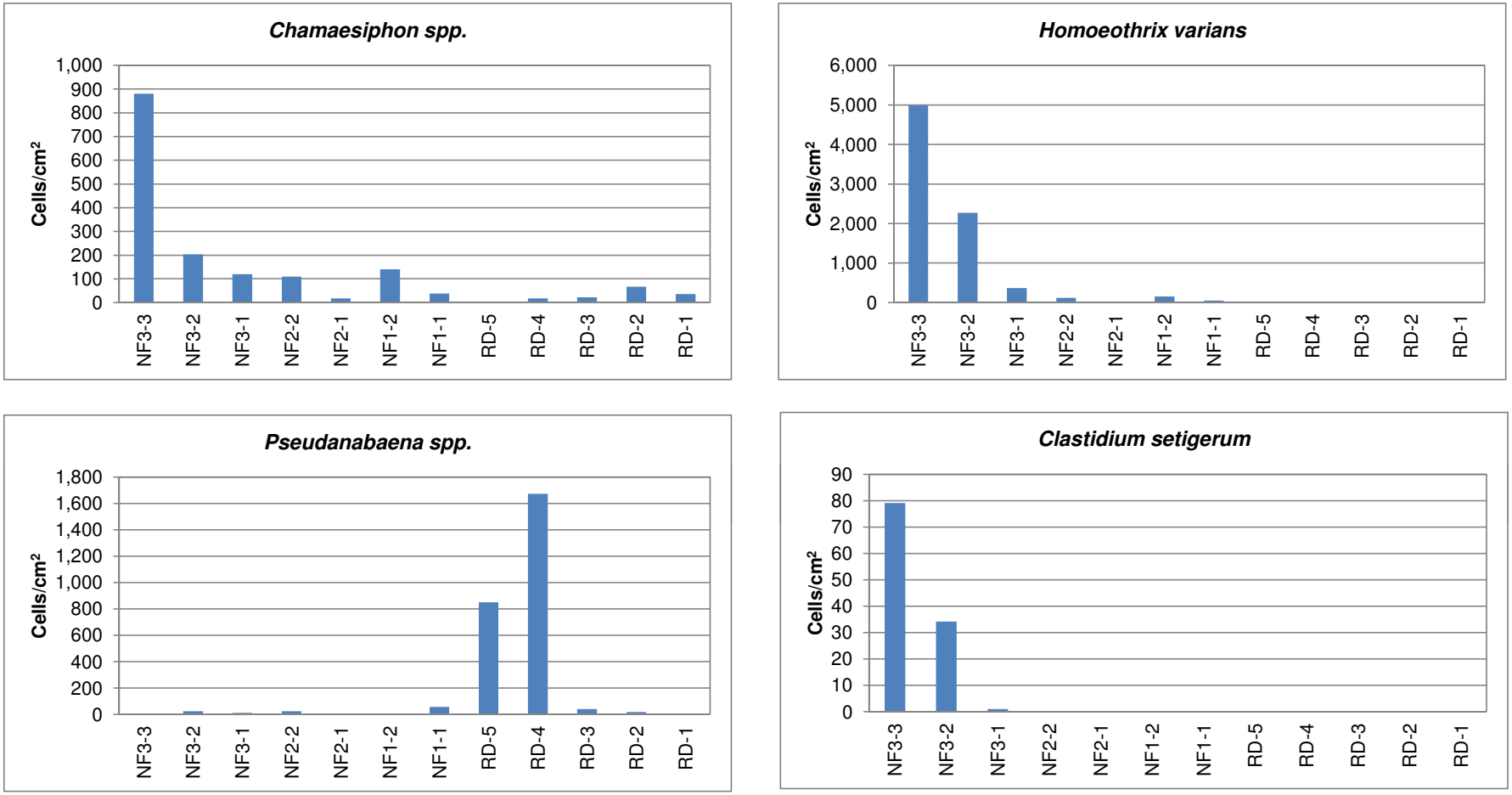

Figure 6H-17: Abundance of the four most common cyanophyta species (mean > 9 cell/cm^2) in the North Fork Rose Creek and Rose Creek Diversion, 2009. Data obtained from de Graff (2013).

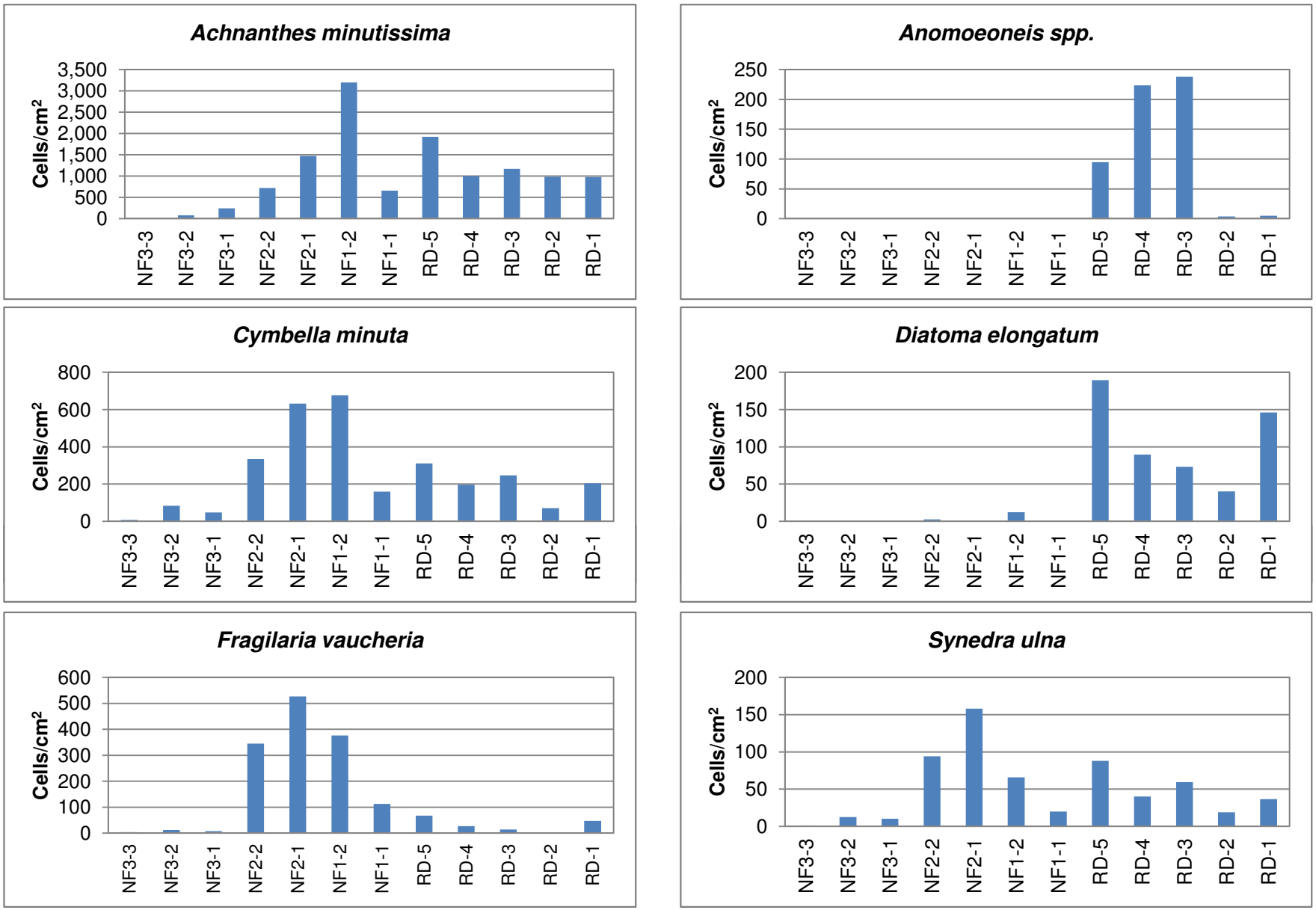

Figure 6H-18: Abundance of the six most common bacillariophyceae (diatom) species (mean > 40 cell/cm^2) in the North Fork Rose Creek and Rose Creek Diversion, 2009. Data obtained from de Graff (2013).

Anomoeoneis spp. and *Diatoma elongatum* were most abundant at stations in the RCD (Figure 6H-18). Data regarding the tolerance to mine-related disturbance of diatom species other than *A. minutissima* are generally sparse or lacking in the published literature.

7.0 BENTHIC INVERTEBRATE COMMUNITIES

7.1 Historical Data (to 2006)

Benthic invertebrate sampling was initiated in 1973 within the Rose-Anvil Creek basin and in 1975 within the Vangorda Creek basin. Table 6H-16 lists and describes the investigations completed. Figures 6H-19 and 6H-20 illustrate the sampling locations.

From 1991 until 2008, benthic invertebrate communities were monitored at standardized locations every second year (alternating between Rose and Vangorda Creeks), as per the requirements of FMC Water Licences. Artificial substrates (rock baskets) were used for the majority of studies, providing some consistency across much of the data set, although studies varied in terms of factors such as numbers of replicate samples and levels of taxonomic identification. Statistical analyses of data from studies conducted in Rose Creek downstream of the Faro Mine Area (e.g., R2-R4; Figures 6H-19 and 6H-20) in 2000, 2002, 2004 and 2006 indicated some differences in community characteristics compared to reference communities (e.g., R6, R7 and minimally impacted R1) (Minnow 2007). Similarly, data from 2001, 2003, and 2005 surveys of Vangorda Creek also revealed significant differences in benthic community composition between the reference station V1 and exposed station V27. However, the community differences between mine-exposed and reference communities in both the Rose Creek and Vangorda Creek basins did not appear to be mine-related, based on higher proportions of Ephemeroptera-Plecoptera-Tricoptera (EPT) and lower proportions of chironomids at some mine-exposed areas, which are patterns generally indicative of a different or improved habitat rather than a deleterious effect. Overall, the data indicated that temporal variability played as large a role as relative station location in structuring benthic communities sampled by artificial substrates in Rose Creek and Vangorda Creek (Minnow 2007). This may be because invertebrate communities have a relatively short window of time for colonization on artificial substrates (e.g., 6-8 weeks), and may be particularly affected (compared to organisms on natural substrate) by inter-annual variations in environmental factors such as water flow and temperature during the substrate deployment period.

7.2 Recent Surveys (2007-2010)

Benthic invertebrate surveys were conducted at the FMC in 2007 (Vangorda Creek) (Laberge 2007; Minnow 2009), 2008 (Rose Creek) (Laberge 2009; Minnow 2009), 2009 (Rose Creek) (de Graff 2013), and 2010 (Rose Creek and Vangorda Creek) (Laberge 2011). The results of each study are briefly summarized below.

Table 6H-16: Summary of sampling locations and methods associated with historical benthic invertebrate community assessments, 1973-2010.

Reference	Year Sampled	Stations	Sampler	Replicates/ station	Replicate Samples or Data Composited?	Incubation or Collection Dates	Mesh Size	Lowest Level of Taxonomy
Hoos and Holman 1973	1973	R1-R3, R5, R11 (A1)	1 square foot circular sampler	3	no	Sept 17-21, 1973	not specified	genus
Baker 1979	1974-1976	R1-R4, R6, R11 (A1) and Pelly River	chrome-plated baskets with rocks	3	no	1974, 1975, and 1976 (dates not given)	100 microns (surber)	genus
Montreal Engineering 1976	1975	West Fork Vangorda, South Fork Rose (u/s R1), Blind Creek	Surber and plankton tow	3 (surber)	yes	August 1975	not specified	Partially to family
Weagle 1981a	1977	R1-R4, R6, R11 (A1) and Pelly River	chrome-plated baskets with rocks	3	yes	August 18 to Oct 5, 1977	100 microns (surber)	genus
Weagle 1981a	1978	R1-R4, R6, R11 (A1) and Pelly River	Surber	3	yes	August 18 to Oct 5, 1977	100 microns (surber)	genus
Weagle 1980	1980	R1-R5, V1, V27, VGMAIN, Blind Creek, Swim Creek	cylindrical BBQ baskets, 17cm dia, 24cm long. Filled with rocks to up to 5 cm	2	yes	Aug 14/15 to Sept 17+G19/-18, 1980	100 microns (surber)	genus/species
Weagle 1981b	1981	R1-R6, V1, V27, Blind Creek, Swim Creek	chrome-plated cylindrical BBQ baskets, 17cm dia, 24cm long. Filled with rocks to up to 5 cm	2	yes	Aug 27/28 to Sept 30/Oct 2, 1981	100 um (surber)	genus/species
Weagle 1982	1982	R1-R5	chrome-plated cylindrical BBQ baskets, 17cm dia, 24cm long. Filled with rocks to up to 5 cm	2	yes	September 7-October 8, 1982	100 um (surber)	genus/species
Godin and Osler 1985	1983	R1-R6, R11 (A1), and Pelly River	Baskets with rocks 1-8 cm diameter	3	yes	July 26 to Sept 15, 1983	0.76mm	genus
Weagle 1983	1983	R1-R5	BBQ baskets, 40 x 40 x 15 cm. Filled with rocks to up to 2.5 cm	2	yes	Aug 19/20 to Oct 13/14, 1983	100 um (drift net)	genus/species
Leverton and Associates 1987	1986	R2-R5	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	no	July 14 to August 27, 1986	not specified	genus/species
Laberge 1989	1988	R1-R5	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	yes	Aug 5 to Sept 21-22, 1988	retrieved into bucket, no net mentioned	genus/species
Laberge 1989	1988	R6, V8 and Blind Creek	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	yes	Aug 5 to Sept 21-22, 1988	retrieved into bucket, no net mentioned	genus/species
Laberge 1991a	1990	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	no	Aug 22/24, 1990	retrieved into bucket, no net mentioned	genus
Harder and Associates 1991b	1990	V8 and Blind Creek	baskets with clean substrata; no details provided	3	no	July 29 to Sept. 5, 1990	not specified	family/genus
Harder and Associates 1992	1990	V1, V5, V27, V8, Blind and Buttle Creeks	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	no	installed July 18-19, 1990, for five weeks	not specified	not specified
Harder and Associates 1993a,b	1992	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	no	July 8/10 to Aug 16/17, 1992	300 micron, animals > 0.25mm enumerated	family/genus
Laberge 1994	1994	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	no	Installed late July and retrieved after about five weeks	300 µm	genus/species
Laberge 1993 1996, 1998, 2000, 2001, 2002b, 2003, 2005, 2007	1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007	V1, V5, V27, V8	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	no	Installed late July and retrieved after about five weeks	300 µm	genus/species
Laberge 1997, 1999, 2001, 2002b, 2004, 2006, 2009	1996, 1998, 2000, 2002, 2004, 2006, 2008	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm diameter Filled with gravel (2-15cm dia)	3	no	Installed late July and retrieved after about five weeks	300 µm	genus/species
Minnow 2009	2007, 2008	V1, V5, V27, V8, X2, R2, 12 reference areas	Hess	1-5	yes	August 25–29, 2007 and August 19-24, 2008	243 µm mesh (but subsequently sieved to 300 µm in field or lab)	genus/species
			kick net	1-3	not applicable			genus/species
de Graff 2013	2009	NF3-3, NF3-2, NF2-2, NF2-1, NF1-2, NF1-1, RD5, RD4, RD3, RD2, RD1	kick net	1	not applicable	late August, 2009	500 µm	genus/species
Laberge 2011	2010	X2, R2, R4, V5, VGMAIN, V8, 8 reference areas	kick net	1	not applicable	August 30-September 3, 2010	400 µm	genus/species

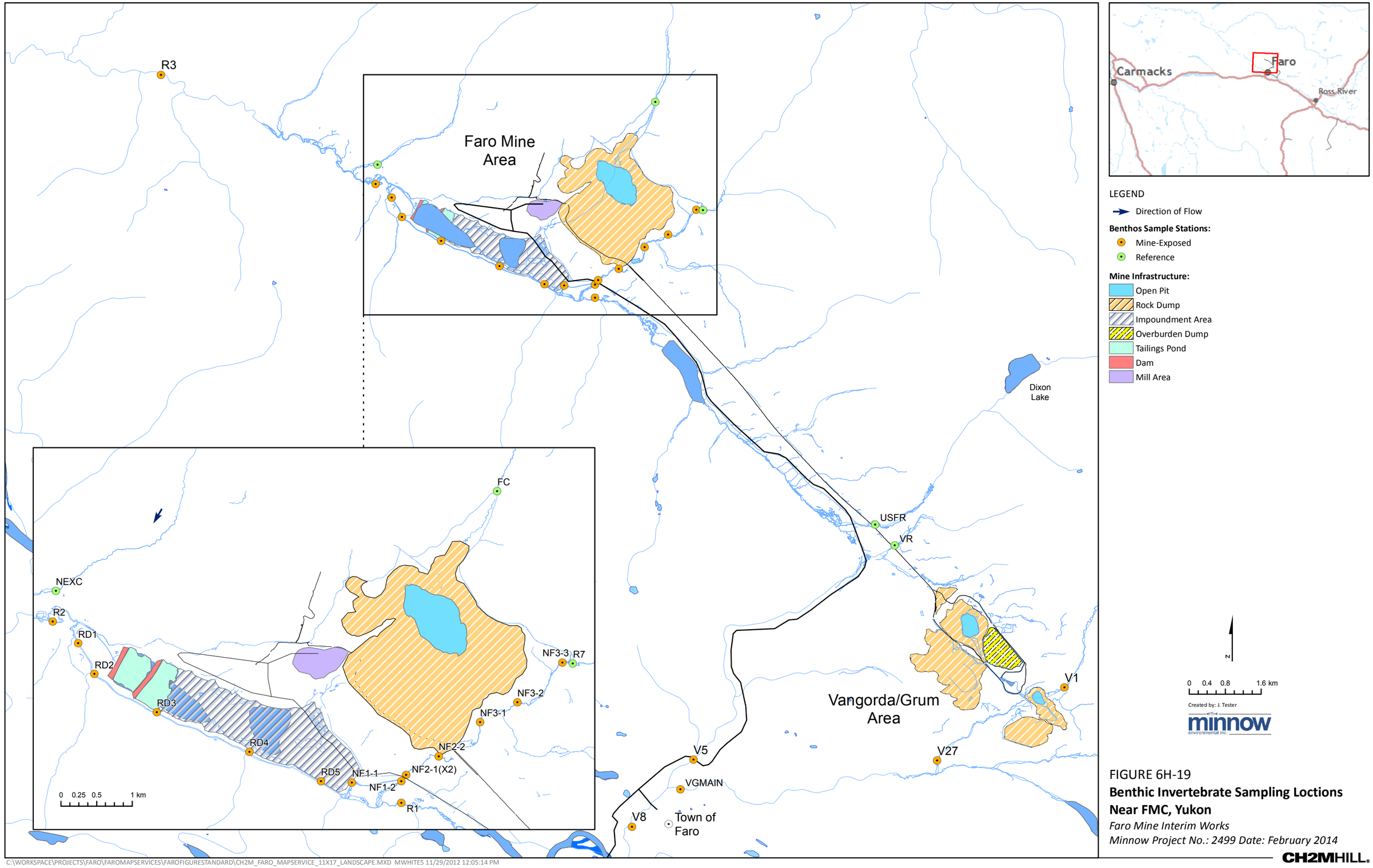

FIGURE 6H-19

Benthic Invertebrate Sampling Loctions Near FMC, Yukon

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

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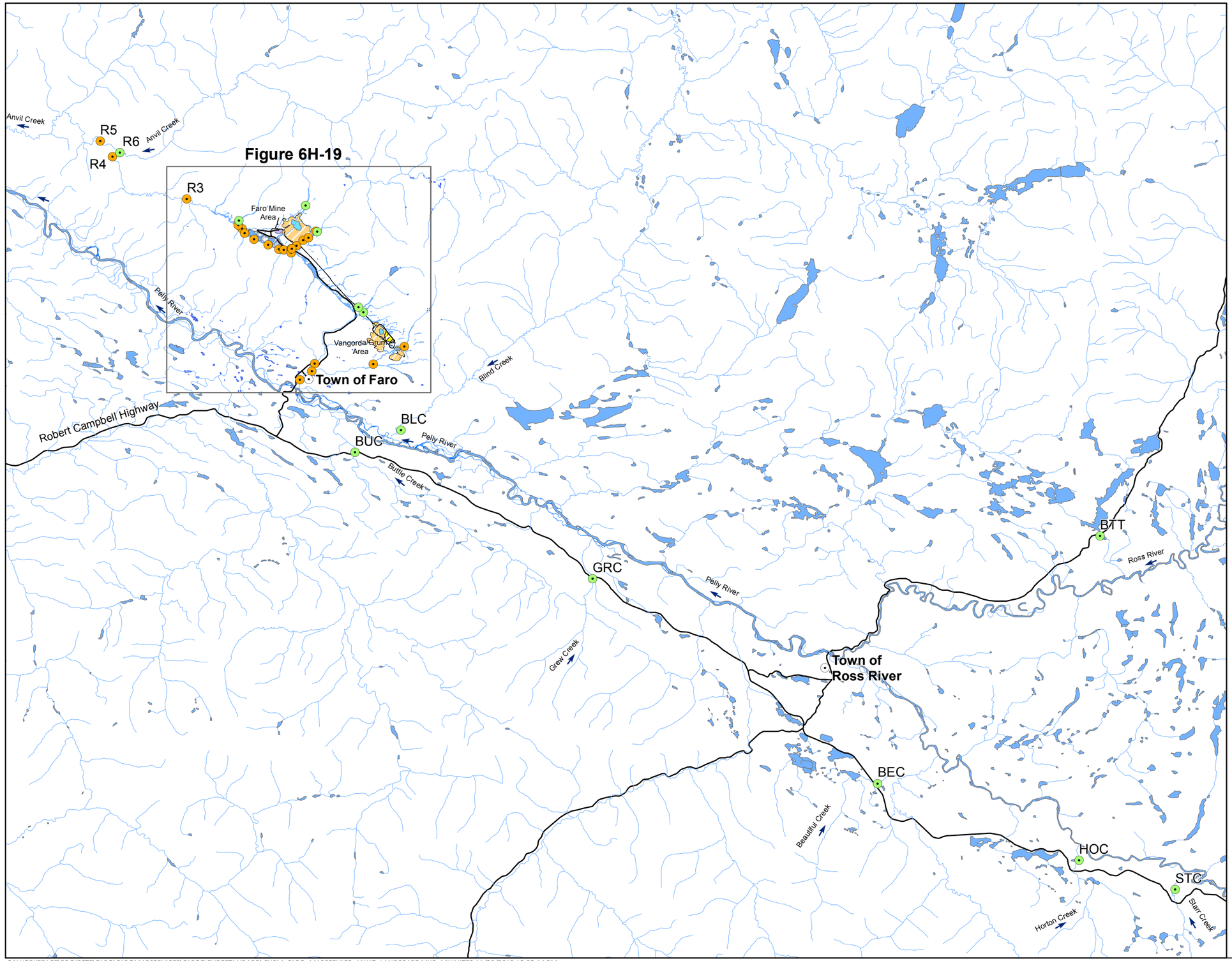
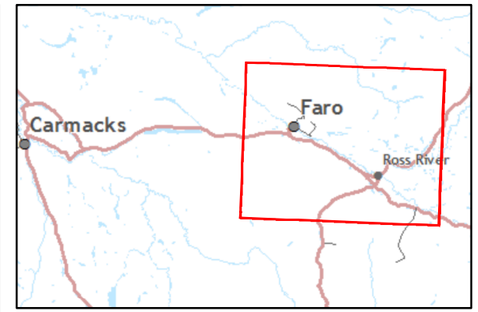


VICINITY MAP



LEGEND

- Direction of Flow

Benthos Sample Stations:

- Mine-Exposed
- Reference

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 1.75 3.5 7 km

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FIGURE 6H-20

Locations of Additional Reference and Mine-Exposed Benthic Invertebrate Monitoring Areas

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

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Using 2007 and 2008 survey data, Minnow (2009) compared results for three different benthic invertebrate community sampling methods (artificial substrates, Hess sampling, and kick net sampling) and two different sampling designs (discussed below) to determine the approach that would be most sensitive for detecting mine-related effects on benthic invertebrate communities in long-term monitoring at the FMC (Minnow 2009). Samples were collected from Vangorda Creek stations V27 (upper main stem), V5 (West Vangorda Creek), and V8 (lower Vangorda Creek), as well as Rose Creek stations X2 (NFRC upstream from Access Road) and R2 (downstream from Faro Mine Area). An additional 12 reference areas within and outside of the Rose Creek and Vangorda Creek watersheds were sampled. Community endpoints included abundance, number of taxa (identified to lowest practical level), percent dominant taxa, Simpson's diversity and evenness, and community structure as defined by correspondence analysis. Benthic community studies based on artificial substrates were concluded to be less sensitive for statistically detecting differences between mine-exposed and reference communities than sampling of resident communities from natural substrates using Hess or kick net methods. Using a traditional control-impact (CI) sampling design (Analysis of Variance [ANOVA] and pre-planned reference-exposure contrasts), Hess and kick samples produced the same number of significant reference-exposure differences among community endpoints, but the significantly different community endpoints differed between sampling methods. Using a reference condition approach sampling design (Bailey et al. 2004), the kick sampling method was slightly more sensitive at detecting benthic invertebrate community differences between mine-exposed and reference areas than the Hess sampling method and was recommended as the most cost-effective approach for long-term monitoring at the FMC. Taken together, the 2007 and 2008 data suggested that there were subtle, mine-related effects on benthic invertebrate community characteristics at X2 and V27, but neither these nor any of the other mine-exposed areas that were evaluated had community characteristics that were statistically conclusive with respect to being outside the range of reference area variability.

In 2009, de Graff (2013) sampled benthic invertebrate communities at stations along the NFRC and RCD using a kick net. Community metrics that were reported included taxonomic richness, Shannon-Weiner diversity index, number of EPT taxa and percent dominant taxa (Attachment Table F.1). However, the data were not evaluated based on these endpoints; instead community health was assessed using Environment Canada's web-portal known as the Canadian Aquatic Biomonitoring Network (CABIN) (Environment Canada 2013b). CABIN allows users to input benthic invertebrate data from areas of concern and, where available, to use regional models to compare community structure

against a suite of reference areas. Such models evaluate the invertebrate community at a test area by comparing it to communities at a group of reference areas using 3-dimensional nonmetric multidimensional scaling ordination The test area is considered divergent from the reference condition if its invertebrate community ordination scores cause it to fall outside of the 99% confidence ellipse in any one of three possible axis pairings.

All of the FMC communities sampled by de Graff (2013) were compared against the Yukon Reference Model January 2010 (Bailey and Reynoldson 2010). All mine-exposed stations were predicted to belong to Reference Group 4 of the territory-wide model. Reference Group 4 includes invertebrate communities sampled from 83 Yukon reference streams between 2004 and 2009; therefore, the reference group incorporates a potentially large amount of temporal and spatial variability that may have confounded the evaluation of communities at the FMC. All of the FMC stations were identified by the model as being within the reference condition, except for three located along the lower NFRC, of which only one (NF1-2; NFRC just downstream from the Access Road) was conclusively different from the reference group (two others were considered "somewhat" divergent from reference meaning results were inconclusive). The community at NF1-2 has not been sampled in other recent studies, but the de Graff (2013) location NF2-1, NFRC just upstream from the Access Road, generally corresponds with location X2 that was also sampled in 2008 (Laberge 2009; Minnow 2009). Results from the different studies were in agreement for the latter location, with de Graff (2013) concluding that the community at NF2-1 was within reference condition, and Minnow (2009) concluding that the community was only subtly different from the reference condition.

The most recent study, conducted in 2010 (Laberge 2011), also used kick nets to sample benthic invertebrate communities and considered community endpoints such as species and taxon richnesses, sample abundance, percent EPT, and percent chironomids (midges). Although results for reference and mine-exposed communities were not statistically compared, the study concluded that there was evidence of some impairment at the mine-exposed areas on Rose Creek (X2 and R2), with full community recovery evident downstream on Rose Creek at R4 (just upstream of the Anvil Creek confluence).

For this baseline characterization, data from the 2008 survey (Minnow 2009) were re-analyzed, along with the 2010 data (Laberge 2011), by comparing communities in each mine-exposed area to the range of community characteristics associated with the seven reference areas that were common to both studies, using the same statistical methods as those of Minnow (2009). Key community characteristics for reference and exposure

stations sampled in 2008 and 2010 are presented in Table 6H-17 and Figure 6H-21. EPT and chironomidae (midges) comprised the majority of taxa in all communities but relative proportions varied among areas and between years (Table 6H-17; Figure 6H-21; Attachment Tables F.2 and F.3). Data from both years indicated that communities at X2 (NFRC upstream of the Access Road), R2 (Rose Creek downstream from the Faro Mine Area), and V8 (lower Vangorda Creek; Figure 6H-19) were within or only slightly different from the reference condition based on all community characteristics examined (Attachment Tables F.4 and F.5).

In summary, benthic invertebrate surveys conducted in 2007, 2008, 2009, and 2010 indicated that most benthic invertebrate communities in streams adjacent to and downstream from mine-related disturbances at the FMC were similar to communities in reference areas uninfluenced by mining. Exceptions were communities along lower NFRC and in Rose Creek immediately downstream from the Faro Mine Area where modest differences from reference communities were evident in some studies.

Table 6H-17: Biotic indices calculated for all benthic invertebrate communities sampled in both 2008 and 2010.

		Station ID	Description	Family Richness	EPT%*	Ephemeroptera%	Plecoptera%	Chironomidae%
2008	Reference	BEC	Beautiful Creek	12	17	2	2	61
		BLC-1	Blind Creek	19	70	34	33	22
		BLC-2	Blind Creek	26	46	19	26	43
		BLC-3	Blind Creek	14	46	16	29	53
		BTT	Unnamed Creek near Big Trout Tributary	16	18	6	6	69
		BUC	Buttle Creek	18	85	50	29	11
		FC	Upper Faro Creek	18	42	13	29	38
		GRC	Grew Creek	10	59	15	44	28
		HOC	Horton Creek	15	70	42	26	16
		NXT	Next Creek	18	77	47	28	19
		R7-1	Upper North Fork Rose Creek	24	31	13	17	46
		R7-2	Upper North Fork Rose Creek	18	53	20	33	35
		STC	Starr Creek	14	22	9	11	45
		USFR	Upper South Fork Vangorda Creek	23	77	31	42	17
		VR	Upper West Fork Vangorda Creek	14	61	26	35	12
	Exposed	X2-1	North Fork Rose Creek u/s mine access Rd	25	41	19	20	50
		X2-2	North Fork Rose Creek u/s mine access Rd	20	13	4	8	71
		X2-3	North Fork Rose Creek u/s mine access Rd	20	8	2	5	73
		R2-1	Rose Creek immediately d/s FMC	20	64	47	17	24
		R2-2	Rose Creek immediately d/s FMC	18	75	53	22	15
		R2-3	Rose Creek immediately d/s FMC	21	63	43	19	28
2010	Reference	BLC	Blind Creek	18	16	7	9	69
		BUC	Buttle Creek	20	42	19	22	49
		FC	Upper Faro Creek	18	30	12	17	61
		HOC	Horton Creek	16	77	36	39	11
		R6	Upper Anvil Creek	16	49	42	7	46
		R7	Upper North Fork Rose Creek	12	15	7	8	82
		USFR	Upper South Fork Vangorda Creek	16	76	53	21	21
		VR	Upper West Fork Vangorda Creek	14	82	29	53	6
	Exposed	X2	North Fork Rose Creek u/s mine access Rd	18	7	5	2	90
		R2	Rose Creek immediately d/s FMC	12	4	3	1	90
		R4	Rose Creek u/s Anvil Creek	18	87	70	11	5
		V5	West Fork Vangorda Creek	17	63	23	34	13
		VGMAIN	Vangorda Creek u/s of West Fork Vangorda Creek	18	82	37	41	11
		V8	Lower Vangorda Creek	19	64	31	28	29

* EPT - Ephemeroptera + Plecoptera + Trichoptera

u/s - upstream

d/s - downstream

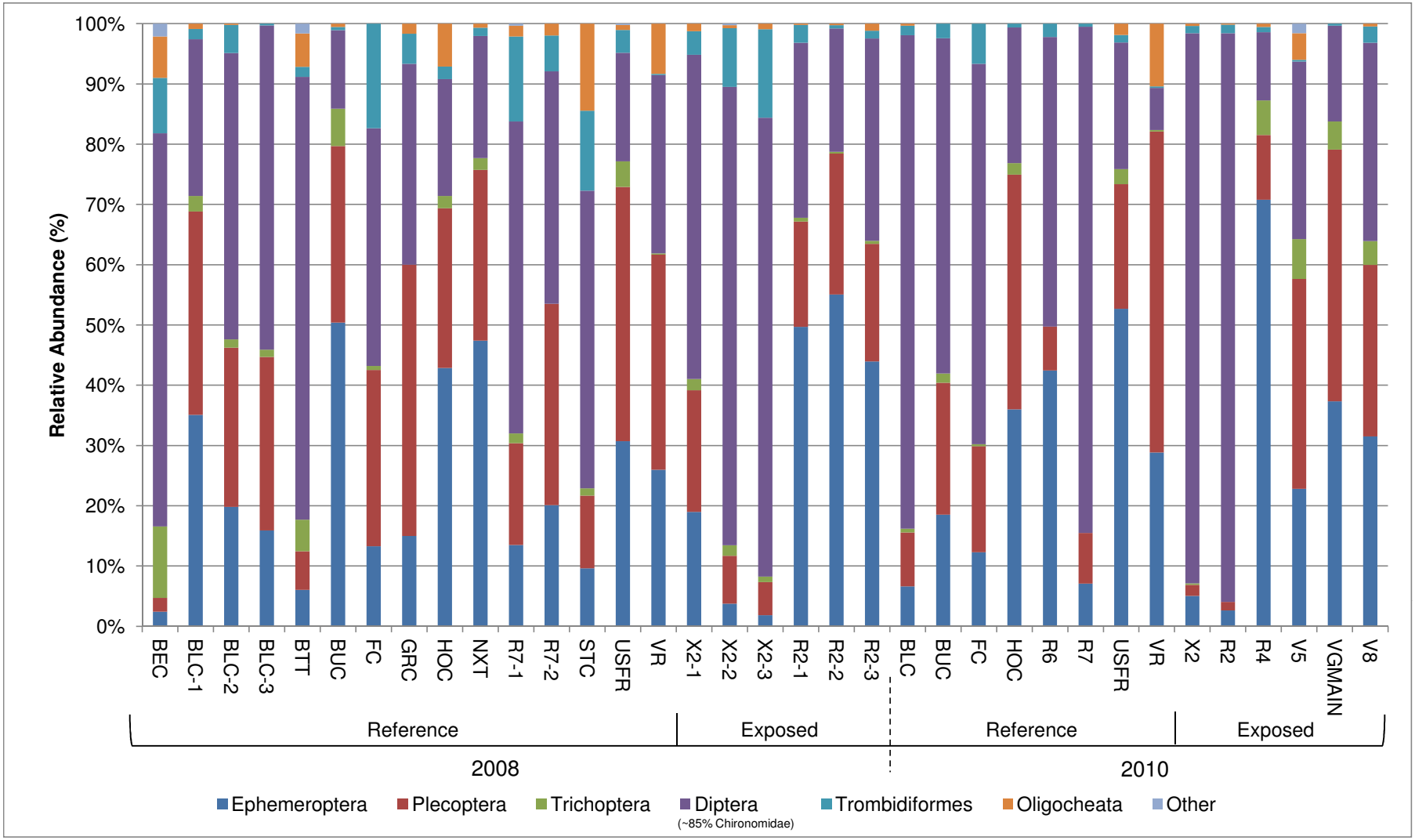


Figure 6H-21: Community composition of all stations sampled in 2008 and 2010 using the CABIN kick sampling method.

8.0 FISH

8.1 Community

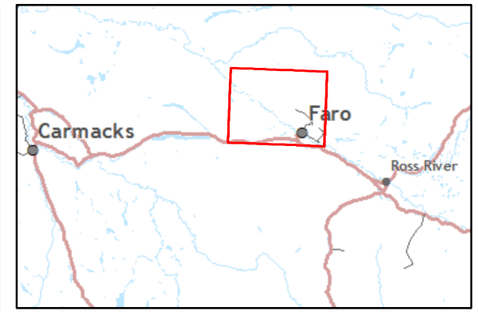
Fish community characteristics were characterized from data presented in historical reports, with detailed records from individual reports presented in Attachment G. The data are summarized in Table 6H-18 and below for the stream reaches identified in Figure 6H-22, for which habitat was previously described (Section 3.0).

8.1.1 Rose Creek and Anvil Creek

Construction of the rock drain supporting the Haul Road has isolated fish in the upper reach of NFRC from the rest of the Rose Creek and Anvil Creek systems. Arctic grayling (*Thymallus arcticus*), slimy sculpin (*Cottus cognatus*), burbot (*Lota lota*), round whitefish (*Prosopium cylindraceum*) and longnose sucker (*Catostomus catostomus*) have been reported within this reach (Table 6H-18). Slimy sculpin were the most abundant species collected upstream of the Haul Road in both 2005 (upstream from Faro Creek Diversion, WMEC 2005b) and in 2009 (downstream from Faro Creek Diversion, de Graff 2013). Very few burbot and round whitefish have been observed and, were only found in the upper reaches of the NFRC (WMEC 2005b). Few arctic grayling were captured upstream from the Haul Road in August and October 2009 (de Graff 2013) and September 2012 (EDI 2013a), though numerous individuals were captured or observed in the pond immediately upstream from the Haul Road in August 2005 (WMEC 2005b). The pond appears to provide important over-wintering habitat for grayling because the water does not freeze to the bottom in the winter (EDI 2013b, WMEC 2005a). Potential grayling spawning habitats in the upper reaches of the NFRC include the mouth of the same pond, and near the ponded areas in the headwaters (WMEC 2005b).

Arctic grayling, slimy sculpin, burbot and round whitefish have been reported in the NFRC downstream from the Haul Road (Table 6H-18). Slimy sculpin were the most abundant species within this reach, though numerous arctic grayling were also present, mostly in close proximity to the Haul Road rock drain, near water monitoring station X3 and within the RCD (WMEC 2005, de Graff 2013, EDI 2013b). Arctic grayling spawning and spawning habitat have been reported in the NFRC downstream from the Haul Road and in the constructed ponds just upstream of the confluence with SFRC (EDI 2013a, WMEC 2005b).

VICINITY MAP



LEGEND

Barrier to Fish Migration

Direction of Flow

Reach 4 South Fork Rose Creek (Haul Road to confluence

Mine Infrastructure:

- Open Pit
- Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Area

N

0 0.75 1.5 3 km

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FIGURE 6H-22

Stream Reaches for which Fish Data have been Summarized

Faro Mine Interim Works

Minnow Project No.: 2499 Date: February 2014

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Table 6H-18: Summary of fish species presence in the vicinity of the Faro Mine Complex (details in Attachment Table G.1).

Reach			Fish Species						
			Arctic Grayling (*Thymallus arcticus*)	**Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*)**	**Slimy Sculpin (*Cottus cognatus*)**	**Burbot (*Lota lota*)**	**Round Whitefish (*Prosopium cylindraceum***	**Longnose Sucker (*Catostomus catostomus*)**	**Lake Chub (*Couesius plumbeus*)**
Anvil-Rose Watershed	North Fork Rose Creek upstream from Haul Road	Reach 1	√	NA	√	√	√	√[a]	-
	North Fork Rose Creek downstream from Haul Road	Reach 2	√	-	√	√	√	-	-
	South Fork Rose Creek upstream from Haul Road	Reach 3	√	-	√	-	-	-	-
	South Fork Rose Creek (Haul Road to confluence with North Fork)	Reach 4	√	√	√	√	√	-	-
	Rose Creek Diversion Channel	Reach 5	√	√	√	√	√	-	-
	Rose Creek downstream from Faro Mine Complex	Reach 6	√	√	√	√	√	√[a]	-
	Anvil Creek downstream of Rose Creek	Reach 7	√	√	√	√	√	√	√
Vangorda Watershed	Upper Vangorda Creek	Reaches 8 and 9	Not Accessible						
	Vangorda Creek at mouth	Reach 10	√	√	√	√	√	√	√

[a] AECOM 2009. No data records provided.

Similar to the NFRC, the fish populations of the upper reach of SFRC have been separated from those in the rest of the system, due to culverts at both the Access Road and the Haul Road, and a steep gradient upstream from the Haul Road, that prevent the upstream migration of fish (GLL 2003, de Graff 2013). Arctic grayling and slimy sculpin were the only species captured upstream from the Haul Road in past studies (Table 6H-18). Although slimy sculpin have not been captured since 1989 (Attachment Table G.1), the section immediately upstream of the Haul Road has only been fished once since then (Minnow and WMEC 2009), and only arctic grayling were targeted in 2012 in and near Dixon Lake (EDI 2013a). Limited numbers of arctic grayling were captured in Dixon Lake and immediately downstream in 2012 (EDI 2013a) and also upstream from the Haul Road in 2008 (Minnow and WMEC 2009). Within the section of SFRC between the Access Road and the confluence with the NFRC, arctic grayling, juvenile Chinook salmon (*Oncorhynchus tshawytscha*), slimy sculpin, burbot and round whitefish have been captured or observed (Table 6H-18). Slimy sculpin was the most abundant species captured, followed by arctic grayling (AECOM 2009). Arctic grayling spawning has been observed in the Pumphouse Pond located at the confluence of the NFRC and SFRC (WMEC 2005b). The observation of juvenile Chinook salmon by WMEC in 2004 (WMEC 2005c) is the only reported occurrence of Chinook salmon upstream from the RCD. A pair of Chinook salmon were observed spawning within the RCD in 2009 by WMEC (Minnow 2010).

Arctic grayling movements within the Anvil and Rose Creek systems were recently characterized using radio telemetry (EDI 2013b). The study determined that some arctic grayling migrate downstream to the Pelly River to overwinter, while others overwinter in the RCD and NFRC. In the latter case, overwintering fish were observed both immediately upstream and downstream from the Haul Road. Upstream migration through the RCD in the spring was also confirmed by tracking a fish from Rose Creek downstream from the Faro Mine Area to the Pumphouse Pond, confirming fish passage can occur through the high-gradient portion of the lower RCD.

Downstream from the FMC, arctic grayling, juvenile Chinook salmon, slimy sculpin, burbot, round whitefish and longnose sucker have been observed or captured (Table 6H-18). The most abundant species below the Faro Mine Area was slimy sculpin, though numerous juvenile Chinook salmon were captured at R2 in 2004 using minnow traps (WMEC 2005c). The same species have been observed or captured in the lower reaches of Anvil Creek downstream from Rose Creek, as well as lake chub (*Couesius plumbeus*), which were captured near the mouth (Access et al. 2006). A study of Chinook spawning

by WMEC in Anvil Creek and the Pelly River suggested Anvil Creek typically has low numbers of spawners (WMEC 2010a). The Rose-Anvil Creek system has been identified as having moderate to low suitability for Chinook salmon spawning, with some habitat suitable for rearing juvenile Chinook salmon, although utilization may be limited at times due to environmental factors or conditions (Yukon Placer Secretariat 2010). Blind Creek, an adjacent watershed located further up the Pelly River, has high suitability for Chinook salmon spawning, providing spawning habitat, and critical migratory corridors required to access spawning habitat (Yukon Placer Secretariat 2010).

8.1.2 Vangorda Creek

An 8-m waterfall located approximately 3 km upstream from the mouth of Vangorda Creek, and a culvert under the Access Road on the west fork, represent barriers to upstream fish migration (Figure 6H-22). Consequently, no fish have been reported in upstream reaches of Vangorda Creek (RGC 1996, Minnow 2009). Within the lower portion of Vangorda Creek, arctic grayling, juvenile Chinook salmon, slimy sculpin, burbot, round whitefish, longnose sucker and lake chub have all been identified (Table 6H-18). The most abundant species in this reach has been juvenile Chinook salmon, though the number captured varies greatly between years (WMEC 2005c, WMEC 2008). The lower portion of Vangorda Creek has been identified as having moderate suitability for Chinook salmon, defined as habitats that are suitable for rearing juvenile Chinook salmon (Yukon Placer Secretariat 2010). High numbers of juvenile Chinook salmon have been reported during spring and summer months in lower Vangorda Creek, likely moving in from both Blind Creek and the Pelly River for the summer months before moving to overwintering or migratory habitats in the fall.

8.2 Tissue Metals

Fish tissues were periodically sampled from Rose, Anvil, Vangorda, and Blind creek areas between 1975 and 2005. Data include metals in muscle and liver collected from arctic grayling and in whole bodies of slimy sculpin (results are provided in Attachment Tables G.2 to G.4). Concentrations have occasionally been slightly elevated in fish collected near the FMC compared to fish collected in reference areas or farther downstream.

9.0 SUMMARY

Habitat

The FMC occupies portions of both the Rose Creek and Vangorda Creek watersheds. Both creeks are tributaries to the Pelly River, which is a major tributary to the Yukon River. Several physical alterations to stream courses have occurred over time around the FMC to accommodate mine features; these include several stream diversions and numerous road crossings, with some of the latter resulting in barriers to fish passage. Common features among most reaches of the Rose-Anvil Creek and lower Vangorda Creek system include boulder and cobble substrate, with boulders and pools providing in-stream cover for fish.

Water Quality

Water quality data for the FMC between 2008 and 2012 indicate that concentrations of a variety of non-metals and metals are elevated in surface waters relative to the typical range of background (reference station) concentrations. Alkalinity, conductivity, hardness, sulphate, total dissolved solids, calcium, cobalt, magnesium, nickel, sodium, strontium, and zinc occur at concentrations above the background range in approximately half or more of samples collected downstream of the Vangorda/Grum Area (V8) and the Faro Mine Area (X14). Concentrations of non-metal analytes are below those expected to have adverse effects on aquatic biota.

Metal concentrations in lower Vangorda Creek (V8) rarely (≤ 15% of samples) exceed guidelines for protection of aquatic life and median concentrations are usually less than half the guideline values. Water concentrations of several metals (cadmium, cobalt, iron, lead, manganese, zinc) are above guidelines in up to one-quarter of samples collected at NF1, on the North Fork Rose Creek (NFRC) upstream from the Haul Road, but zinc is the only mine-related metal that exceeds guidelines at stations between NF1 and Rose Creek station X14, just downstream of the Faro Mine Area. Cobalt and manganese are also found at concentrations above water quality guidelines for protection of aquatic life in up to 40% of samples collected at X14, but median concentrations for all metals but zinc are below the guidelines. Water quality guidelines are infrequently exceeded at stations farther downstream in Rose Creek (R4) and Anvil Creek (A1) indicating that mine related effects on biota, if any, are likely localized around the Faro Mine Area. Mine-related effects on water quality do not extend into the Pelly River.

Sediment Quality

Arsenic, lead, manganese, and zinc concentrations tend to be elevated in sediment samples collected at mine-exposed areas relative to sediment quality guidelines. However, the survival and growth of the invertebrate *Hyalella azteca* were not affected in 14-day laboratory tests of sediments collected from mine-exposed areas. Mine-related contaminants tend to be associated with fine sediment particles; however the aquatic environments around and downstream from the FMC are typically moderately to swiftly flowing, with sediments composed of particles that are mainly sand-sized or larger. Therefore, sediment exposure to mine-related contaminants represents a relatively minor pathway for potential effects to aquatic biota to mine-related contaminants.

Periphyton

Periphyton communities were characterized in 2009 along the NFRC and the RCD. The group of photosynthetic bacteria known as Cyanophyta dominated the communities in the NFRC just downstream from the confluence with the Faro Creek Diversion, but a shift to diatom (Bacillariophyceae)-dominated communities occurred closer to the Haul Road and continued downstream throughout the RCD. *Achnanthes minutissima* made up roughly 44% (4 – 72%) of the diatom assemblage at all stations and was more abundant downstream than upstream of mine-related influences. *Achnanthes*, especially *A. minutissima*, is generally considered tolerant of a wide variety of environmental conditions and, in other studies, has been observed in streams affected by mining or metals. Data regarding the tolerance to mine-related disturbance of diatom species other than *A. minutissima* are generally sparse or lacking in the published literature.

Benthic Invertebrate Communities

Benthic invertebrate surveys conducted annually between 2007 and 2010 indicated that communities are dominated by organisms in the mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) groups, as well as midges (chironomids). Most communities in streams adjacent to and downstream from mine-related disturbances at the FMC are similar to communities in local reference areas uninfluenced by mining. Exceptions are communities along lower NFRC and in Rose Creek immediately downstream from the Faro Mine Area where modest differences from reference communities have been evident in some studies.

Fish

Slimy sculpin (*Cottus cognatus*), Arctic grayling (*Thymallus arcticus*), Chinook salmon (*Oncorhynchus tshawytscha*), burbot (*Lota lota*), round whitefish (*Prosopium cylindraceum*) and longnose sucker (*Catostomus catostomus*) have been reported in surface waters around and downstream from the FMC. Within the Rose-Anvil Creek system, slimy sculpin tend to be most abundant, followed by Arctic grayling. Both species appear to utilize surface waters around the Faro Mine Area year-round, although some Arctic grayling migrate to the Pelly River for overwintering. Although juvenile Chinook salmon have occasionally been observed in the Rose Creek system near the FMC, the Rose-Anvil Creek system has been classified as having low to moderate suitability for Chinook salmon spawning and adults have rarely been observed in surface waters around the FMC. Blind Creek, to the east of Vangorda Creek, is a local stream that provides more important habitat for salmon. Downstream of the Vangorda/Grum Area, in lower Vangorda Creek, juvenile Chinook salmon are typically the most abundant fish because this area provides valuable rearing habitat for juveniles that move in from the Pelly River and other tributaries.

Culverts and rock drains associated with road crossings have isolated fish populations in upper NFRC and upper South Fork Rose Creek from populations in the rest of the Rose-Anvil Creek system. Also, a culvert on West Vangorda Creek and a waterfall on the main stem of Vangorda Creek have prevented upstream migration so that fish are only found in the lower reach of Vangorda Creek.

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ATTACHMENT A

HABITAT INFORMATION

HABITAT INFORMATION FROM

MINNOW (2009)

Table C.1: Habitat summary for Vangorda Creek sampling areas, Faro Mine, August 2007. (Minnow 2009)

Characteristics		Reference				Effluent-Exposed (Vangorda Creek)		
		Upper West Fork Vangorda Creek (Ref-1)	Upper South Fork Rose Creek (Ref-2)	Next Creek (Nex-C1)	Upper Vangorda Creek (V1)	V27	V5	V8
Average Length of Reach Assessd (m)		50	10	50	7.8 (4.5 - 13.0)	11.2 (9 - 14)	9.6 (8.0 - 10)	15
Bottom Flow Velocity (m/s)	Mean	0.31 (0.12 - 0.65)	0.37 (0.08 - 0.80)	0.25 (0.03 - 0.72)	0.22 (0.12 - 0.42)	0.16 (0.12 - 0.21)	0.22 (0.18 - 0.24)	0.13 (0.09 - 0.18)
	Maximum	0.65	0.8	0.72	0.5 (0.32 - 0.72)	0.45 (0.36 - 0.62)	0.53 (0.44 - 0.66)	0.38 (0.26 - 0.74)
Depth (m)	Mean	0.10	0.23 (0.050 - 0.390)	0.19 (0.130 - 0.260)	0.17 (0.01 - 0.48)	0.21 (0.08 - 0.40)	0.14 (0.03 - 0.35)	0.26 (0.08 - 0.40)
	Maximum	0.25	0.45	0.35	0.37 (0.19 - 0.50)	0.40 (0.34 - 0.46)	0.30 (0.24 - 0.37)	0.39 (0.35 - 0.43)
Width (m)	Wetted	1.6 (1.43 - 1.8))	7.7 (4.5 - 11)	6.1 (4.5 - 9.0)	4.7 (4.3 - 5.3)	4.5 (4.1 - 5.1)	3.4 (2.7 - 4.0)	5.19 (3.23 - 6.59)
	Bankfull	2.1 (1.61 - 2.52)	8.6 (6.0 - 11)	6.5 (5.0 - 9.0)	7.4 (6.7 - 8.5)	6.1 (5.3 - 7.8)	5.6 (5.2 - 6.5)	7.8 (6.0 - 10.1)
Gradient	%	4.8	4.8	4	6.8	2.8	3.2	3.9
Water Appearance		clear; colourless	clear; colourless	clear; colourless	clear	clear	slightly turbid/cloudy	mostly clear; slightly turbid light brown
General Morphology	%pool	0	30	0	<5 (0 - 10)	0	<5 (0 - 5)	0
	%riffle	100	70	100	85 (25 - 100)	60 (30 - 100)	65 (50 - 80)	30 (20 - 50)
	%run	0	0	0	25 (0 - 70)	40 (0 - 80)	35 (15 - 50)	70 (50 - 80)
Bank Condition		mostly stable	Stable/No Bank Erosion	Stable/No Bank Erosion	Stable/No Bank Erosion	Stable/No Bank Erosion	Stable/No Bank Erosion	moderately stable
Substrate (% areal coverage)	%bedrock	0	0	0	<5 (0 - 5)	0	0	0
	%boulder	25	55	10	50 (20-65)	30 (15 - 50)	30 (20-45)	40 (20 - 60)
	%cobble	40	30	55	45 (30 - 75)	55 (40 - 65)	15 (5 - 25)	45 (30 - 60)
	%gravel	20	15	35	<10 (5 - 25)	15 (10 - 20)	45 (30- 50)	10 (10 - 15)
	%sand&finer	15		0	0	<5	10 (5 - 20)	5 (<1 - <15)
Instream Cover (%total Surface)	undercut banks	0	0	0	0	<5	5 (0 - <10)	<5 (0 - 5)
	boulder	10	70	< 5	20 (10 - 20)	15 (10 - 30)	10 (5 - 15)	15 (10 - 20)
	woody debris	0	< 5	< 5	5 (5 - 75)	0	7.5 (<5-10)	5 (0 - 10)
	deep pool	<5	30	5	<5 (0 - 10)	0	0	<5 (0 - 10)
	macrophytes	0	0	0	0	0	0	0
Av. Residual (Refuge) Pool Depth (m)		0.1	0.25	0.1	< 0.2	< 0.2	< 0.1	< 0.2
Overhead Canopy (%Surface)	Dense	0	0	0	0	0	0	0
	Partially Open	0	10	60	15 (0 - 25)	15 (5 - 25)	85 (75 - 90)	30 (5 - 45)
	Open	100	90	40	85 (75 - 100)	85 (75 - 95)	15 (0 - 25)	70 (35 - 95)
Riparian Vegetation Types	descending dominance	willow, scattered black poplar, cinqfoil, some dwarf birch	willow, scattered poplar, then spruce	spruce, willow, black poplar	willow , moss, spruce, dwarf birch, berry shrubs, cinqfoil, rip-rap	willow, grasses, alder, moss, cinqfoil, equisetum, spruce	alder, willow, moss, equisetum, highbush cranberry, poplar, grass	alder, willow , grasses, poplar, forbs, berry shrubs, spruce, moss
Aquatic Vegetation (% areal coverage)	Emergent	0	0	0	0	0	0	0
	Submergent	0	0	0	0	0	0	0
	Floating	0	0	0	0	0	0	0
	Attached Algae	< 5	< 5	< 1	<10	0	0	0
Surrounding Land Use		U/S of old gravel pit haul road	Haul Road ~30m D/S of site	old gravel pit haul road	U/S mine road; forest	none; mature forest	forest	bridges/road crossings
Evidence of Anthropogenic Disturbance		modified channel, likely to ensure flow to culvert	none	culverts, pushed around substrate	rip-rap & metal culverts	none	none	bridges/road crossings
General Comments/Notes		Stream channel much smaller & shallower than Vangorda but substrate is comparable, in spots, to lower Vangorda. First sample taken 22m U/S of culvert, with next 2 samples taken U/S of that.	Assessed a very small portion of the stream, afterwhich the gradient was steeper with larger boulders. Mayflies noted when shocking. Conductivity will not calibrate, used Hanna meter instead. Site is more a pool/step kind of habitat with an increasing gradient that becomes a canyon type environment.	Sampled D/S of culverts. Loosely compacted substrate. U/S of road has alot of moss, channel narrows to < 9m. Small woody debris and some overhanging willow. LWD up on banks indicating Hgh water mark/flow.	Most sites have some orange fuzzy moss on rocks	Some sites in valley with access down steep hills	Lots of fines and small gravel making Hess sampling difficult	

[a] Numbers provided represent mean values with numbers in parenthesis representing the corresponding range for each respective description.

[b] Morphology type based on Rosgen (1994) classification. B= moderately entrenched, moderate-gradient, riffle-dominated channel with infrequently spaced pools, very stable plan and profile, stable banks; C= low-gradient, meandering, alluvial riffle-pool, channels with point-bars, broad, well-defined floodplains E= low-gradient, meandering, riffle/pool stream with low width:depth ratio and little deposition, very efficient and stable, high meander width ratio; G= entrenched, "gully" step-pool channel, on moderate gradients, with low width:depth ratio

Table C.2: Habitat summary for Rose Creek sampling areas, Faro Mine, August 2008 (Minnow 2009).

Characteristics		Reference												Mine-Exposed	
		UWFV (VR)	USFR	Next Creek (NEC,NXT, NEXC)	R7	FC	BLC	STC	BEC	HOC	GRC	BTT	BUC	X2	R2
Average Length of Reach Assessd (m)		40		25		30	50	20	20	30	25	25	20		50
Bottom Flow Velocity (m/s)	Mean	0.29	0.35	0.22	0.3	0.4	0.25	0.35	0.6	0.35	0.5	0.5	0.6	0.42	0.43
Depth (m)	Mean	0.15	0.19	0.09	0.1	0.28	0.4	0.35	0.2	0.2	0.2	0.15	0.15	0.38	0.47
	Maximum	0.18	0.30	0.15	0.15	0.6	0.8	0.6	0.25	0.3	0.25	0.2	0.4	0.7	0.6
Width (m)	Wetted	1.5	8.5	6	7	3.5	26	12	3.5	12	2.5	5	4	5.75	11
	Bankfull	2	9.5	7.5	8	5	30	13	4	12	10	6	5	8	11
Gradient (reach sampled)	%	3	7	4	3	4	2	3.5	2	3		4	2.5	3.5	2
Water Appearance		clear	clear	clear	clear	clear	clear	clear, blue	clear	-	clear, brown	clear, brown	clear, brown	clear	clear, brown
General Morphology	%pool	0	3	0	0	0	0	0	0	0	0	0	0	0	0
	%riffle	100	97	100	10	50	50	20	20	50	90	100	100	50	0
	%run	0	0	0	90	50	50	80	80	50	10	0	0	50	100
Bank Condition		moderate	stable	moderate	unstable to moderate	stable	moderate to stable	stable		stable	unstable			moderate	unstable to moderate
Substrate (% areal coverage)	%bedrock	0	10	0	0	0	0	0	0	0	0	10	0	0	0
	%boulder	10	20	5	5	60	5	20	0	5	0	20	5	40	0
	%cobble	70	50	80	0	20	70	60	65	55	45	50	70	40	35
	%gravel	20	20	15	80	10	20	10	25	30	45	10	10	15	35
	%sand&finer	some	0	0	10	10	5	10	10	10	10	10	15	5	30
Instream Cover (%total Surface)	undercut banks	0	0	0	10	10	2	5	10	10	0	20	5	5	10
	boulder	10	40	5	5	0	0	25	0	10	0	30	2	10	0
	woody debris	0	0	5	0	0	2	0	10	5	10	0	0	0	<5
	deep pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	macrophytes	0	0	0	0	0	0	0	20	0	0	0	0	0	0
Av. Residual (Refuge) Pool Depth (m)		-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
Overhead Canopy (%Surface)	Dense	0	0	0	0	0	0	0	0	0	0	50	0	0	0
	Partially Open	0	70	5	0	100	0	0	100	0	0	50	100	0	0
	Open	100	30	95	100	0	100	100	0	100	100	0	0	100	100
Riparian Vegetation Types	descending dominance	willow/cherry, black spruce, moss	willow, scattered poplar, spruce	willow, black spruce	grasses, willow, black spruce	willow, moss, sedges	alder, aspen, willow, black spruce	willow, black spruce, sedges	small willow, sedges	willow, sedges, alder, black & white spruce	aspen, willow, spruce	poplar, black spruce, willow, moss	grasses, shrubs, willow, alder, black spruce	willow, black spruce, alder, blueberry, moss	black spruce, willow, sedges
Aquatic Vegetation (% areal coverage)	Emergent	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Submergent	0	0	0	0	0	0	0	25	0	0	0	0	0	0
	Floating	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Attached Algae	25	50	5	30	30	30	30	20	20	<3 (thin film on cobble)	70	0	50	0
Surrounding Land Use		U/S of haul road	mine north of haul road	quarry to west, treed	forest	road d/s, beside ATV trail	old bridge u/s	culvert & road u/s		culvert & road u/s	road d/s	undisturbed, natural, soil black	natural, hwy u/s	U/S of Anvil access road D/S of "S" wells	mine upstream
General Comments/Notes					sediment chemistry & toxicity sample taken near confluence with Faro Creek.				wetland area upstream			waterfall u/s, lots of algae but habitat similar to X2 & R2		d/s of GW inputs from S-wells, Faro Mine	d/s of Faro Mine effluent and GW discharges. Slight brown stain on rocks

HABITAT INFORMATION FROM

AECOM (2009)

Table 4.4-3. Channel, Cover and Morphology Characteristics from Stream Reaches of Rose Creek Associated with the Former Reservoir, Dam Breach Section and Downstream from the Breach Construction Area (August 2007)

	Parameter	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	X-14
Site	Survey Date (dd/mm/yr)	14/08/2007	15/08/2007	15/08/2007	15/08/2007	15/08/2007	15/08/2007
	Reach Length (m)	370	690	950	265	335	360
	Survey Location (UTM)	08V 05 86 359 E 69 10 168 N	08V 05 86 190 E 69 104 00 N	08V 05 85 908 E 69 110 90 N	08V 05 85 523 E 69 113 22 N	08V 05 85 300 E 69 114 22 N	08V 05 79 349 E 69 150 78 N
Channel	Ave. Channel Width (m)	6.0	8.1	8.7	8.7	4.9	13.1
	Ave. Wetted Width (m)	4.7	7.2	6.3	6.9	4.2	10.9
	Ave. Residual Pool Depth (m)	0.3	0.6	0.9	0.4	0.4	1.1
	Bankfull Channel Depth (m)	0.3	0.3	0.8	0.5	0.6	0.3
	Discharge (m^3/sec)	0.432	0.664	–	0.613	0.554	2.039
	Gradient (%)	2.5	0.2	0.1	1.2	0.6	0.2
Cover	Cover Abundance (%)	moderate (~15)	moderate (~15)	abundant (~25)	moderate (~15)	moderate (~15)	abundant (~20)
	Dominant Cover Type	boulders and scour pools	deep pools	deep pools	Boulders	boulders	deep pools
	Subdominant Cover Type	undercut banks	undercut banks	undercut banks	deep pools	undercut banks and overhanging vegetation	large and small woody debris
	Other Cover Types Present	overhanging vegetation, small and large woody debris	boulders, overhanging vegetation, small and large woody debris	overhanging and instream vegetation, and small woody debris	Overhanging and instream vegetation, and small woody debris	instream vegetation, small woody debris, and scour pools	overhanging and instream vegetation
	LWD Frequency	Few	Few	none	None	none	few
	% Crown Closure	0	0	0	0	0	0
Bank Characteristics	Left Bank Shape	vertical (>45°)	vertical (>45°)	vertical (>45°)	vertical (>45°)	vertical (>45°)	sloping (<45°)
	Bank Texture	fines	fines	fines	cobbles and boulders	fines	gravels
	Riparian Vegetation	grasses	grasses	grasses	grasses and shrubs	shrubs	shrubs
	Riparian Stage	Initial	Initial	initial	Initial	shrub/herb	shrub/herb
	Right Bank Shape	vertical (>45°)	vertical (>45°)	sloping (<45°)	vertical (>45°)	vertical (>45°)	vertical (>45°)
	Texture	fines	fines	fines	cobbles and boulders	fines	fines
	Riparian Vegetation	grasses	grasses	grasses	grasses and shrubs	shrubs	shrubs
	Riparian Stage	initial	Initial	initial	Initial	shrub/herb stage	shrub/herb stage

Source: AECOM 2009

	Parameter	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	X-14
Morphology	Dominant Bed Material (cm)	boulder (> 25.6)	gravel (0.2 – 6.4)	fines (<0.2)	Fines (<0.2)	cobble (6.4 – 25.6)	fines (<0.2)
	Subdominant Bed Material (cm)	cobble (6.4 – 25.6)	fines (<0.2)	gravel (0.2 – 6.4)	cobble (6.4 – 25.6)	fines (<0.2)	gravel (0.2 – 6.4)
	D95 (cm)	60	30	5	35	40	8
	D (cm)	20	10	5	18	15	5
	Morphology	riffle-pool	riffle-pool	riffle-pool	step-pool	riffle-pool	riffle-pool
	Pattern	sinuous	Tortuous meanders	tortuous meanders	regular meanders	sinuous	irregular meanders
	Islands	none	none	occasional	None	none	none
	Bars	side	side	mid-channel and span	Side	side	side
	Confinement	unconfined	unconfined	unconfined	Confined	unconfined	occasionally confined
Water Quality	Temperature (°C)	8.5	12.5	13.5	12.0	-	9.0
	pH	8.9	9.0	8.8	8.8	-	8.6
	Conductivity (µS/cm)	120	160	170	170	-	440
	Turbidity	clear	clear	clear	Clear	clear	clear

Source: AECOM 2009

HABITAT INFORMATION FROM

DEGRAFF (2013)



Figure 1 Sample sites associated with the Rose Creek Channel Diversion (RD1 to RD5) and North Fork of Rose Creek (NF1 to NF3).

0.5 0 1 2 km

SCALE 1 : 22,200

Source: deGraff 2013

Table 5 Aquatic habitat characteristics determined at 7 study sites in the North Fork of Rose Creek during August 2009.

	Parameter	NF1-1	NF1-2	NF2-1	NF2-2	NF3-1	NF3-2	NF3-3
Site	Survey Date	Aug. 27, 2009	Aug. 28, 2009	Aug. 25, 2009	Aug. 26, 2009	Aug. 26, 2009	Aug. 27, 2009	Aug. 27, 2009
	Site Elevation (m)	1,054	1,070	1,077	1,085	1,099	1,110	1,120
	Site Survey Length (m)	80	50	60	70	100	70	60
Channel	Ave. Channel Width (m)	7.8	9.0	9.4	7.1	12.6	7.1	11.3
	Ave. Wetted Width (m)	6.1	7.4	6.9	6.0	10.4	5.7	6.7
	Ave. Bankfull Channel Depth (m)	1.0	1.6	0.9	1.4	0.9	1.4	1.3
	Ave. Residual Pool Depth (m)	0.3	0.7	0.4	0.6	0.3	0.6	0.8
	Stage	moderate	moderate	moderate	moderate	moderate	moderate	moderate
	Gradient (%)	0.3	0.4	2.4	0.7	0.9	0.7	0.4

Source: deGraff 2013

	Parameter	NF1-1	NF1-2	NF2-1	NF2-2	NF3-1	NF3-2	NF3-3
Cover	Cover Abundance (%)	trace (<5)	moderate (5-20)	moderate (5-20)	moderate (5-20)	moderate (5-20)	abundant (>20)	moderate (5-20)
	Dominant Cover Type	boulders	deep pools	boulders	deep pools	boulders	undercut banks	deep pools
	Subdominant Cover Type	deep pools	boulders	deep pools, o/h vegetation	boulders, undercut banks	undercut banks	deep pools, boulders, large	undercut banks
	Other Cover Types Present	undercut banks and o/h	undercut banks, instream and	undercut banks, small woody	small and large woody debris,	small / large woody debris,	instream vegetation and	small and large woody debris,
	LWD Frequency	none	none	none	few	few	few	few
	Crown Closure (%)	0	0	0	0	0	0	0
	Left Bank Shape	sloping (<45°)	vertical (>45°)	sloping (<45°)	vertical (>45°)	sloping (<45°)	vertical (>45°)	sloping (<45°)
	Texture	cobble	boulder	boulder	fines	cobble	fines	cobble
	Riparian Vegetation	shrubs	shrubs	shrubs	shrubs	shrubs	shrubs	shrubs
	Riparian Stage	shrub/herb	initial	mature forest	mature forest	shrub/herb	mature forest	mature forest
	Right Bank Shape	vertical (>45°)	vertical (>45°)	vertical (>45°)	sloping (<45°)	vertical (>45°)	vertical (>45°)	vertical (>45°)
	Texture	cobble	cobble	boulder	fines	cobble	fines	fines
	Riparian Vegetation	shrubs	shrubs	shrubs	shrubs	shrubs	shrubs	shrubs
	Riparian Stage	initial	young forest	mature forest	mature forest	mature forest	mature forest	mature forest
	Instream Vegetation	none	moss	algae and moss	algae and moss	algae and moss	moss	none

Source: deGraff 2013

	Parameter	NF1-1	NF1-2	NF2-1	NF2-2	NF3-1	NF3-2	NF3-3
Morphology	Dominant Bed Material	gravel	cobble	boulder	gravel	cobble	cobble	cobble
	Subdominant Bed Material	cobble	boulder	cobble	boulder	boulder	gravel	gravel
	D95 (cm)	60	50	44	80	60	33	20
	D (cm)	12	13	8	10	8	11	12
	Morphology	riffle-pool	riffle-pool	cascade-pool	riffle-pool	riffle-pool	riffle-pool	riffle-pool
	Pattern	irregular meanders	irregular meanders	sinuous	sinuous	sinuous	sinuous	sinuous
	Islands	occasional	none	none	occasional	occasional	none	none
	Bars	side	mid channel	none	side	none	side	side
	Confinement	confined	confined	confined	frequently confined	occasionally confined	frequently confined	frequently confined

Source: deGraff 2013

Table 6 Aquatic habitat characteristics determined at 5 study sites in the Rose Creek Diversion Channel during August 2009.

Parameter		RD1	RD2	RD3	RD4	RD5
Site	Survey Date	Aug. 30, 2009	Aug. 30, 2009	Aug. 29, 2009	Aug. 29, 2009	Aug. 28, 2009
	Site Elevation (m)	1,027	1,030	1,031	1,036	1,047
	Site Survey Length (m)	100	100	100	100	100
Channel	Ave. Channel Width (m)	16.5	16.0	28.4	13.8	18.1
	Ave. Wetted Width (m)	14.7	14.2	13.7	12.8	14.6
	Ave. Bankfull Channel Depth (m)	1.5	1.4	> 1.5	> 1.5	> 1.5
	Ave. Residual Pool Depth (m)	0.8	0.7	>1.0	>1.0	-
	Stage	moderate	moderate	moderate	moderate	moderate
	Gradient (%)	5.5	5.0	0.2	0.2	0.1
Cover	Cover Abundance (%)	abundant (>20)	abundant (>20)	moderate (5-20)	moderate (5-20)	trace (<5)
	Dominant Cover Type	boulders	boulders	boulders	boulders	boulders
	Subdominant Cover Type	deep pools	deep pools	deep pools	instream vegetation	instream vegetation
	Other Cover Types Present	small woody debris and overhanging vegetation	overhanging and instream vegetation	instream vegetation	small woody debris	overhanging vegetation and large woody debris
	LWD Frequency	none	none	none	none	few
	% Crown Closure	0	0	0	0	0

Source: deGraff 2013

	Parameter	RD1	RD2	RD3	RD4	RD5
Cover	Left Bank Shape	vertical (>45°)	vertical (>45°)	sloping (<45°)	vertical (>45°)	sloping (<45°)
	Texture	rock	rock	boulders	rock	variable
	Riparian Vegetation	shrubs	shrubs	shrubs	shrubs	shrubs
	Riparian Stage	shrub/herb	shrub/herb	initial	initial	initial
	Right Bank Shape	vertical (>45°)	vertical (>45°)	sloping (<45°)	sloping (<45°)	sloping (<45°)
	Texture	rock	rock	boulders	boulders	variable
	Riparian Vegetation	shrubs	shrubs	shrubs	shrubs	shrubs
	Riparian Stage	shrub/herb	shrub/herb	initial	initial	pole-sapling
	Instream Vegetation	none	mosses	mosses	mosses	mosses
Morphology	Dominant Bed Material	large pieces of bedrock	large pieces of bedrock	angular boulders	boulder	gravel
	Subdominant Bed Material	boulder	boulder	cobble	cobble	cobble
	D95 (cm)	117	110	68	62	75
	D (cm)	17	17	9.4	5.5	4.5
	Morphology	cascade-pool	cascade-pool	riffle-pool	riffle-pool (few)	extended riffle
	Pattern	straight	straight	straight	straight	straight
	Islands	none	none	none	none	none
	Bars	none	none	none	none	none
	Confinement	entrenched	entrenched	entrenched	entrenched	entrenched

Source: deGraff 2013

Table 7 Results from culvert assessments associated with various road crossings of Rose Creek tributary streams at the Faro Mine Complex, 2009.

Parameter	Culvert(s) Location			
	Rose Creek North Fork Tributary u/s Constructed Ponds	Rose Creek North Tributary Access Road Crossing	Rose Creek South Tributary Access Road Crossing	Rose Creek South Tributary Haul Road Crossing
Survey Date	Aug. 31, 2009	Aug. 31, 2009	Aug. 31, 2009	Oct. 8, 2010
# of Culverts	2	1	1	2
Culvert(s) Length (m)	15.1	24.6	24.3	150 to 200
Culvert(s) Diameter	1 = 0.5 2 = 1.0	3.8	2.5	2
Construction	1 = round spiral 2 = cast iron	round multiplate	round multiplate	round spiral
Outlet Drop (m)	1 = 0.9 2 = 0.5*	0	1.25	2
Slope (%)	1 = 3.9 2 = 1.7	1.8	3.8	n/a
Velocity (m/s)	n/a	1.73	2.6	n/a
Downstream Pool Depth (m)	1.4	~2.0	1.5	1.0
Stream Length Upstream (km)	72.2	72.0	12.7	12.2
Determination	Complete barrier to upstream movement of fish	Partial barrier to upstream movement of fish	Complete barrier to upstream movement of fish	Complete barrier to upstream movement of fish

* Outlet drop measured from top of steel plate that was wielded to the downstream end of the cast iron culvert.

Source: deGraff 2013

HABITAT INFORMATION FROM

LABERGE (2011)

habitat at each site. There are habitat similarities with Horton and Blind Creeks as well, although both are located at lower elevations.

TABLE 4 HABITAT CHARACTERISTICS, BENTHIC INVERTEBRATE MONITORING SURVEY, 2010

	EXPOSED SITES						REFERENCE SITES							
Site Code	VGMAIN	V5	V8	X2	R2	R4	R6	R7	FC	VR	USFR	BLC	BUC	HOR
River/Stream	Vangorda Cr	Vangorda Cr	Vangorda Cr	North Fork Rose Cr	Rose Creek	Rose Creek	Anvil Creek	North Fork Rose Creek	Upper Faro Creek	upper West Fork Vangorda Creek	Upper South Fork Vangorda Creek	Blind Creek	Buttle Creek	Horton Creek
Sampling Date (D/M/Y)	1/9/2010	2/9/2010	1/9/2010	31/8/2010	2/9/2010	1/9/2010	1/9/2010	31/8/2010	31/8/2010	2/9/2010	31/8/2010	2/9/2010	3/9/2010	30/8/2010
Time	8:30	16:50	10:30	17:30	11:30	14:30	13:00	10:00	15:30	9:30	12:15	14:45	9:30	14:00
Stream Order	Second	Second	Third	Second	Third	Third	Third	Second	First	First	First	Third	Third	Third
Surrounding Land Use	Forest & residential	Forest	Forest	Forest, mining, access road	Forest	Forest	Forest	Forest, mining	Forest, mining	Forest, mining, haul road	Forest, mining, haul road	Forest, cabin, bridge	Forest, highway	Forest, mining
Dominant Surrounding Land Use	Forest	Forest	Forest	Mining	Forest	Forest	Forest	Forest	Forest	Mining	Forest	Forest	Forest	Forest
GPS Datum	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83	NAD 83
Easting	585875	586200	584851	584068	579223	587823	587882	586808	5835361	590878	590243	593865	601897	656437
Northing	6901505	6902058	6900647	6912783	6915018	6921789	6921803	6914181	6916777	6908906	6907372	6895992	7104449	6855443
Elevation m	703	651	673	1077	1016	932	932	1120	1316	1220	1236	656	721	826
Habitat Type	riffle	riffle, rapids and pool/back eddy	riffle, rapids, straight run	riffle, rapids, straight run, pool/back eddy	straight run, pool/back eddy, riffle,	riffle, rapids, straight run, pool/back eddy	riffle, rapids, straight run, pool/back eddy	straight run, pool/back eddy, rapid,	riffle, rapids, straight run	riffle, rapids	riffle	riffle, rapids, straight run	riffle, rapids	riffle, straight run, pool/back eddy
Canopy Coverage (%)	0	76 - 100%	26 - 50	1 - 25	0	1 - 25	1 - 25	0	51 - 75	1 - 25	1 - 25	1 - 25	1 - 25	0
Macrophyte Coverage (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Streamsite Vegetation	shrubs, deciduous trees, coniferous trees, moss	deciduous trees, equisetum and moss	shrubs, deciduous trees, moss	moss, grasses, shrubs, deciduous trees, coniferous trees	equisetum, shrubs, coniferous trees	grasses, shrubs, coniferous trees	moss/grasses, shrubs, coniferous trees	grasses, shrubs, coniferous trees	moss, sedges, shrubs	grasses, shrubs	forbs, grasses, shrubs, coniferous trees	grasses, shrubs, deciduous trees	sedges, grasses, shrubs, coniferous trees	grasses, shrubs, deciduous trees, coniferous trees
Dominant Streamside Vegetation	deciduous trees	deciduous trees	deciduous trees (alder, willow, aspen)	shrubs	shrubs (mainly dwarf birch)	shrubs, mostly alder	shrubs	grasses	shrubs (willows)	shrubs	shrubs (willows - some tree like)	deciduous trees (large alders and willows)	coniferous trees	shrubs
Periphyton	1	2	1	4	4	3	4	3	1	1	1	1	3	1
Habitat sampled	riffle	riffle	riffle	riffle	straight run	riffle	riffle	straight run	rapids	riffle	riffle	riffle	riffle	riffle
Typical Depth (cm)	25.0	10.0	25.0	40.0	20.0	25.0	30.0	50.0	20.0	7 to 10	20.0	30.0	10.0	20.0
Surrounding / Interstitial Material	3	2	4	4	1	4	2	1	3	3	3	2	3	2
Water Temp oC	4.1	5.1	4.3	7.1	5.7	6.2	4.5	4.4	7.6	3.6	8.1	6.5	4.8	7.8
pH	8.32	8.48	8.39	7.87	7.93	8.29	8.51	8.13	7.81	7.95	7.91	8.22	8.32	8.46
Conductivity uS/cm	420	503	466	201	561	510	306	177	35	69	58	175	506	645
Total Dissolved Solids ppm	209	251	233	100	280	255	153	91	17	34	29	87	253	322
Slope (surveyed in the field) (%)	4.6	5.1	2.6	1.2	0.06	0.7	1.2	0.2	3.1	3.8	5.3	0.03	0.08	0.45
Bankfull Width (m)	5.8	6.4	9.3	9.5	11.8		18.7	3.7	5.4	3.1	9.4	18.5	6.5	10.4
Wetted Stream Width (m)	3.6	3.45	5.4	5.9	11.8		16.6	3.7	1.95	1.4	7.9	13.3	4.75	6.8
Bankfull-wetted depth (cm)	50	40	90	53.4	62		80	50	50	45	50	100	40	85
Average velocity (m/s)	0.29	0.58	0.28	0.54	0.44		0.43	0.37	0.18	0.22	0.37	0.70	0.32	0.46
Total Discharge (cms) Price Meter	0.259	0.1181	0.377	0.7551	1.6444		2.1204	0.5645	0.0392	0.0184	0.4517	2.3572	0.3485	0.6297
Comments			Very bouldery substrate, difficult to kick net		Flow measured at X-14	No discharge data etc as creek too pushy to safely wade.			Substrate has a lot of moss on it					

There were no matches for VR and USFR. VR is a small stream with very soft water and is unlike any of the exposed sites. USFR is a steep sloped stream also with very soft water. Although it has some similar attributes with V5 and X2, it likely does not represent a very useful reference site. FC was indicated as the second best match for X2. FC is a small creek located at a much higher elevation and has extremely soft water. The substrate at X2, mostly cobbles and boulders, is

Source: Laberge 2011

HABITAT INFORMATION FROM

WMEC (2008)

APPENDIX 1
GENERAL SITE DESCRIPTIONS

SITE: R1 Rose Creek

UTM: Down stream end 05 83 739 E, 69 12 390 N
Site Location: reach starts 10 meters upstream of the confluence of the north and south forks of Rose Creek and extends upstream for 110 meters.
Date Sampled: August 17 and 18, 2004, August 13 and 14, 2005
August 16 and 17, 2006, August 14 and 15, 2007
August 16 and 17, 2008

CHANNEL CHARACTERISTICS:

Surveyed Length:	3000 m
Average Channel Width:	4 meters
Average Wetted Width:	4 meters
Average Depth:	0.4 meters
Average Velocity	1.5 meters per second
% Pool, Riffle, Run / Glide:	65% riffles through boulders, 25% run and 10% small boulder and side pools
Cover	Dominant cover is boulder pools and perched boulders
Overhead vegetation	10% overhanging
Riparian Vegetation	Willow, dwarf birch, cinquefoil, with spruce adjacent

BED MATERIAL:

70% boulder, 20% cobble, 5% gravel, 5% sand with occasional bedrock outcrop in lower part of reach

BANK CHARACTERISTICS: Well defined channel with bedrock confining the channel on the left bank, the right bank has an open flood plain above an abrupt bank rise of 0.4 meters.

CHANNEL MORPHOLOGY CHARACTERISTICS: Uniform channel with a mostly flat bottom, some contour is provided by small pools near submerged bedrock along the left bank and boulders causing small cascades. A small island exists at the top of the reach. Flows within the South Fork of Rose Creek at site R1 in 2008 were similar to those of 2006. A long riffling run that extends approximately 800 meters upstream of the sample station was used as a collection area for angling Arctic grayling; this reach has similar morphology to the sample area although with more small pools and less velocity.

Source: WMEC 2008



Photo 1: Rose Creek looking upstream at Site R1 from the bottom of the sample reach, 2008. The North Fork of Rose Creek enters on the left of the photo.

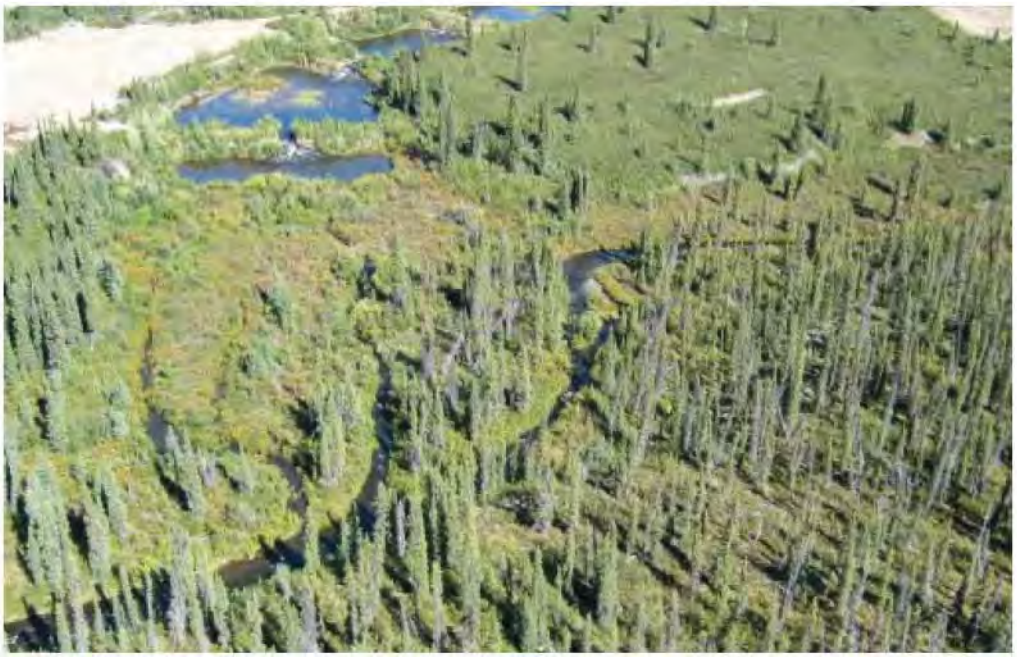


Photo 2: Ariel view of site R1 (on right) and the confluence with North Fork Rose Creek, 2007. The sample reach extends from the confluence to just below the first bend of the creek in the centre of the photo.

Source: WMEC 2008

SITE: R2 Rose Creek

UTM: down stream end 05 79 401 E, 69 14 972 N
Site Location: reach starts at the confluence of the tailing pond discharge channel with Rose Creek and extends downstream for 110 meters through the mix water zone.
Date Sampled: August 18 and 19, 2004 August 15 and 16, 2005
August 15 and 16, 2006 August 14 and 15, 2007
August 16 and 17, 2008

CHANNEL CHARACTERISTICS:

Surveyed Length:	110 meters
Average Channel Width:	14 meters
Average Wetted Width:	12 meters
Average Depth:	0.7 meters
Average Velocity	0.8 meters per second
% Pool, Riffle, Run / Glide:	30% pool, 30% riffle, 40% glide
Cover	Large woody debri, undercut banks and deep pools
Overhead vegetation	No overhead vegetation
Riparian Vegetation	Willow, dwarf birch and dead spruce

BED MATERIAL:

30% cobble, 50% gravel, 20% sand with sand and gravel increasing in deeper pools and exposed point bars mostly sand and gravel.

BANK CHARACTERISTICS: Sand and gravel point bars opposite of mud cut banks that rise 1.5 to 2.5 meters to an open flood plain.

CHANNEL MORPHOLOGY CHARACTERISTICS: Meandering channel with corner pools, small riffles and point bars adjacent to cut banks. Water levels in 2008 were similar to, 2006 and approximately 0.3 meters lower than the highest flows experienced in 2005.

Source: WMEC 2008



Photo 3: The tailings pond discharge channel entering Rose Creek at the upstream end of the sample reach site R2 during August, 2008.



Photo 4: Site R2, Rose Creek. The downstream end of the diversion channel flows in to the photo from the right upstream of the out flow of treated water and the sample site. August 2007.

Source: WMEC 2008

SITE: R4 Rose Creek

UTM: down stream end 05 67 827 E, 69 21 736 N
Site Location: reach starts 80 meters upstream of the confluence of Rose Creek and Anvil Creek and extends upstream for 110 meters.
Date Sampled: August 12, 2004 August 17 and 18, 2005
August 16 and 17, 2006, August 17 and 18, 2007
August 19, 2008

CHANNEL CHARACTERISTICS:

Surveyed Length:	130 meters
Average Channel Width:	20 meters
Average Wetted Width:	14.5 meters
Average Depth:	0.5 meters
Average Velocity	> 1.0 meters per second
% Pool, Riffle, Run / Glide:	60% riffle, 15% boulder pool and 25% run
Cover	Boulder pools and overhead vegetation
Overhead vegetation	20% coverage
Riparian Vegetation	Alder and willow with spruce behind

BED MATERIAL:

5% large boulder, 20% boulder, 30% cobble, 40% gravel, 5% sand.

BANK CHARACTERISTICS: Open flood plain with gentle rise adjacent to well defined stepped banks that rise to a maximum of 2 meters to an open flood plain.

CHANNEL MORPHOLOGY CHARACTERISTICS: Mostly flat channel with one side typically deeper than the opposite side. Some exposed large boulders and a large side pool exists near the bottom of the reach. Water levels in 2008 were slightly higher than those of 2007 and similar to those of 2006.

Source: WMEC 2008



Photo 5: Rose Creek at site R4 during August of 2008. Water levels are slightly higher than in 2007 and similar to those of 2006.

Source: WMEC 2008

SITE: R6 Anvil Creek

UTM: down stream end 05 67 917 E, 69 21 804 N
Site Location: reach starts 100 meters upstream of the confluence of Anvil Creek with Rose Creek and extends upstream a further 100 meters.
Date Sampled: August 12, 2004
August 17 and 18, 2005

Anvil Creek just upstream of the confluence with Rose Creek (control site).
This reach is located at and begins 150 meters upstream of the confluence and then extends upstream for 100 meters. This site has not been sampled for fish since 2005 due to impracticalities with flow conditions. Site R6A, 500 meters upstream on Anvil Creek was established in 2006 as an alternate site for fish and benthic collections.

CHANNEL CHARACTERISTICS:

Surveyed Length:	100 meters
Average Channel Width:	15 meters
Average Wetted Width:	14 meters
Average Depth:	0.4 meters
Average Velocity	1.5 meters per second
% Pool, Riffle, Run / Glide:	15% rapid, 45% riffle, 20% run, 20% boulder pool
Cover	Turbulence, perched boulders and cobbles, and limited undercut and cut banks.
Overhead vegetation	< 5% cover
Riparian Vegetation	Willow with a sedge fringe and spruce adjacent

BED MATERIAL:

5% large boulder, 50% small boulder, 30% cobble, 15% sand

BANK CHARACTERISTICS: Well defined and stable banks rise to even 2 meter height on 50% slope.

CHANNEL MORPHOLOGY CHARACTERISTICS: Channel mostly flat but the mid channel areas are elevated with deep flows occurring towards the banks. Water levels in Anvil Creek were 0.5 meters deeper during 2005 investigations than those of 2004 and 0.2 meters higher again in 2006. This site has not been sampled since 2005.

Source: WMEC 2008



Photo 6: Looking upstream to the top of the sample reach at site R6, from the edge of the confluence with Rose Creek, 2005.

SITE: R6A Anvil Creek

UTM: down stream end 05 68 768 E, 69 21 412 N
Site Location: reach starts 1.35 km by creek channel (800 meters direct) upstream of the confluence of Anvil Creek with Rose Creek and extends upstream a further 100 meters.
Date Sampled: August 16 and 17, 2006 August 17 and 18, 2007
August 19, 2008

Anvil Creek upstream of the confluence with Rose Creek (control site).

CHANNEL CHARACTERISTICS:

Surveyed Length:	130 meters
Average Channel Width:	14 meters
Average Wetted Width:	9 meters
Average Depth:	0.7 meters
Average Velocity	>1 meter per second
% Pool, Riffle, Run / Glide:	10% rapid, 15% riffle, 20% run, 40% race, 15% pool
Cover	Large boulders, pools and LOD and undercut bank.
Crown Closure	< 5% cover
Riparian Vegetation	Alder, spruce, willow mix with grasses, sedge and cinquefoil

BED MATERIAL:

80% small boulder, 15% cobble, 5% gravel, with sand deposits at downstream point bar.

Source: WMEC 2008

BANK CHARACTERISTICS: Consistent well defined and stable banks rise abruptly 0.7 to 1.0 meter height.

CHANNEL MORPHOLOGY CHARACTERISTICS: The channel is partially entrenched by a small hill on the upper right bank, becomes confined and deep centered before spreading to over 50 meters wide at a small side channel in the lower portion of the reach on the right bank. The reach ends with a shoot rapid entering a deep corner pool with undercut banks.



Photo 7: Reach R6a sample site, flowing right to left. August, 2008. The corner pool in the lower end of the reach is the location used to capture Arctic grayling samples.

Source: WMEC 2008

SITE: B1 Blind Creek

UTM: down stream end 05 36 680 E, 68 96 005 N
Site Location: reach starts immediately upstream of the bridge and extends upstream for 100 meters; reaches below the bridge have been used for fish sample collections.
Date Sampled: August 14 and 15, 2004 August 19 and 20, 2005
August 18 and 19, 2006 August 17 and 18, 2007
August 19 and 20, 2008

CHANNEL CHARACTERISTICS:

Surveyed Length:	350 meters
Average Channel Width:	15.5 meters
Average Wetted Width:	14 meters
Average Depth:	0.7 meters
Average Velocity	0.4 meters per second
% Pool, Riffle, Run / Glide:	100% glide
Cover	Fine organic debris, cut banks (up to 40%), small woody debris against shore and a beaver lodge
Overhead vegetation	10% cover
Riparian Vegetation	Alder, willow with some spruce, with high bush cranberry, raspberry and cinquefoil adjacent

BED MATERIAL:

Sand silt and organic debris overlaying 60% cobble, 40% gravel.

BANK CHARACTERISTICS: Shallow point bars occur opposite of cut and eroding banks near gentle corners. Cut banks rise between 1 and 2 meters to an open flood plain.

CHANNEL MORPHOLOGY CHARACTERISTICS: Uniform channel with a deep side opposite of a side of deposition. Flows in Blind Creek were slightly higher in 2006 than during 2005 sampling which were very similar to those encountered during 2004.

Source: WMEC 2008



Photo 8: Collecting minnow traps in Blind Creek near the weir site during August of 2008.

SITE: V8 Vangorda Creek

UTM: down stream end 05 84 790 E, 69 00 606 N
Site Location: reach starts immediately upstream of a small foot bridge that crosses the creek at the site of the town of Faro sewage discharge pipe crossing and extends upstream for 100 meters
Date Sampled: August 14 and 15, 2004 August 17 and 18, 2005
August 17 and 18, 2006 August 15, 16, 17 and 23, 2007
August 17 and 18, 2008

CHANNEL CHARACTERISTICS:

Surveyed Length:	100 meters
Average Channel Width:	6.0 meters
Average Wetted Width:	3.3 meters
Average Depth:	0.5 meters
Average Velocity	1.5 meters per second
% Pool, Riffle, Run / Glide:	80% riffle (almost rapid), 20% eddy and side pools
Cover	Over head vegetation, large and small woody debri, flood washed shrubby vegetation and boulder pools
Overhead vegetation	20% cover
Riparian Vegetation	Alder and willow with occasional spruce and poplar

Source: WMEC 2008

BED MATERIAL: Exposed substrate consists of 50% boulder, 20% cobble, 15% gravel, 15% sand with occasional bedrock outcrop in upper part of reach. Most substrates loosely consolidated and highly silted. Creek channel was heavily modified by a high water event this season.

BANK CHARACTERISTICS: Well defined channel with newly eroded, but stable, banks that rise gently to a maximum of 2 meters. A small area of bedrock confines the channel on the left bank at the upstream end of the reach.

CHANNEL MORPHOLOGY CHARACTERISTICS: Very little meandering in an entrenched valley, unconsolidated materials from 2004 have been washed out and boulders protrude in most of the channel.

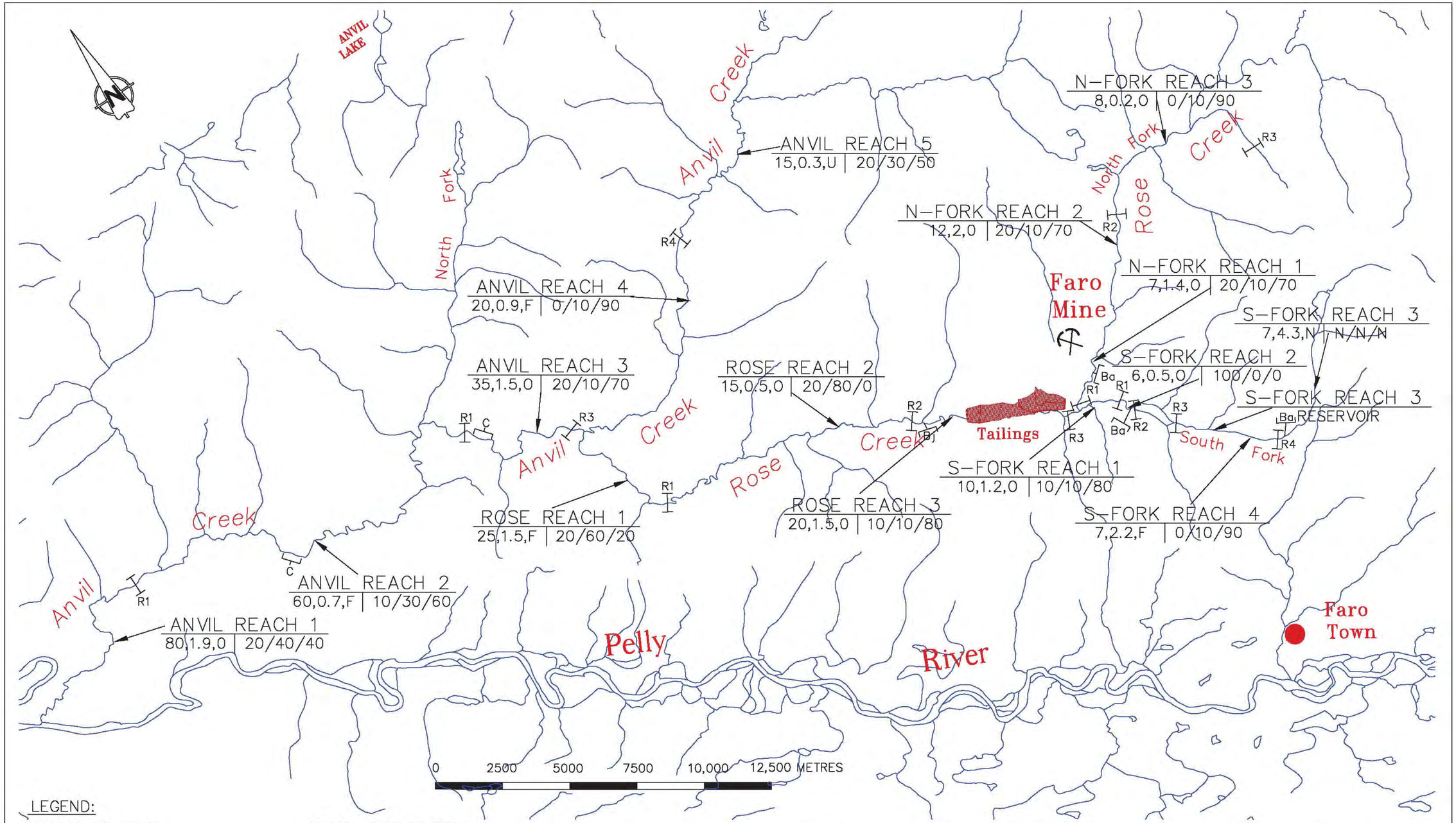


Photo 9: Rock slide at the upstream end of Vangorda Creek site V8 sample site during 2008. The materials that slid are surrounded by mineralized materials visible on the left side of the photo.

Source: WMEC 2008

HABITAT INFORMATION FROM

ROBERTSON (1996)



Source: Robertson 1996

LEGEND:

CHANNEL FEATURES
- W = Slump Bank
- X = Debris
- F = Waterfalls (m)
- C = Culvert
- R = Reach Break

REACH DESCRIPTION
REACH 1
channel width (m) — 10,1.5,U | 20/70/10 — large (%)
slope — channel type — sand (%) — gravel (%)
C: confined
B: bounded
U: unconfined

REACH 8
4,6.4,B | 0/20/80

REACH 7
4,6.3,C | 0/30/70

2,1.5,4 | 20/20/60

Grum Mine

Grum Dump

Vangorda Mine

Dump

GRUM CREEK

R7

C

R6

W

Shrimp Creek

REACH 6
4,3.4,B | 0/10/90

Shrimp Lake

AEX Creek

Blind Creek

W

R5

REACH 5
6,3.5,B | 20/60/20

Vangorda Creek

W

REACH 4
5,4.4,C | 10/20/70

W

XXX

XX

R4

F8

C

REACH 3
5,3.0,C | 20/30/50

Faro Town

Pelly River

WW

R3

R2

R1

REACH 2
8,2.0,B | 0/40/60

Pelly River

REACH 1
10,1.5,U | 20/70/10

0 1000 2000 3000 metres

Scale 1: 60 000

Note: After Harder & Associates Ltd., 1987

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Anvil Range Mining Corporation

Anvil Complex Closure Plan

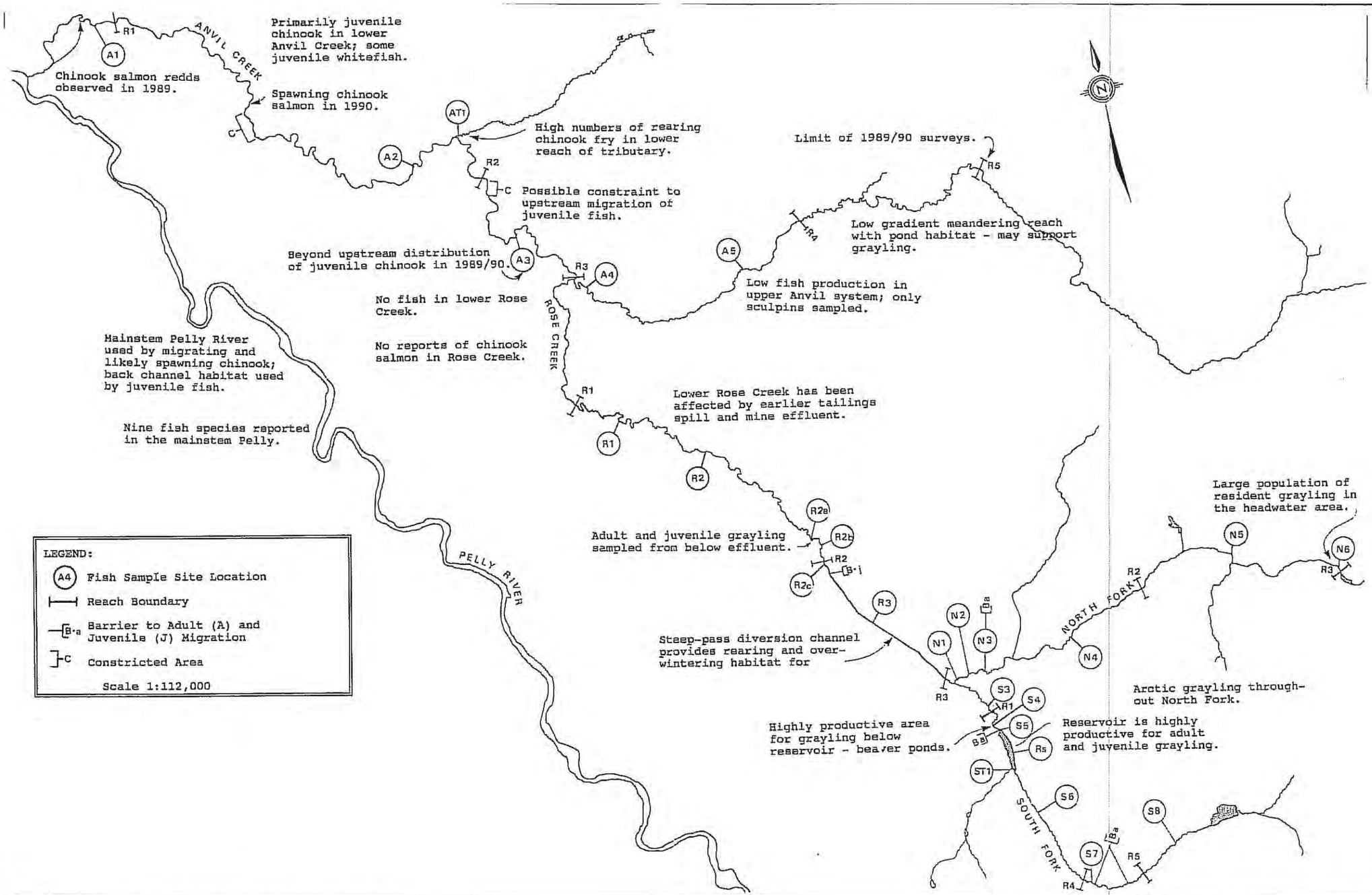
VANGORDA CREEK DRAINAGE
BIOPHYSICAL STREAM
SUMMARY

PROJECT NO. 033001 | DATE Nov. 1996 | APPROVED | FIGURE 3-42

Source: Robertson 1996

HABITAT INFORMATION FROM

GLL (2002)



SOURCE OF FIGURE:
DRAWING SHOWN BELOW DRAWN FROM REPORT BY P.A. HARDER AND ASSOCIATES LTD. FOR CURRAGH RESOURCES INC. DATED APRIL, 1991. "OVERVIEW ASSESSMENT OF FISH RESOURCES IN ANVIL AND ROSE CREEKS"

FIGURE 1.1 Location of fish sample sites (1989/90), reach boundaries and annotations on fish habitat use in the Anvil/Rose drainage.

DRAWING INFORMATION:	
REVIEWED BY:	ED
DRAWN BY:	CPW
DATE ISSUED:	APRIL, 2002
PROJECT NUMBER:	22-943
FILE NAME:	22943-01-09.DWG
REVISION:	0

ANVIL/ROSE CREEK WATERSHED
FISH HABITAT

ANVIL RANGE MINE COMPLEX
2002 BASELINE ENVIRONMENTAL INFORMATION

Gartner Lee Limited | Deloitte & Touche | Figure No. 4.29

Source: Gartner Lee 2002

ATTACHMENT B

WATER QUALITY DATA, REFERENCE STATIONS

B.1: Water quality summary statistics for pooled reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]	Lower Background Benchmark (5th percentile)	Upper Background Benchmark (95th percentile)
Non-Metals	Alkalinity, Total	mg/L	209	5.1	160	40.1	55.1	43.3	10.0	150
	Ammonia-N	mg/L	225	<0.005	0.36	0.01	0.018	0.033	-	0.054
	Conductivity, Field	µS/cm	164	4.4	620	110	137	101	-	292
	Hardness, Total ($CaCO_3$)	mg/L	237	8.2	251	48.0	64.2	48.4	-	159
	Nitrate-N	mg/L	166	<0.002	0.24	0.04	0.06	0.06	-	0.20
	Organic carbon, Dissolved	mg/L	149	<0.5	30.3	2.4	4.4	5.8	0.8	19.0
	Organic carbon, Total	mg/L	151	<0.5	27.8	2.3	4.2	5.4	0.7	15.0
	pH, Field	pH units	184	5.23	9.15	7.73	7.65	0.56	6.6	8.4
	Sulfate	mg/L	234	0.3	25	7.4	8.0	6.0	-	21.5
	Total dissolved solids	mg/L	202	16	300	64	82	50	-	180
	Total suspended solids	mg/L	227	<1	400	<1	7	32	-	20
	Turbidity, Lab	NTU	67	<0.1	6.2	0.53	0.77	1.02	-	2.23
Metals	Cadmium, Total	mg/L	212	<0.000005	0.000348	0.0000120	0.0000256	0.0000396	-	0.000107
	Cadmium, Dissolved	mg/L	199	<0.000005	0.000669	0.000014	0.000024	0.000052	-	0.000067
	Calcium, Total	mg/L	230	2.47	74.6	14.9	19.0	13.8	-	45.7
	Cobalt, Total	mg/L	207	0.000006	0.00127	0.0000300	0.0000756	0.000168	-	0.000248
	Iron, Total	mg/L	227	<0.001	3.15	0.082	0.15	0.31	-	0.46
	Lead, Total	mg/L	228	<0.000005	0.017	0.000215	0.000600	0.00152	-	0.00203
	Magnesium, Total	mg/L	228	0.27	15.8	2.52	3.86	3.37	-	11.0
	Manganese, Total	mg/L	229	<0.00005	0.212	0.00609	0.0126	0.0230	-	0.0378
	Nickel, Total	mg/L	230	0.00015	0.0107	0.00034	0.00052	0.00092	-	0.0011
	Potassium, Total	mg/L	221	<0.05	2.18	0.55	0.67	0.41	-	1.39
	Silver, Total	mg/L	200	<0.000005	0.0005	<0.000005	0.000009	0.00005	-	0.000020
	Sodium, Total	mg/L	226	<0.05	4.9	1.84	1.86	0.66	-	3.08
	Strontium, Total	mg/L	222	0.0168	0.251	0.0681	0.0781	0.0466	-	0.175
	Uranium, Total	mg/L	225	<0.000002	0.00619	0.000683	0.000975	0.000907	-	0.00251
	Zinc, Total	mg/L	230	<0.0001	0.0389	0.0021	0.0039	0.0057	-	0.014
	Zinc, Dissolved	mg/L	222	0.0001	0.197	0.0031	0.0056	0.014	-	0.017

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

B.2: Water quality summary statistics for station V1 (reference), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	61	12	52	38	35	12
	Ammonia-N	mg/L	61	<0.005	0.36	0.010	0.023	0.049
	Conductivity, Field	µS/cm	48	30	303	97	101	47
	Hardness, Total ($CaCO_3$)	mg/L	62	16	59.7	42.0	40.3	12.8
	Nitrate-N	mg/L	40	0.0067	0.15	0.04	0.06	0.05
	Organic carbon, Dissolved	mg/L	52	<0.5	27.1	1.7	2.7	4.1
	Organic carbon, Total	mg/L	53	<0.5	11.7	1.7	2.3	2.5
	pH, Field	pH units	51	5.23	8.67	7.80	7.72	0.59
	Sulfate	mg/L	63	<0.5	17.9	9.6	9.3	3.2
	Total dissolved solids	mg/L	57	26	100	62	61	17
	Total suspended solids	mg/L	62	<1	16	<1	1	2
	Turbidity, Lab	NTU	26	<0.1	1	0.20	0.22	0.20
Metals	Cadmium, Total	mg/L	57	<0.000005	0.000114	0.0000080	0.0000110	0.0000160
	Cadmium, Dissolved	mg/L	56	<0.000005	0.000042	0.0000090	0.000012	0.0000085
	Calcium, Total	mg/L	58	5.01	18.5	14.2	12.9	4.0
	Cobalt, Total	mg/L	54	0.000006	0.000978	0.0000185	0.0000464	0.000135
	Iron, Total	mg/L	57	<0.001	0.344	0.02	0.03	0.05
	Lead, Total	mg/L	62	<0.000005	0.00138	0.000126	0.000257	0.000303
	Magnesium, Total	mg/L	61	0.27	3.06	2.15	2.00	0.76
	Manganese, Total	mg/L	63	<0.00005	0.0471	0.00066	0.0027	0.0071
	Nickel, Total	mg/L	58	0.00016	0.0107	0.00025	0.00050	0.0014
	Potassium, Total	mg/L	54	0.281	1.43	0.51	0.53	0.24
	Silver, Total	mg/L	53	<0.000005	0.0005	<0.000005	0.000013	0.000068
	Sodium, Total	mg/L	59	0.79	2.72	1.89	1.79	0.43
	Strontium, Total	mg/L	59	0.0278	0.094	0.0687	0.0643	0.0175
	Uranium, Total	mg/L	58	<0.000002	0.00172	0.000579	0.000738	0.000467
	Zinc, Total	mg/L	61	<0.0001	0.0349	0.0014	0.0027	0.0048
	Zinc, Dissolved	mg/L	60	0.0004	0.197	0.0029	0.0077	0.026

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

B.3: Water quality summary statistics for station VR (reference), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	27	7.7	41	30	29	10
	Ammonia-N	mg/L	25	<0.005	0.124	<0.005	0.011	0.024
	Conductivity, Field	µS/cm	18	25.1	188.8	74	88	48
	Hardness, Total ($CaCO_3$)	mg/L	27	14.6	44.9	30.8	31.2	9.2
	Nitrate-N	mg/L	27	0.0154	0.09	<0.02	0.03	0.03
	Organic carbon, Dissolved	mg/L	12	1.6	25	3.6	6.6	7.4
	Organic carbon, Total	mg/L	13	1.2	24.5	4.1	6.9	7.0
	pH, Field	pH units	18	6.32	9.15	7.39	7.35	0.72
	Sulfate	mg/L	28	<0.5	8.1	5.7	4.8	2.5
	Total dissolved solids	mg/L	26	28	78	49	50	15
	Total suspended solids	mg/L	28	<1	400	3	34	84
	Turbidity, Lab	NTU	3	0.3	2.02	1.21	1.18	0.86
Metals	Cadmium, Total	mg/L	26	0.000008	0.000348	0.0000240	0.0000552	0.0000724
	Cadmium, Dissolved	mg/L	25	<0.000005	0.000135	0.000019	0.000028	0.000031
	Calcium, Total	mg/L	28	4.54	13.8	9.3	9.5	2.9
	Cobalt, Total	mg/L	27	0.000014	0.00118	0.0000460	0.000161	0.000279
	Iron, Total	mg/L	28	0.018	1.82	0.06	0.22	0.41
	Lead, Total	mg/L	25	0.000051	0.0125	0.000322	0.00137	0.00269
	Magnesium, Total	mg/L	28	0.8	2.55	1.8	1.7	0.5
	Manganese, Total	mg/L	22	0.00069	0.212	0.00282	0.0188	0.0452
	Nickel, Total	mg/L	26	0.00015	0.00733	0.000305	0.000743	0.00141
	Potassium, Total	mg/L	27	<0.05	1.31	0.38	0.49	0.29
	Silver, Total	mg/L	25	<0.000005	0.000029	<0.000005	0.000008	0.000008
	Sodium, Total	mg/L	28	0.59	2.23	1.55	1.55	0.41
	Strontium, Total	mg/L	23	0.0251	0.0717	0.0481	0.0500	0.0154
	Uranium, Total	mg/L	26	<0.000002	0.00619	0.000479	0.000961	0.00148
	Zinc, Total	mg/L	27	0.0002	0.0309	0.0034	0.0066	0.0079
	Zinc, Dissolved	mg/L	26	0.0002	0.0135	0.0030	0.0041	0.0037

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

B.4: Water quality summary statistics for station USFR (reference), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	5	7.6	26.3	16	16.3	6.7
	Ammonia-N	mg/L	6	<0.01	0.16	0.016	0.040	0.059
	Conductivity, Field	µS/cm	1	-	-	-	-	-
	Hardness, Total ($CaCO_3$)	mg/L	6	15.3	30.8	20.9	21.2	5.5
	Nitrate-N	mg/L	6	0.0157	0.04	<0.02	0.02	0.01
	Organic carbon, Dissolved	mg/L	3	3.7	26.8	6.6	12.4	12.6
	Organic carbon, Total	mg/L	3	1.63	27.8	6.7	12.0	13.9
	pH, Field	pH units	2	7.03	7.39	-	-	-
	Sulfate	mg/L	6	<0.5	7.38	4.7	4.5	2.8
	Total dissolved solids	mg/L	6	24	58	38	40	13
	Total suspended solids	mg/L	5	<1	20	<4	7	9
	Turbidity, Lab	NTU	1	-	-	-	-	-
Metals	Cadmium, Total	mg/L	6	<0.000005	0.000071	0.0000163	0.0000236	0.0000262
	Cadmium, Dissolved	mg/L	5	<0.000005	0.00006	0.0000070	0.000017	0.000024
	Calcium, Total	mg/L	6	4.98	9.61	6.44	6.66	1.69
	Cobalt, Total	mg/L	6	0.000022	0.000208	0.0000533	0.0000848	0.0000761
	Iron, Total	mg/L	6	0.087	0.474	0.21	0.26	0.17
	Lead, Total	mg/L	6	0.000032	0.000719	0.000162	0.000255	0.000264
	Magnesium, Total	mg/L	6	0.7	1.64	1.1	1.1	0.3
	Manganese, Total	mg/L	6	0.00728	0.0939	0.0232	0.0335	0.0333
	Nickel, Total	mg/L	5	0.00016	0.000901	0.00040	0.00046	0.00028
	Potassium, Total	mg/L	4	0.23	2.08	0.29	0.72	0.91
	Silver, Total	mg/L	5	<0.000005	0.0000061	<0.000005	0.000004	0.000002
	Sodium, Total	mg/L	5	0.73	1.86	1.41	1.32	0.42
	Strontium, Total	mg/L	6	0.0293	0.0598	0.0394	0.0408	0.0105
	Uranium, Total	mg/L	4	0.000352	0.000871	0.000642	0.000627	0.000257
	Zinc, Total	mg/L	4	0.0003	0.0089	0.0033	0.0040	0.0043
	Zinc, Dissolved	mg/L	5	0.00033	0.0085	0.0010	0.0025	0.0034

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

B.5: Water quality summary statistics for station R7 (reference), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	40	17	140	83	87	34
	Ammonia-N	mg/L	58	<0.005	0.15	0.020	0.024	0.026
	Conductivity, Field	µS/cm	43	40	292	192	186	69
	Hardness, Total ($CaCO_3$)	mg/L	64	25.2	149	93	96	34
	Nitrate-N	mg/L	29	0.005	0.19	0.06	0.07	0.07
	Organic carbon, Dissolved	mg/L	45	0.7	21.8	2.5	3.8	4.2
	Organic carbon, Total	mg/L	42	0.8	21.3	2.2	3.4	3.9
	pH, Field	pH units	55	7.12	8.83	7.80	7.79	0.34
	Sulfate	mg/L	61	0.3	17	8.5	7.8	3.2
	Total dissolved solids	mg/L	46	52	190	119	113	35
	Total suspended solids	mg/L	57	<1	43	<1	3	7
	Turbidity, Lab	NTU	26	0.34	2.17	0.69	0.81	0.37
Metals	Cadmium, Total	mg/L	50	<0.000005	0.000073	0.0000100	0.0000144	0.0000150
	Cadmium, Dissolved	mg/L	46	<0.000005	0.000097	0.000013	0.000016	0.000018
	Calcium, Total	mg/L	61	7.87	42.5	26.5	28.0	10.3
	Cobalt, Total	mg/L	46	0.000011	0.000316	0.0000385	0.0000502	0.0000490
	Iron, Total	mg/L	63	0.028	0.98	0.15	0.19	0.17
	Lead, Total	mg/L	61	0.00001	0.003	0.000352	0.000476	0.000548
	Magnesium, Total	mg/L	56	1.34	9.39	5.7	5.8	2.1
	Manganese, Total	mg/L	61	0.006	0.0752	0.0171	0.0188	0.0105
	Nickel, Total	mg/L	62	0.00015	0.002	0.00039	0.00044	0.00031
	Potassium, Total	mg/L	62	0.325	1.75	0.75	0.76	0.31
	Silver, Total	mg/L	46	<0.000005	0.0004	<0.000005	0.000012	0.000059
	Sodium, Total	mg/L	57	0.66	3.81	2.04	2.22	0.78
	Strontium, Total	mg/L	59	0.0368	0.194	0.118	0.118	0.0455
	Uranium, Total	mg/L	61	0.000367	0.00282	0.00127	0.00144	0.000759
	Zinc, Total	mg/L	62	0.0003	0.014	0.0023	0.0034	0.0034
	Zinc, Dissolved	mg/L	61	0.0003	0.0328	0.0044	0.0047	0.0055

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

B.6: Water quality summary statistics for station FC (reference), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	28	5.1	25	16	16	6
	Ammonia-N	mg/L	29	<0.005	0.034	<0.005	0.0068	0.0083
	Conductivity, Field	µS/cm	22	10.6	487	31	78	120
	Hardness, Total ($CaCO_3$)	mg/L	30	8.2	20.4	14.6	14.4	3.5
	Nitrate-N	mg/L	28	0.0048	0.1	<0.02	0.03	0.03
	Organic carbon, Dissolved	mg/L	12	0.7	20.7	3.2	4.7	5.8
	Organic carbon, Total	mg/L	11	<0.5	22.9	2.5	5.0	6.6
	pH, Field	pH units	19	6.1	8.18	7.34	7.23	0.65
	Sulfate	mg/L	27	<0.5	3	1.5	1.4	0.9
	Total dissolved solids	mg/L	25	16	76	32	35	13
	Total suspended solids	mg/L	28	<1	11	<1	2	3
	Turbidity, Lab	NTU	3	0.45	4.54	0.86	1.95	2.25
Metals	Cadmium, Total	mg/L	27	<0.000005	0.00012	0.0000140	0.0000252	0.0000268
	Cadmium, Dissolved	mg/L	25	<0.000005	0.000112	0.000012	0.000023	0.000026
	Calcium, Total	mg/L	29	2.47	6.02	4.4	4.3	1.1
	Cobalt, Total	mg/L	29	0.000012	0.000157	0.0000260	0.0000452	0.0000383
	Iron, Total	mg/L	27	0.015	0.469	0.04	0.07	0.10
	Lead, Total	mg/L	27	0.000061	0.017	0.000324	0.00131	0.00323
	Magnesium, Total	mg/L	26	0.49	1.29	0.9	0.9	0.2
	Manganese, Total	mg/L	28	0.00062	0.0145	0.00207	0.00348	0.00393
	Nickel, Total	mg/L	29	0.00015	0.00086	0.00032	0.00037	0.00021
	Potassium, Total	mg/L	27	<0.05	1.36	0.18	0.30	0.32
	Silver, Total	mg/L	29	<0.000005	0.0000352	<0.000005	0.000005	0.000007
	Sodium, Total	mg/L	28	<0.05	2.88	1.94	1.82	0.60
	Strontium, Total	mg/L	28	0.0168	0.0366	0.0270	0.0263	0.00580
	Uranium, Total	mg/L	28	<0.000002	0.000325	0.000107	0.000134	0.0000777
	Zinc, Total	mg/L	29	0.0001	0.0304	0.0025	0.0051	0.0066
	Zinc, Dissolved	mg/L	25	0.0017	0.0301	0.0031	0.0058	0.007

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

B.7: Water quality summary statistics for station R6 (reference), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	32	43	160	140	125	34
	Ammonia-N	mg/L	31	<0.005	0.03	<0.005	0.006	0.007
	Conductivity, Field	µS/cm	21	4.4	620	252	256	137
	Hardness, Total ($CaCO_3$)	mg/L	32	47.5	251	150	142	39
	Nitrate-N	mg/L	29	<0.02	0.24	0.14	0.13	0.08
	Organic carbon, Dissolved	mg/L	11	0.8	22.2	1.8	5.0	6.7
	Organic carbon, Total	mg/L	13	0.7	22.9	2.2	5.4	6.5
	pH, Field	pH units	25	6.43	8.46	7.93	7.83	0.51
	Sulfate	mg/L	31	<0.5	25	21.0	18.5	6.4
	Total dissolved solids	mg/L	27	74	300	170	166	46
	Total suspended solids	mg/L	31	<1	85	2	9	19
	Turbidity, Lab	NTU	5	0.37	6.2	0.64	2.23	2.55
Metals	Cadmium, Total	mg/L	30	0.000007	0.000236	0.0000170	0.0000364	0.0000489
	Cadmium, Dissolved	mg/L	27	<0.000005	0.000669	0.000016	0.000047	0.00013
	Calcium, Total	mg/L	32	12.8	74.6	43.0	39.8	12.3
	Cobalt, Total	mg/L	30	0.00002	0.00127	0.0000465	0.000135	0.000279
	Iron, Total	mg/L	30	0.037	3.15	0.14	0.35	0.66
	Lead, Total	mg/L	30	0.000016	0.00177	0.0000995	0.000291	0.000478
	Magnesium, Total	mg/L	33	3.8	15.8	10.5	9.9	2.6
	Manganese, Total	mg/L	32	0.00609	0.166	0.0138	0.0260	0.0357
	Nickel, Total	mg/L	33	0.00019	0.0046	0.00041	0.00071	0.00091
	Potassium, Total	mg/L	31	0.69	1.8	1.19	1.17	0.26
	Silver, Total	mg/L	28	<0.000005	0.000037	<0.000005	0.000005	0.000007
	Sodium, Total	mg/L	32	0.6	4.9	1.92	1.88	0.77
	Strontium, Total	mg/L	31	0.0418	0.251	0.125	0.120	0.0423
	Uranium, Total	mg/L	32	<0.000002	0.00261	0.00188	0.00174	0.000698
	Zinc, Total	mg/L	31	<0.0001	0.015	0.0015	0.0024	0.0032
	Zinc, Dissolved	mg/L	30	0.0001	0.0078	0.0021	0.0025	0.0021

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

B.8: Water quality summary statistics for station W10 (reference), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	16	15	65	42	40	16
	Ammonia-N	mg/L	15	<0.005	0.06	<0.01	0.016	0.018
	Conductivity, Field	µS/cm	11	41	123.8	87	84	28
	Hardness, Total ($CaCO_3$)	mg/L	16	21.2	63.4	41.9	41.4	14.4
	Nitrate-N	mg/L	7	<0.002	0.02	<0.02	0.01	0.003
	Organic carbon, Dissolved	mg/L	14	2.7	30.3	4.8	8.5	8.4
	Organic carbon, Total	mg/L	16	2.7	27.8	4.5	7.7	7.1
	pH, Field	pH units	14	7	8.5	7.44	7.54	0.43
	Sulfate	mg/L	18	0.3	6.5	2.4	2.4	1.9
	Total dissolved solids	mg/L	15	40	88	56	59	15
	Total suspended solids	mg/L	16	<1	12.9	<1	2	3
	Turbidity, Lab	NTU	3	0.24	1.43	0.67	0.78	0.60
Metals	Cadmium, Total	mg/L	16	0.000011	0.000166	0.0000230	0.0000455	0.0000459
	Cadmium, Dissolved	mg/L	15	0.000012	0.000152	0.0000250	0.0000474	0.0000452
	Calcium, Total	mg/L	16	6.56	21	14.7	13.5	4.5
	Cobalt, Total	mg/L	15	0.000019	0.000112	0.000025	0.000042	0.000031
	Iron, Total	mg/L	16	0.013	0.149	0.027	0.05	0.05
	Lead, Total	mg/L	17	0.000085	0.00234	0.000461	0.000702	0.000740
	Magnesium, Total	mg/L	18	0.99	2.68	1.9	1.8	0.6
	Manganese, Total	mg/L	17	0.00026	0.0119	0.000810	0.00199	0.00301
	Nickel, Total	mg/L	17	0.0003	0.001	0.00049	0.00049	0.00014
	Potassium, Total	mg/L	16	0.05	2.18	0.48	0.68	0.53
	Silver, Total	mg/L	14	<0.000005	0.000024	<0.000005	0.000007	0.000008
	Sodium, Total	mg/L	17	0.45	2.89	1.62	1.56	0.58
	Strontium, Total	mg/L	16	0.0234	0.0673	0.0468	0.0452	0.0137
	Uranium, Total	mg/L	16	<0.000002	<0.0005	0.000124	0.000130	0.0000621
	Zinc, Total	mg/L	16	0.0001	0.0389	0.0030	0.0062	0.0099
	Zinc, Dissolved	mg/L	15	0.0005	0.0386	<0.005	0.0104	0.0120

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Non-metals												Metals	
		Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
	Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
V1	23-Jan-08	42	< 0.005	126.4	51.3	0.11	1.5	0.8	7.28	12.2	58	< 1		0.000008	0.000018
V1	21-Feb-08	48	< 0.005	126.5	54.6	0.12	0.7	0.7	6.86	12.2	82	< 1		0.000006	< 0.000005
V1	10-Mar-08	49.4	< 0.01		59				7.2	12.3		< 1	< 0.1	< 0.0002	< 0.0002
V1	11-Mar-08	47	< 0.005	125.4	54.1	0.13	0.8	0.8	6.3	11.9	88	< 1		0.000006	0.000009
V1	29-Apr-08	45	< 0.005	129	51.2	0.12	0.8	0.9	7.82	11	86	< 1		0.000007	0.000007
V1	22-May-08	22	< 0.005	70.1		< 0.02		9.4	7.7	1.4	60	< 1		0.000114	0.000026
V1	24-May-08	15	0.13		23.1	< 0.02		8		1.6	52	16		0.000047	
V1	10-Jun-08	16.2	0.02		17				7.5	4.25		< 1	0.5	< 0.0002	< 0.0002
V1	25-Jun-08	12	< 0.005	48.8	16.5	< 0.02	3	3	6.76	3.8	38	2		< 0.000005	0.00001
V1	29-Jul-08	27	< 0.005	92.3	32.2	< 0.02	2.5	2.4		7.3	58	< 1		0.000011	0.000014
V1	2-Sep-08	28.2	< 0.01							7.22		6	0.3	< 0.0002	< 0.0002
V1	17-Sep-08	29	< 0.005	83.4	30.3	< 0.02	2.6	2.9	6.93	7.7	72	< 1		0.000009	0.000017
V1	7-Oct-08	29	< 0.005		29.9	0.04	1.6			9.6	58	3		< 0.000005	
V1	2-Dec-08	40.8	0.02							10.8		< 1	0.11	< 0.0002	< 0.0002
V1	11-Dec-08	44	< 0.005	303	51.3	0.06	1.6	1.5		11	100	1		0.000009	0.000006
V1	22-Jan-09	48	< 0.005		50.6	0.08				11	60	< 1		0.000007	0.000009
V1	25-Feb-09	50	< 0.005		52.8	0.12				12		< 1		0.000021	0.000015
V1	4-Mar-09	51	< 0.01	95	55.7		1.5	1	8.2	12	96	< 1		0.000009	0.000007
V1	26-Mar-09	51	0.027		52.8	0.14					66	< 1		0.000006	0.000007
V1	8-Apr-09	52	< 0.01	69.3	57.2		1.9	2	6.95	13	90	< 1		0.000009	< 0.000005
V1	5-May-09	13	0.05	39	16		10.4	10.6	7.16	< 0.5	38	5		0.000041	0.000026
V1	10-Jun-09				18.8		2.9	2.5	7.7	6.2	36	< 1		0.000008	0.00001
V1	13-Jul-09	31	< 0.01		36.4		2.3	2.1	8.2	7.6	54	< 1		0.000009	0.000006
V1	10-Aug-09	26	0.06	54	35.2		2.6		8.1	7.8	74	< 1		0.000011	0.000015
V1	10-Sep-09	23	< 0.01	50	28.8		2.2	2.2	7.8	8.1	66	< 1		0.000006	0.000012
V1	7-Oct-09	24	< 0.01	53	29.6		2.3	1.9	7.67	8.9	66	< 1		0.000006	0.000009
V1	9-Nov-09	38	< 0.01	110	42.1		0.9	0.7		9.5	64	< 1		< 0.000005	0.000014
V1	15-Dec-09	42	0.02	123	48.9		< 0.5	< 0.5	7.87	10	52				
V1	7-Jan-10	45	< 0.01	140	53.4		1	0.8	7.76	10	68	< 4		< 0.000005	< 0.000005
V1	18-Feb-10	49	0.03	80	50.8		0.8	< 0.5	8.34	11	68	< 1		< 0.000005	< 0.000005
V1	29-Mar-10		< 0.01	122	51.5		1.6	1.4	7.91	12		< 1		< 0.000005	0.000006
V1	20-Apr-10	46	0.02	101	48		1.5	1	7.9	12	46	< 1		0.000007	0.000006
V1	12-May-10	39	< 0.01	99	44.3			4.5	7.94	7.6	62	< 1		0.000008	0.000011
V1	16-Jun-10	17	< 0.05	54	20.1		2.2	1.8	7.16	5.5	30	2		0.000012	0.000042
V1	14-Jul-10	26	< 0.05	60	27.2		1.1	1.8	8.2	6.8	38	< 1		0.000008	0.000024
V1	4-Aug-10	35	< 0.05		37.3		1.6	1.7	8.29	10	64	< 1		0.000008	0.000014
V1	7-Sep-10	29		30	33.7		1.8	1.8	8.38	9.1	62	< 1	0.2	0.000008	0.000007
V1	5-Oct-10	34	0.36	103	39.9	0.03	1.1	1.7	5.23	9.6	82	< 1	0.2	0.000007	0.000015
V1	1-Nov-10	38	0.008		39.1	0.04	1	0.9	8.67	12	60		0.15	0.000011	< 0.000005
V1	1-Dec-10	39	< 0.05	140	48.5	0.07	< 0.5	< 0.5		13	56		1	0.000014	
V1	24-Jan-11	47	0.036	192	59.7	0.12	27.1	0.7	7.93	11	62	< 1	< 0.25	0.000013	0.000038
V1	17-Feb-11	45	< 0.005	134	49	0.13	0.9	1.1	7.84	11	62	< 4	< 0.25	< 0.000005	0.000007
V1	22-Mar-11	45	0.013	137	50.7	0.15	0.7	0.6	8.03	12	66	< 1		0.00001	< 0.000005
V1	21-Apr-11	46	0.019	90	56.5	0.15	0.8	0.7	8.52	15	64	< 1	< 0.25	< 0.000005	0.000017
V1	17-May-11	36		88	40.7	< 0.02	12.1	11.7	8.08	7.5	42	< 1	0.5	0.000018	0.000022
V1	15-Jun-11	14	0.024	38	17.6	< 0.02	3	2.3	7.62	6.9		< 1	< 0.25	< 0.000005	0.000006
V1	13-Jul-11	24	0.02		30.2	< 0.02	1.9	2.3	7.65	9.2	48	< 1		0.000008	0.000009
V1	10-Aug-11	26	< 0.005	73	31.3	< 0.02	2.5	2.3	7.68	7.9	64	< 1	0.34	0.000011	0.000007

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Metals													
		Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
V1	23-Jan-08	16.1	0.000013	0.007	0.000027	2.68	0.00056	0.0002	0.52	< 0.000005	2.08	0.0843	0.0012	0.0005	0.0031
V1	21-Feb-08	17.4	0.000011	0.006	0.00001	2.69	0.00062	0.00021	0.58	< 0.000005	2.31	0.0823	0.00135	0.0005	0.0004
V1	10-Mar-08	18.5	< 0.001	< 0.05	< 0.001	3.06	< 0.001	< 0.001	0.7	< 0.00025	2.58	0.094	0.0014	< 0.005	< 0.005
V1	11-Mar-08	17.1	0.000013	0.005	0.000035	2.77	0.00062	0.00024	0.59	< 0.000005	2.28	0.0819	0.00147	0.0041	0.0048
V1	29-Apr-08	16.3	0.000012	0.005	0.000059	2.54	0.00061	0.00025	0.58	< 0.000005	2.08	0.0817	0.00144	0.004	0.0046
V1	22-May-08	9.36	0.000116	0.168	0.00123	1.46	0.0228	0.00099	1.43	0.000007	1.35	0.0444	0.000459	0.0166	0.0058
V1	24-May-08	7.4	0.000255	0.344	0.000748		0.0471	0.00082	0.98	0.000009	0.96	0.0378	0.000613	0.0058	
V1	10-Jun-08	5.56	< 0.001	0.09	< 0.001	0.87	0.023	< 0.001	0.4	0.0005	1.05	0.028	< 0.0005	< 0.005	< 0.005
V1	25-Jun-08	5.38	0.000038	0.055	0.000136	0.75	0.00259	0.0003	0.31	< 0.000005	0.96	0.0289	0.000399	0.0012	0.0021
V1	29-Jul-08	10.4	0.000021	0.031	0.000112	1.5	0.00083	0.00028	0.37	< 0.000005	2.32	0.0515	0.000374	0.0016	0.0023
V1	2-Sep-08		< 0.001	< 0.05	< 0.001	1.11	0.001	< 0.001	0.3	< 0.00025	1.48	0.042	< 0.0005	< 0.005	0.03
V1	17-Sep-08	9.76	0.000023	0.027	0.000195	1.44	0.00116	0.00025	0.38	< 0.000005	1.53	0.0496	0.000343	0.0032	0.0013
V1	7-Oct-08			< 0.001	< 0.000005	0.27	< 0.00005	0.0107		0.0561		< 0.00005	< 0.000002	< 0.0001	0.002
V1	2-Dec-08	16.8	< 0.001	< 0.05	< 0.001	2.88	0.001	< 0.001	0.6	< 0.00025	2.3	0.072	0.0007	< 0.005	< 0.005
V1	11-Dec-08	16.2	0.000014	0.008	0.000192	2.62	0.00021	0.00025	0.53	< 0.000005	1.95	0.077	0.000918	0.0015	
V1	22-Jan-09	16.2	0.00001		0.000104	2.48	0.00028	0.00018	0.53	< 0.000005	2.72	0.0789	0.00132	0.0024	0.0029
V1	25-Feb-09	16.9	0.00001	0.005	0.000201	2.56	0.00066	0.00019	0.55	< 0.000005	1.83		0.00151	0.0014	0.0029
V1	4-Mar-09	17.4	0.000011	0.005	0.000023	2.96	0.00016	0.00021			2.07	0.0863		0.0006	0.0005
V1	26-Mar-09	16.7	0.000011	0.002	0.000008	2.72	0.00014	0.00017			1.9	0.0848	0.00172		0.0144
V1	8-Apr-09	18	0.000006	0.004	0.000025	2.96	0.00018		0.6	< 0.000005	2.14	0.0808	0.00165	0.0007	0.0014
V1	5-May-09	5.01	0.000111		0.000331	0.85	0.0147	0.00061	1.41	0.000006	0.79	0.0278	0.000554	0.004	0.004
V1	10-Jun-09		0.00003	0.047	0.000061	0.86	0.00111	0.00022	0.34		0.98		0.000388	0.0005	
V1	13-Jul-09	10.7	0.000021	0.018	0.000188	1.56	0.00047	0.00026				0.0531	0.000366	0.0009	0.0032
V1	10-Aug-09	11.4	0.000051		0.000798	1.62	0.00299	0.00046	0.46	< 0.000005	1.85	0.0569	0.000377	0.0349	0.0116
V1	10-Sep-09	9.25	0.000029		0.000162	1.38	0.00161	0.00018	0.33	< 0.000005	1.74	0.049	0.000343	0.0034	0.004
V1	7-Oct-09	9.23	0.00002	0.027	0.000311	1.43	0.00186	0.00025	0.31	< 0.000005		0.0488		0.0019	0.0056
V1	9-Nov-09	13.3		0.013	0.000209	2.14	0.00037	0.00023		< 0.000005	1.89	0.0662	0.000602	0.0029	0.0017
V1	15-Dec-09	15.5		0.008	0.000162		0.00035		0.51	< 0.000005	2.04	0.0743	0.00088	0.0005	0.0007
V1	7-Jan-10	15.5	0.000012	0.007	0.00014	2.53	0.00024	0.00026	0.5	< 0.000005	1.97	0.0774	0.00105	0.0008	0.0024
V1	18-Feb-10	16.3	0.000012	0.005	0.000087	2.68	0.00028	0.00021	0.54	< 0.000005	2	0.0743	0.00125	0.0008	0.0007
V1	29-Mar-10	15.4	0.000012	0.003	0.000104	2.77	0.00022	0.00018	0.51	< 0.000005	2.13	0.0761	0.00147	0.001	0.0011
V1	20-Apr-10	14.6	0.000019	0.007	0.000373	2.43	0.00064	0.00018		< 0.000005	1.76	0.0793		0.0008	0.0026
V1	12-May-10	13.9		0.111	0.000107		0.00188	0.00052	0.78	< 0.000005	1.74	0.07	0.00064	0.0034	0.0061
V1	16-Jun-10	6.39	0.00003	0.032	0.000977	1	0.00258	0.00027	0.31	< 0.000005	1.29		0.000331	0.0046	0.0414
V1	14-Jul-10	7.76	0.000017	0.022	0.000087	1.07	0.00114	0.00018	0.29		1.22	0.0436	0.00029	0.0008	0.0145
V1	4-Aug-10		0.000034	0.011	0.000108	1.79		0.00025	0.41	< 0.000005	1.81	0.0608	0.000391	0.0059	0.005
V1	7-Sep-10	11	0.000011	0.024	0.000091	1.5	0.00064	0.00016	0.33	< 0.000005	1.69	0.0564	0.000328	0.0011	0.0034
V1	5-Oct-10	12.3	0.000017	0.016	0.000105	1.9	0.00076	0.0002	0.42	< 0.000005	1.94	0.0601	0.000526	0.0008	0.0075
V1	1-Nov-10		0.000015	0.008	0.000962	2.15	0.00053	0.0002	0.42	< 0.000005	1.94	0.0687	0.000556	0.0021	
V1	1-Dec-10	14.9	0.000033		0.00138	2.47	0.00328	0.00029	0.52	< 0.000005	2.04	0.0767	0.000761	0.0064	0.002
V1	24-Jan-11	17.6	0.000018	0.009	0.000514	2.85	0.00063	0.00024	0.64	0.000014		0.0829		0.0021	0.0103
V1	17-Feb-11	15	0.00001	0.004	0.000062	2.84	0.00026	0.00023			2.18	0.0818			0.0004
V1	22-Mar-11	14.5	0.000011	0.006	0.000278	2.94	0.00142		0.58	< 0.000005	2.22	0.0842	0.00155	0.0029	0.0022
V1	21-Apr-11	17.9	0.000014	0.007	0.000605	2.88	0.00057	0.0013	0.54	< 0.000005	2.18	0.0857	0.00172	0.0005	0.0045
V1	17-May-11	12.5	0.000059	0.081	0.000215	2.15	0.00385		1.12		1.45	0.0598	0.000673	0.0017	0.0017
V1	15-Jun-11	5.65	0.000023	0.03	0.000087	0.83	0.001	0.00025	0.31	< 0.000005	1.13	0.0312	0.000325	0.0004	0.0043
V1	13-Jul-11	9.7		0.027	0.000109		0.00113		0.36	< 0.000005	1.56	0.0511	0.00032	0.0005	0.0007
V1	10-Aug-11	10	0.000022	0.027	0.000299	1.51	0.00069	0.0003		< 0.000005	1.62	0.0523	0.000333	0.0028	0.0019

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Non-metals												Metals	
		Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
	Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
V1	13-Sep-11	26	0.047	61	30.6	< 0.02	2.2	1.8	7.75		44	< 1	0.17	0.000008	0.000018
V1	18-Oct-11	36	0.032	110	41.8	< 0.02	1.6	1.5	7.78	10.8	54	< 1	< 0.1		0.000008
V1	23-Nov-11	40.1	0.028	127	53.9		2.34	1.28	8.41	17.9	58	< 1	< 0.1	< 0.000005	0.000014
V1	8-Dec-11	42.8	0.071	104	47.7	0.073	1.04	1.23	7.89	13.4	64	< 4	< 0.1	0.000006	0.000006
V1	25-Jan-12	47.7	0.055	90	49.6	0.12	1.17	1.08	8.04	11.6	76	< 1		0.000016	0.000019
V1	27-Feb-12	46	0.023	125	54.1	0.121		0.91	7.97	11.1	64	< 1	0.12	0.00001	< 0.000005
V1	7-Mar-12	47.4	0.023	113	51.6	0.137	< 0.5	0.65	7.71	11.9	84	< 1	< 0.1	< 0.000005	0.000006
V1	26-Apr-12			147									0.26		
V1	22-May-12	39.6	0.022	179	46.7	0.026	9.3	7.37	8.29	8.04	74	< 1		0.000021	0.0000232
V1	2-Jun-12	27.8	< 0.005		37.7	0.0067	< 6.06			7.43		2.2		0.0000114	< 0.0000101
V1	19-Jun-12	14.2	0.0097		17.3	< 0.02	3.94	3.43	7.59	4.3	26	1.2		0.0000109	0.0000224
V1	18-Jul-12		0.015	65	27.9	< 0.02	3.2	2.63		6.41	40	< 1	0.33	0.000009	0.0000131
V1	14-Aug-12	22.1	0.0057	92	27			2.27	7.69	6.2	60	< 1	0.25	0.000006	
V1	12-Sep-12	23.9	0.0066	85	29.3	< 0.02	2.38	2.47	7.6	8.77	50	< 1		< 0.000005	0.000006
V1	23-Sep-12	20.8			26.4	0.0136	2.34			9.28	41	< 1	-3.8	< 0.00001	< 0.00001
V1	15-Oct-12	28.7	0.01	56	34	0.03	1.93	1.6	8.22	9.59	42	< 1	0.16		< 0.000005
V1	13-Nov-12		0.008		43.1	0.055	1.96	0.62	8.01	10.5	74	< 1	0.12		0.000006
V1	11-Dec-12	42.4	0.0069	137	53.9	0.088	0.97		7.7	10.9	88	< 1	0.16	< 0.000005	0.000009
VR	24-Jan-08	36	< 0.005	188	39	0.08	1.6	1.7		5.9	30	96		0.000067	0.000017
VR	21-Feb-08	40	< 0.005	88.7	40.5	0.06	1.6	1.2	7.7	8.1	64	< 1		0.000016	0.000016
VR	11-Mar-08	41	< 0.005	113.1	42.6	0.08	1.8	1.8	7.43	6.6	76	1		0.000015	0.000019
VR	29-Apr-08	41	0.006	112.5	44.9	0.07	2.4	2.6	7.45	7.2	66	4		0.000048	0.000033
VR	22-May-08	12	< 0.005	188.8		< 0.02	16.4	16.5	7.1	< 0.5	38	41		0.000113	0.000061
VR	24-May-08	7.7	< 0.01		16.4	< 0.02	11.9	12.2		3.4	34	100		0.000127	
VR	25-Jun-08	9.6	< 0.005		14.6	< 0.02	4.6	5	6.73	< 0.5	32	3		0.000015	0.000015
VR	29-Jul-08	21	< 0.005	63.8	22.9	< 0.02	4.4	4.4	6.61	4.1	40	< 1		0.000016	
VR	19-Aug-08	25	< 0.01		26.6	< 0.02	4.2			4.6	60	< 1		0.000013	0.000013
VR	17-Sep-08	21	< 0.005	56.5	22.8	< 0.02		4.1	6.37	4.4	50	< 1		0.000011	0.000006
VR	7-Oct-08	25	< 0.005	68.5	25.1	< 0.02	1.8	2.9	6.8	6.9	28	< 1		0.000009	0.000008
VR	11-Dec-08	33	< 0.005	78.3	35.3		2.9	2.6		6.3	44	2		0.000017	0.000018
VR	22-Jan-09	35	< 0.005		33.7	0.04				7.8	62	19		0.000026	0.000029
VR	25-Feb-09	38	0.006		42.1	0.09				7.6	78	400			0.000026
VR	20-May-09	23			24.3	< 0.02			6.32	1.3	38	11		0.000043	0.00003
VR	23-Jun-09	24	< 0.005	163	24.9	< 0.02			7.67	2.4		1		0.000107	0.000135
VR	30-Jul-09	30	0.008	76.3	32.6	< 0.02			7.49	3.5	64	< 1		0.000023	0.000022
VR	25-Aug-09		< 0.005	72.5	30.2	0.02			7.82	4.3	52	< 1		0.000013	0.00001
VR	30-Sep-09	29		77.9	28	< 0.02			7.35	5.3	42	< 1		0.000025	0.000031
VR	21-Oct-09	33	< 0.005		30.8	0.02				5.5	52	< 1		0.000012	0.000009
VR	24-Nov-09	34	< 0.005	25.1	34	0.04			9.15	6.8	48	< 1			< 0.000005
VR	21-Jan-10	39	0.022	52.9	41.5	0.07				6.2		14		0.00008	0.000028
VR	24-Feb-10	41	0.124	60.6	44.8	0.09			8.4	6.1	78	200		0.000348	0.000023
VR	30-Mar-10	40	< 0.005	55.9	44.4	0.08			7.84	7.1	48	46		0.000108	0.000022
VR	3-Nov-10	35	0.014	44.6	34.8	0.02			7.3	6.1	58	< 4		0.000008	0.000005
VR	18-May-11	11	0.025		18.3	< 0.02	25	24.5	6.77	< 0.5	28	9	2.02	0.00013	0.000107
VR	30-May-12	16.9			19.2	0.0314		9.98		0.5	40	4.7	1.21	0.0000345	
VR	30-Aug-12				28.6									0.00001	0.000008
VR	23-Oct-12	29.9	0.013			0.0154				5.96	54	< 1	0.3		
USFR	24-May-08	7.6	0.16		15.3	< 0.02	6.6	6.7		< 0.5	34	20		0.000033	

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Metals													
		Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
V1	13-Sep-11		0.00002	0.025	0.000591	1.44	0.00121	0.00027	0.38		1.61	0.0534	0.000376	0.002	0.0056
V1	18-Oct-11	13.3	0.000016			2.09	0.00042	0.00024	0.46	< 0.000005	1.84	0.0658	0.000618	0.0008	0.0018
V1	23-Nov-11	17.3	0.000019	0.009	0.000182	2.6	0.00059	0.00022	0.53	< 0.000005	2.14		0.000798	0.0008	0.003
V1	8-Dec-11	14.8	0.000013	0.006	0.000009	2.58	0.00034	0.0002	0.54	< 0.000005		0.0781	0.000905	0.0012	0.0011
V1	25-Jan-12	15.3	0.00001	0.004	0.000093	2.76	0.00021	0.0003	0.57	< 0.000005	2.11	0.0795	0.00112	0.0016	0.0022
V1	27-Feb-12	17	0.000018	0.015		2.87	0.00065	0.00027		< 0.000005	2.2	0.0819	0.00136	0.0028	0.0014
V1	7-Mar-12	15.6	0.000978	0.02	0.000128	2.65	0.00044		0.55	< 0.000005	2.17	0.0819		0.0009	
V1	26-Apr-12														
V1	22-May-12	14.7	0.0000357	0.0384	0.0000478	2.36	0.00183	0.000549		< 0.000005	1.91	0.0721		0.00068	0.00666
V1	2-Jun-12	10.5	0.0000468	0.117	0.000116	1.59	0.00495		0.843	< 0.000005		0.0478	0.000401		< 0.00371
V1	19-Jun-12	5.74	0.0000456	0.068	0.000396	0.726	0.00226	0.000356	0.372	0.0000092	0.915		0.000318		0.00658
V1	18-Jul-12	9	0.0000371	0.0382	0.000123	1.31	0.00128	0.000284	0.312	< 0.000005	1.31	0.0453	0.000339	0.00098	0.00221
V1	14-Aug-12	8.04	0.000019	0.0288	0.000047	1.23	0.00104	0.000234	0.281	< 0.000005	1.44	0.0529	0.00045	0.00035	0.197
V1	12-Sep-12	9.58			0.000018	1.29	0.00167	0.000283	0.308	< 0.000005	1.54	0.0472	0.000373	0.00047	0.0009
V1	23-Sep-12			0.034	< 0.00005	1.23		< 0.0005	0.323	< 0.00001	1.64	0.0464	0.000316	0.0053	0.0014
V1	15-Oct-12	10.1	0.000022	0.0167	0.000061	1.67	0.000606	0.000213		< 0.000005	1.7	0.0555	0.000412	0.00072	0.00092
V1	13-Nov-12	13.6	0.000017	0.0071		2.26	0.000188	0.000236	0.484	< 0.000005	1.94	0.074	0.0007	0.00076	0.00058
V1	11-Dec-12	16.6	0.000011		0.000078	2.73	0.000224	0.000289	0.555	< 0.000005	2.09	0.0783	0.000903	0.00083	0.00087
VR	24-Jan-08	11.9	0.000203	0.255		2.22	0.0376	0.00049	0.41	0.000007	1.64	0.06	0.00112	0.0062	0.0028
VR	21-Feb-08	12.6	0.000025	0.03	0.000129	2.2	0.00119		0.54	< 0.000005	1.79	0.0641	0.000416	0.0012	0.002
VR	11-Mar-08	13.2	0.000015	0.022	0.000117	2.34	0.00081	0.00017	0.52	< 0.000005	1.76	0.0677	0.000423	0.0048	
VR	29-Apr-08	13.8	0.000048	0.058	0.000843	2.52	0.00307	0.00733	1.2	0.000005	2.14	0.0715	0.000507	0.0099	0.0082
VR	22-May-08	6.28	0.000414	0.488	0.00426	1.15	0.0291	0.00107	1.03	0.000029	1	0.0316		0.0127	0.0089
VR	24-May-08	5.09	0.000455	0.488	0.00543	0.89		0.00097		0.000014	0.8	0.0292		0.0137	
VR	25-Jun-08	4.54	0.000043	0.075	0.000275	0.8	0.00164	0.00031	0.24	0.000005	1.03	0.0251	0.000695	0.0021	0.0033
VR	29-Jul-08	7.02		0.026	0.000083	1.3	0.00084	0.00023	0.27	< 0.000005	2.23	0.0376	0.000407	0.0021	0.0043
VR	19-Aug-08	8.15	0.000023	0.021	0.000051	1.52		0.0002	0.29	< 0.000005	1.52	0.0458	0.000397	0.0007	0.0018
VR	17-Sep-08	7.02	0.000022	0.022	0.000066	1.27	0.00069	0.00021	0.31	< 0.000005	1.39		0.000376	0.001	0.0002
VR	7-Oct-08	7.64	0.000019	0.02	0.000322	1.46	0.00077	0.0003	< 0.05	0.0412	1.46	< 0.00005	< 0.000002	0.0002	0.0018
VR	11-Dec-08	10.9	0.000028	0.04	0.000602	2	0.00256	0.00015	0.38	< 0.000005	1.57	0.0556	0.000481		0.0025
VR	22-Jan-09	10.5	0.000051	0.085	0.000632	1.82	0.0107	0.00017	0.4		2.18		0.000605	0.0036	0.0048
VR	25-Feb-09	13.2	0.00118	1.82		2.19		0.00174	0.54	0.00002	1.43	0.0717	0.00619	0.0273	0.0045
VR	20-May-09	7.41	0.000079	0.129	0.00127	1.41	0.00727	0.00049	0.6	0.000008	1.15	0.039	0.000739	0.0042	0.0035
VR	23-Jun-09	7.35	0.000175	0.075	0.000277	1.6	0.00578	0.00041	0.31	0.000009	1.96	0.0359	0.000476	0.0034	0.0039
VR	30-Jul-09	10.2	0.000046	0.057	0.000507	1.73	0.0056	0.00023	0.35		1.53		0.000517	0.0014	0.0015
VR	25-Aug-09	9.17	0.000021	0.027	0.00007	1.78			0.32	< 0.000005	1.58	0.0481	0.000406	0.0012	0.001
VR	30-Sep-09	8.56	0.000021	0.02	0.000272	1.61	0.00155	0.00029	0.31	< 0.000005	1.47	0.0447	0.000355	0.0037	0.0023
VR	21-Oct-09	9.38	0.000014	0.021	0.000156	1.78	0.00096	0.00018	0.32	< 0.000005	1.51		0.000374	0.0017	0.0014
VR	24-Nov-09	10.4	0.000018	0.022		1.98		0.00024	0.34	< 0.000005	1.56	0.055	0.000439	0.002	0.0017
VR	21-Jan-10	12.6	0.000097	0.176	0.00204	2.42	0.0267	0.00045	0.52	< 0.000005	1.83	0.0643	0.000789	0.0153	0.0124
VR	24-Feb-10	13.8	0.000869	1.31	0.0125	2.52	0.212	0.0016	0.79	0.000026	2.18	0.0685	0.00559	0.0309	0.011
VR	30-Mar-10	13.6	0.000274	0.438	0.0026	2.55	0.0469	0.00067	0.57	0.000024	1.78	0.0693	0.00164	0.0108	0.004
VR	3-Nov-10	10.5	0.000017	0.018	0.000083	2.12	0.00135	0.00016	0.34	< 0.000005	1.73	0.0569	0.000457	0.0012	0.0008
VR	18-May-11	5.62	0.000095	0.175	0.00102	1.04	0.0165	0.0006	1.31	0.000011	0.59	0.029	0.000554	0.0124	0.0135
VR	30-May-12	5.9	0.0000833	0.117	0.000584	1.08		0.000455	0.575	0.0000131	1.07	0.0332	0.000727	0.00243	0.00317
VR	30-Aug-12	8.71	0.000017	0.0217	0.000051	1.66	0.000924	0.000196	0.339	< 0.000005	1.51	0.0455	0.000317	0.00074	0.00052
VR	23-Oct-12														
USFR	24-May-08	4.98	0.000144	0.44	0.000719	0.7	0.0445	0.00052		0.000006		0.0293	0.000871	0.0089	

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Non-metals												Metals	
		Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
	Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
USFR	19-Aug-08	17	< 0.01		21.5	< 0.02	3.7			4.4	50	< 1		0.000009	0.000007
USFR	3-Nov-10		0.015	30.2	30.8	0.04			7.39	7.2	58	< 4		< 0.000005	< 0.000005
USFR	18-May-11	16	0.034		20.3	< 0.02	26.8	27.8	7.03	5	32	11		0.000071	0.00006
USFR	30-May-12	14.5	0.012		16.8	0.0183				2.5	24		2.25	0.0000235	0.0000115
USFR	30-Aug-12				22.6									< 0.000005	< 0.000005
USFR	24-Oct-12	26.3	0.016			0.0157		1.63		7.38	42	< 1			
R7	8-Jan-08		0.01		119				7.9	9.67		< 1		< 0.0002	< 0.0002
R7	19-Feb-08		0.01		132				8.1	8.99		< 1		< 0.0002	< 0.0002
R7	18-Mar-08		< 0.01		139				7.5	9.94		< 1		< 0.0002	< 0.0002
R7	14-Apr-08		0.02		141				7.7	10.4		< 1		< 0.0002	< 0.0002
R7	15-May-08		0.03		40				8.8	2.2		3		< 0.0002	< 0.0002
R7	25-May-08	17	0.15		25.2	< 0.02	9.6	10.4		< 0.5	52	33		0.000071	
R7	17-Jun-08		0.02		69				8.2	5.76		4		< 0.0002	< 0.0002
R7	15-Jul-08		< 0.01		47				7.8	4.18		43		< 0.0002	< 0.0002
R7	22-Jul-08	58	< 0.01		63.6					6.9				0.000009	0.000007
R7	12-Aug-08		0.01		76				7.6	6.52				< 0.0002	< 0.0002
R7	21-Aug-08	78	< 0.01		80.1	< 0.02	3.7			6.6	98	< 1		0.00001	
R7	4-Sep-08	68	0.04		70.3					7.2		4		0.000017	0.000016
R7	15-Sep-08		0.02		58				7.3	6.76		1		< 0.0002	< 0.0002
R7	15-Oct-08		0.02		79				7.6	7.72		< 1		< 0.0002	
R7	4-Nov-08		0.02		99				8.2	8.48				< 0.0002	< 0.0002
R7	2-Dec-08		0.02		116				7.8	8.96		3		< 0.0002	
R7	13-Jan-09		0.01		131				7.5	10.4		< 1		< 0.0002	
R7	3-Feb-09		0.03		129				7.7	10.8				< 0.0002	< 0.0002
R7	4-Mar-09	130	0.09	226	136		1.4	1.5	8.3	17	160	< 1		0.000007	0.000006
R7	7-Apr-09	140	< 0.01	150.3	136		1.6	1.1		17	170	< 1		0.000006	0.000009
R7	5-May-09	26	0.02	48	29.1		21.8	21.3		< 0.5	54	5		0.000073	0.000059
R7	10-Jun-09	44	< 0.005	85	44.7		3.9	3.7	7.3		60	6			< 0.000005
R7	14-Jul-09	80	0.02	155	80.1		3.2		7.7	8.7	84	< 1		0.000051	0.000061
R7	6-Aug-09	97	< 0.01	182	98		1.8	2.2	7.5	7.6	110			0.000007	0.000045
R7	2-Sep-09	74	< 0.01	110	74.1		2.8	2.8	8.2	6.5	90	< 1		0.000011	
R7	4-Oct-09	82	< 0.01	110	81.8		1.7		8	6	92	< 4		0.000008	0.000006
R7	4-Nov-09			194	108		2.6	2.4	7.54	7.3	120			0.00002	0.00002
R7	2-Dec-09	110		215	129		1.8	1.7		9.6	130			0.000012	0.00001
R7	11-Jan-10		0.02	235	131		0.7	0.9	7.21	11	130	< 1		0.00001	< 0.000005
R7	23-Feb-10		< 0.01	260	138		0.8	0.9	7.95	9.7	160	< 1		< 0.000005	< 0.000005
R7	10-Mar-10	130	< 0.01	239	140		1.1	1.3	7.78	9.7	190	< 1		< 0.000005	< 0.000005
R7	11-Apr-10	140	< 0.01	240	139				7.78	9.9	150	< 1		< 0.000005	0.000009
R7	3-May-10		0.014	91	56.3		16	13.4	7.66	0.3	68	4		0.000034	0.000027
R7	5-Jun-10	52	< 0.05	97	55.2			2.9	7.85	4.5	62	4		0.000012	0.000019
R7	8-Jul-10	64	< 0.05	123			3.5	4	8.04	6.4	76	2		0.000012	0.00002
R7	3-Aug-10	91	< 0.05	183	86			2.2	7.37	6.3	100	< 1		< 0.000005	0.000009
R7	1-Sep-10		0.12	186	87.6	< 0.02	3	2.7	7.84	7.5		< 1	0.9	< 0.000005	0.000021
R7	19-Oct-10	96	0.026		103	0.07	2.5	1.6	7.2	8.1		< 1	1	0.000008	0.000017
R7	10-Nov-10	110	< 0.005	215	118	0.09	1.4	1.5	7.9	10	120	< 1	0.66	0.000009	0.000013
R7	1-Dec-10	120	< 0.05	100	123	0.09	0.9	0.8	7.12	10	120	< 4	1	0.00001	0.000006
R7	20-Jan-11	130	< 0.05	292	149	0.15	1	0.9	7.64	10	150	< 1	0.69	0.00001	< 0.000005
R7	15-Feb-11	130	0.018	285	123	0.16	1.1	1.1	8.01		140	< 1	0.58	0.000009	0.000007

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Metals													
		Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
USFR	19-Aug-08	6.81	0.00003	0.119	0.000108	1.1	0.00728	0.00033	0.23		1.49	0.0422			0.0017
USFR	3-Nov-10	9.61	0.000028	0.087	0.000032	1.64	0.011	0.00016	0.32	< 0.000005	1.86	0.0598	0.000464	0.0003	0.001
USFR	18-May-11	6.07	0.000208	0.474	0.000396	1.24	0.0939		2.08	< 0.000005	0.73	0.0345	0.000819	0.0062	0.0085
USFR	30-May-12	5.24	0.0000766	0.295	0.000215	0.894	0.0353	0.000402		0.0000061	1.12	0.0365			0.00085
USFR	30-Aug-12	7.22	0.000022	0.119	0.000057	1.1	0.00925	0.000901	0.26	< 0.000005	1.41	0.0422	0.000352	0.00041	0.00033
USFR	24-Oct-12														
R7	8-Jan-08	36	< 0.001	0.11	< 0.001	7.14	0.008	< 0.001	0.9	< 0.00025	2.66	0.14	0.0018	0.008	< 0.005
R7	19-Feb-08	39.2	< 0.001	< 0.05	0.0005	8.12	0.009	< 0.001	0.8	< 0.00025	3.21	0.17	0.0015	< 0.005	< 0.005
R7	18-Mar-08	40.1	< 0.001	0.05	< 0.001	9.39	0.006	< 0.001	1.1	< 0.00025	3.81	0.17	0.0025	< 0.005	< 0.005
R7	14-Apr-08	42.5	< 0.001	< 0.05	< 0.001	8.37	0.006	< 0.001	1.1	< 0.00025	3.42	0.18	0.0026	< 0.005	< 0.005
R7	15-May-08	12	< 0.001	0.47	< 0.001	2.33	0.038	0.001	1.5	< 0.00025	1.05	0.051	0.0005	0.014	< 0.005
R7	25-May-08	7.87	0.000316	0.89	0.000954	1.34	0.0752	0.00124	0.93	0.000012	0.71	0.0385	0.000385	0.01	
R7	17-Jun-08	19.5	< 0.001	0.18	< 0.001	4.87	0.015	< 0.001	0.6	< 0.00025	1.69	0.071	0.0007	0.008	0.005
R7	15-Jul-08	14.1	< 0.001	0.98	0.001	2.86	0.033	0.002	0.5	0.0004	1.28	0.057	0.0005	0.012	< 0.005
R7	22-Jul-08	18.9	0.000047	0.114			0.0147	0.00038	0.34	< 0.000005	1.37	0.0687	0.000638	0.0008	0.0006
R7	12-Aug-08	22.8	< 0.001	0.22	0.002	4.65	0.021	< 0.001	0.5	< 0.00025	1.78	0.084	0.0007	< 0.005	0.006
R7	21-Aug-08	23.9	0.000038	0.152	0.0003	5	0.0166	0.00039	0.5	< 0.000005	2.04	0.0977	0.000962	0.0016	0.0043
R7	4-Sep-08	21.1	0.000061	0.166	0.00009	4.26	0.0169	0.00038	0.46		1.64	0.0813	0.000794	0.0008	0.0012
R7	15-Sep-08	17.5	< 0.001	0.22	0.003		0.019	< 0.001	0.4	< 0.00025	1.59	0.084	0.0009	< 0.005	< 0.005
R7	15-Oct-08	24.3	< 0.001	0.05	< 0.001	4.49		< 0.001	0.5	< 0.00025	1.67	0.095	0.001	< 0.005	< 0.005
R7	4-Nov-08	29.7	< 0.001	< 0.05	0.0005		0.015	< 0.001	0.7	< 0.00025	2.22	0.12	0.0013	< 0.005	< 0.005
R7	2-Dec-08	35.3	< 0.001	0.09	< 0.001	6.74		< 0.001	0.9	< 0.00025	2.67	0.13	0.0017	0.014	0.013
R7	13-Jan-09	39.3	< 0.001	0.12	< 0.001	8.06	0.017	< 0.001	0.9	< 0.00025	2.86	0.16	0.0024	< 0.005	< 0.005
R7	3-Feb-09	38.6	< 0.001	0.2	< 0.001		0.018	< 0.001	0.9	< 0.00025	2.98	0.18	0.0021	< 0.005	< 0.005
R7	4-Mar-09	41.4	0.000017	0.088	0.000052	7.97	0.0118	0.00017	0.96	< 0.000005	3.1	0.177	0.00261	0.0007	0.0004
R7	7-Apr-09	41.3	0.000016	0.075	0.000022	8.03	0.0101	0.00019	0.99	< 0.000005	3.09	0.178	0.00276	0.0017	0.0006
R7	5-May-09	8.3	0.000108	0.432	0.001	1.66	0.0369	0.00089	1.75		0.66	0.0368		0.0092	
R7	10-Jun-09	12.8	0.000041	0.117		2.68	0.0113	0.00029	0.43	< 0.000005	0.99	0.0498	0.000546	0.0015	0.0011
R7	14-Jul-09	23.3	0.000047	0.14	0.00201	5.05	0.0182	0.00033	0.58	< 0.000005	1.82	0.0874	0.00095	0.0104	0.0109
R7	6-Aug-09	29.5	0.000021	0.127	0.0001	5.89	0.0108	0.00022	0.61	< 0.000005	2.07	0.123	0.00132	0.0007	0.0042
R7	2-Sep-09	20.6	0.000046	0.176	0.0003	3.86	0.0185	0.00023	0.44	< 0.000005	1.69	0.0913	0.000842	0.001	0.0007
R7	4-Oct-09	23.7	0.000043	0.216	0.000261	4.66	0.0263	0.00025	0.51	< 0.000005	2.01		0.00113	0.0023	0.0042
R7	4-Nov-09	33.7	0.000039	0.148	0.00183	5.88	0.0207	0.00047	0.82	< 0.000005		0.129	0.00153	0.0048	0.004
R7	2-Dec-09	34.7	0.000022	0.12	0.000086	6.55	0.0164	0.0002	0.76	< 0.000005		0.149	0.00193	0.0012	0.0013
R7	11-Jan-10	39.6	0.000021	0.091	0.000058	7.81	0.0149	0.00018	0.93	< 0.000005	3.05	0.161	0.00226	0.0006	0.0004
R7	23-Feb-10		0.000011	0.079	0.00001	8.31	0.0101	0.00015	0.95		3.27		0.00262	0.0003	
R7	10-Mar-10	41.2	0.000016	0.082	0.00005	8.09	0.00987	0.00017	0.96	< 0.000005	3.23	0.175	0.00279	0.0004	0.0003
R7	11-Apr-10	42.4	0.000014	0.028	0.000079	8.06	0.00749	0.00018	1.04	< 0.000005	3.3	0.177	0.00282	0.0008	0.0011
R7	3-May-10	16.5	0.000097	0.409	0.000517		0.0399	0.00108	1.3	< 0.000005		0.0724	0.000736	0.004	0.0053
R7	5-Jun-10	16.1	0.00005	0.168	0.00033	3.44	0.0151	0.00044	0.52	< 0.000005		0.0637		0.0029	0.0044
R7	8-Jul-10	16.8	0.00005	0.142	0.000592	4.01	0.0164	0.0004	0.41	< 0.000005	1.61	0.0791	0.000714	0.002	0.0052
R7	3-Aug-10	25.4	0.000026	0.168	0.000391	5.52	0.0134	0.00028	0.56	< 0.000005	2.01	0.107	0.0011	0.0019	0.0021
R7	1-Sep-10	26.5		0.208	0.000105	5.22		0.00025	0.54	< 0.000005	2.02	0.109	0.00107	0.0006	0.0197
R7	19-Oct-10	29.6	0.000034	0.181	0.000281	6.04	0.0196	0.00028	0.64		2.3	0.127		0.0016	0.0072
R7	10-Nov-10	35.4		0.124	0.000454	7.2	0.0173		0.79	< 0.000005	2.74	0.146	0.00171	0.006	0.0213
R7	1-Dec-10	36.9	0.000024	0.145	0.000056	7.2	0.0181	0.00019	0.82	< 0.000005	2.73		0.00183	0.0009	0.0029
R7	20-Jan-11	39.6	0.000022	0.097	0.000545	7.68	0.0112		0.97	< 0.000005	2.83	0.188	0.00251	0.0049	0.0013
R7	15-Feb-11	35.8	0.000036	0.092	0.000272	8.15	0.0101	0.00023		< 0.000005	3.15	0.176	0.00249		0.0021

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Non-metals												Metals	
		Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
	Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
R7	16-Mar-11	140	0.021	281	139	0.19	1.4	1	7.73		170	< 1	0.48	0.000014	
R7	12-Apr-11			284	144	0.18	2.5	2.8	8.03	9.2	150		0.53	0.000018	0.000009
R7	9-May-11	95	0.062	217	85.2	0.07	12.1	9.3	7.8	4.2	130	2	2.17	0.000029	0.000021
R7	22-Jun-11	43	0.038	94	46.5		5.4	5.3	7.98		64	6	1.16	0.000014	0.000014
R7	21-Jul-11	59	0.035	123	63.8	< 0.02	5.3	4.7	8.83	6	90	2	0.54	0.00001	
R7	24-Aug-11	68	0.039	140	71.6	< 0.02		3.2	7.6	8.9	86	2	0.34	0.000006	0.000097
R7	22-Sep-11	78	0.037	192	82.1	< 0.02	2.5	1.7	7.52	11	130	< 1	0.63	0.00001	0.000012
R7	19-Oct-11	93		170	101	0.06	1.5	1.9	7.89	8.7		< 1	0.65	0.000015	0.000009
R7	15-Nov-11	105	0.014	220	103	0.124	2.6	2.29	7.36	9.63	116	< 1	0.61	0.000015	0.000019
R7	6-Dec-11	107	0.033	223	110	0.113	2.04	1.46		9.23	120	< 1	1.01	< 0.000005	0.000013
R7	11-Jan-12	114	0.022		112		1.83	1.27	8.25	9.61	130	< 1	0.83	< 0.000005	< 0.000005
R7	14-Feb-12	125	0.021	266	136	0.166	1.64	1.99		8.92	146	< 1	0.87	0.000008	0.000013
R7	6-Mar-12		0.023	241	140	0.18	1.53	1.1	7.84	8.52	146	< 1	1.14	0.00001	0.000007
R7	19-Apr-12			274					7.92				1.08		
R7	17-May-12	83.4	0.03	173	84.8	0.055	7.73	8.37	7.92	2.92	118	2.3		0.0000268	0.0000215
R7	31-May-12	34.7	< 0.005		37.9	0.0089	9.04			2.95	66	7		0.0000254	< 0.0000172
R7	13-Jun-12	39.9	0.012	40	40.9	< 0.02	5.16		7.45	5	60	17.3		0.0000281	0.0000102
R7	11-Jul-12	47.7	0.034	184	53.1	< 0.02	5.37	5.93	7.88	4.06	70	7.4	1.24	0.0000145	0.0000199
R7	8-Aug-12	82.4		140	87.7	< 0.02	3.34	2.78	7.9	7.42	94	< 1	0.56	0.000007	0.000014
R7	6-Sep-12			196	83.8	< 0.02	2.93	2.43	7.72	7.3	110	< 1	0.69	< 0.000005	< 0.000005
R7	20-Sep-12	79.1	< 0.005		86.3	0.005	3.09			7.39	106	1.3		0.000011	< 0.000026
R7	11-Oct-12				85.7	0.053	2.43	2.13	7.9	8.8	126	< 1	0.44	0.000007	0.00003
R7	6-Nov-12		0.018	279	114	0.1	1.19	1.06	7.82	9.54	132	1.3	0.7	0.000011	0.000006
R7	5-Dec-12		0.017	243	134	0.167	1.6	1.9	7.78	10.1	138	< 1	0.68	0.000006	< 0.000005
FC	24-Jan-08	18	< 0.005	74.2	16.7	0.06	1.1	1		1.7	52	< 1			0.000014
FC	21-Feb-08	23	< 0.005	487	17.7	0.08	0.7	< 0.5	7.15	2.4	44	< 1		0.00001	0.000007
FC	11-Mar-08	23	< 0.005	53.3	18.7	0.08	0.9		6.1	2	76	< 1			0.000006
FC	29-Apr-08	24	< 0.005	55	20.4	0.09	1.2	1.2	7.34	2.7	44	< 1		0.000014	0.000011
FC	22-May-08	7.1	< 0.005	23.8	10.1	< 0.02	11.3		6.49	< 0.5	48	3		0.000071	0.000067
FC	25-Jun-08	5.1	< 0.005	27.2	8.2	< 0.02	5	5.2	6.55	< 0.5	16	< 1		0.000019	0.000011
FC	30-Jul-08	13	< 0.005	35.6	11.7	< 0.02	4.2	3.8	6.84	0.6	32	< 1		0.000027	0.000025
FC	22-Aug-08	11	0.02		12.5	< 0.02	3.9			0.9		5		0.000016	
FC	18-Sep-08	9.1	< 0.005	28.9	9.8	< 0.02	3.8	3.8	6.26	0.8	50	2		0.000011	0.000015
FC	7-Oct-08	9.4	< 0.005	30.9	9.7	< 0.02	2.6	2.5	7.52	2.2	22	3		0.000009	0.000009
FC	11-Dec-08	16	< 0.005	103	14.6	0.03	1.5	1.5		1.5	22	1		0.000031	0.000007
FC	22-Jan-09	21	< 0.005		15.9						30	< 1		0.000014	0.00001
FC	25-Feb-09	22			18.1	0.08				2.5	42	< 1		0.000012	
FC	27-Mar-09	24	0.034		19.1	0.1				3		< 1		0.000006	0.000012
FC	20-May-09	9.5	< 0.005	87.3	11	< 0.02			6.61	< 0.5	24	2		0.000062	0.000062
FC	23-Jun-09	10	< 0.005	80.2	11.1	< 0.02			7.97		20	1		0.000013	0.000039
FC	30-Jul-09	20	0.007	21	16.4	< 0.02			7.32	< 0.5	40	< 1		0.000012	
FC	25-Aug-09	17	< 0.005	43	16.3	< 0.02			8.16	0.7		< 1		0.000023	0.000018
FC	30-Sep-09	14	< 0.005	391	12.3	< 0.02			7.8	2.3	30	< 1		0.000017	0.000036
FC	21-Oct-09	16	< 0.005		12.8	< 0.02				1.7	38	< 1		0.000012	0.000013
FC	24-Nov-09	16	< 0.005	25.5	14.5					2.3				< 0.000005	< 0.000005
FC	21-Jan-10	21	< 0.005	24.7	17.7	0.06				2	42	< 1		0.000008	0.000007
FC	24-Feb-10	21	0.009	25.5	18.5	0.06			8.08	1.5	42	< 1		0.000008	0.000008
FC	30-Mar-10	25	0.013	24.6	18.8	0.08			8.18	2	26	11		0.000025	0.000011

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Metals													
		Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
R7	16-Mar-11	41		0.074	0.000645	8.87	0.00938		1.12	< 0.000005	3.55	0.194		0.0068	0.0065
R7	12-Apr-11	40.4	0.000021	0.208	0.00114	8.03	0.00696	0.00034	1.03	< 0.000005	3.14	0.177	0.00271	0.0023	0.003
R7	9-May-11		0.000048	0.453	0.000264	5.43	0.0231	0.0006	1.54	< 0.000005	2.04	0.117	0.00127	0.0025	0.0103
R7	22-Jun-11	13.9	0.000066	0.186	0.000242	2.85	0.0166	0.00069	0.36	< 0.000005	1.18		0.00045	0.0011	0.0023
R7	21-Jul-11	19.3	0.000046			3.78	0.0171	0.0004	0.33	< 0.000005	1.43	0.0696	0.000532	0.0016	0.0116
R7	24-Aug-11		0.000037	0.145	0.000165	4.09	0.0179	0.00043	0.4		1.53		0.000683	0.0018	
R7	22-Sep-11	24.8	0.000045	0.16	0.000102	4.94	0.0206	0.00031	0.58	< 0.000005	1.82	0.097	0.000981		0.0011
R7	19-Oct-11	28.1	0.000056	0.177	0.000834	5.83	0.0252	0.00028	0.61	0.000036	2.29	0.118	0.00151	0.0103	0.0017
R7	15-Nov-11	30.1			0.000373		0.0167	0.0003	0.78	< 0.000005		0.141	0.0017	0.0034	0.0042
R7	6-Dec-11	33.3		0.176	0.00004	6.45	0.0181	0.00019		< 0.000005	2.46	0.137	0.00181	0.0004	0.0061
R7	11-Jan-12		0.000022	0.149	0.000045	7.23	0.0122	0.00018	0.82	< 0.000005	2.74	0.155	0.002	0.0003	0.0036
R7	14-Feb-12	40.2	0.000018	0.116		7.46	0.0113	0.00021	0.99	< 0.000005	2.96	0.163	0.00209	0.0013	0.0035
R7	6-Mar-12	39.6	0.000028	0.111	0.00016	7.85		0.00044		< 0.000005		0.168	0.00229	0.0022	0.0022
R7	19-Apr-12														
R7	17-May-12	26	0.0000627	0.43	0.000757	4.84	0.021	0.000989	1.28	< 0.000005	1.97	0.105	0.0012	0.00625	0.00633
R7	31-May-12	11.8	0.00011	0.354	0.000246	2.11	0.0258	0.000719	0.957	0.0000052	0.998	0.0462	0.000367	0.00457	< 0.00454
R7	13-Jun-12	11.9	0.000144	0.329	0.000372		0.027	0.000585	0.545	0.0000064		0.0491	0.000401	0.00231	0.00072
R7	11-Jul-12	15.5	0.0000955	0.219	0.000352	3.31	0.0195	0.000598	0.325	< 0.000005	1.37	0.0607	0.000476	0.0033	0.00641
R7	8-Aug-12	26.4	0.000038	0.185	0.000041		0.0225	0.000254	0.495	< 0.000005	1.85		0.000979	0.00036	0.00897
R7	6-Sep-12	25.3	0.000037	0.176	0.000063	5.01	0.0238	0.000296	0.611	< 0.000005	2.05	0.0985	0.000977		0.00109
R7	20-Sep-12	24.5	< 0.0001	0.204	0.000487	4.76	0.026	< 0.0005	0.545	< 0.00001	1.92	0.0972	0.001	< 0.003	< 0.0328
R7	11-Oct-12	25.3	0.000036	0.14	0.000314	5.15	0.0244	0.000253	0.605		1.98	0.104	0.00122	0.00202	0.0297
R7	6-Nov-12	34.7	0.000063	0.187	0.000135		0.0275	0.000385	0.745	< 0.000005		0.139	0.00176	0.00191	0.00108
R7	5-Dec-12	40.6	0.000021	0.1	0.000034	7.85	0.0199	0.000242	0.914	< 0.000005	2.8	0.161	0.00211	0.00176	0.00146
FC	24-Jan-08	5.03	0.000015	0.021			0.00062	0.0002	0.2	< 0.000005	2.23	0.031	0.000071	0.0018	0.0032
FC	21-Feb-08	5.29	0.000015	0.023	0.000097	1.08	0.00115	0.00015	0.21	< 0.000005	2.39		0.000064	0.0015	0.0021
FC	11-Mar-08	5.64	0.000012	0.017		1.12	0.00085	0.00017	0.21	< 0.000005	2.43	0.0342	0.000063	0.0045	0.0055
FC	29-Apr-08	6.02	0.000017	0.018	0.000201	1.29	0.0013	0.00018	0.25	< 0.000005		0.0366	0.000065	0.0053	0.006
FC	22-May-08	3.05	0.000098		0.00195	0.6	0.00999	0.00074	1.11	0.000012	< 0.05	0.019	0.000264	0.0194	0.0182
FC	25-Jun-08	2.47	0.000038	0.055	0.000215	0.49	0.00141	0.00041	0.15	< 0.000005	1.27	0.0168		0.0032	0.0035
FC	30-Jul-08	3.51	0.000051	0.062	0.000403	0.71	0.00238	0.00047	0.12	< 0.000005	2.46	0.0229	0.000192	0.005	0.005
FC	22-Aug-08	3.7	0.000084	0.139	0.000849	0.79	0.00436	0.00051	0.12	< 0.000005		0.0226	0.000195	0.0035	
FC	18-Sep-08	2.95	0.000055	0.096	0.000404	0.59	0.00246	0.00036		< 0.000005	1.5	0.02		0.0025	
FC	7-Oct-08	2.91	0.000044	0.065	0.000324	0.59	0.00208	0.00031	< 0.05	0.000005	1.45	0.0191	< 0.000002	0.0001	0.0025
FC	11-Dec-08	4.35	0.000017	0.032	0.000176	0.91	0.00069	0.00022	0.15	< 0.000005	1.85	0.0271	0.0001	0.0025	0.0031
FC	22-Jan-09	4.84	0.000014	0.022	0.000149	0.93	0.00118	0.00019	0.19	0.000005	2.88	0.0299	0.000081	0.0034	0.004
FC	25-Feb-09	5.44	0.000014	0.02	0.000102	1.09	0.00098	0.00016	0.2	< 0.000005	1.99	0.0344	0.000069	0.0019	0.0019
FC	27-Mar-09	5.61	0.000016	0.015	0.000061	1.23	0.00088	0.00015	0.22	< 0.000005	2.27	0.034	0.000064	0.0011	0.0022
FC	20-May-09	3.31	0.000056		0.00164	0.66	0.00477	0.00067	0.83	0.000005	1.0	0.0211	0.000259	0.014	0.0148
FC	23-Jun-09	3.11	0.000042	0.077	0.0003	0.81	0.00239	0.00045	0.17	< 0.000005	1.76	0.0207	0.000224		0.0048
FC	30-Jul-09	5.03	0.000018	0.029	0.000539	0.94	0.00116	0.00022		< 0.000005	2.05	0.0299	0.000103	0.0015	0.003
FC	25-Aug-09	4.79	0.000045	0.082	0.00236	1.05	0.0029	0.00054	0.18	< 0.000005	2.1	0.03	0.000181	0.0033	0.0031
FC	30-Sep-09	3.68	0.000026	0.049	0.000287	0.76	0.00205	0.00036	0.12		1.67	0.0235	0.000144	0.0024	
FC	21-Oct-09	3.83	0.000025	0.031	0.000068	0.8	0.00093		0.12	< 0.000005	1.71	0.0236	0.00011	0.0014	0.002
FC	24-Nov-09		0.000021	0.035	0.000159	0.89	0.00083	0.00034	0.14	< 0.000005	1.89	0.0269	0.000098	0.0016	0.0021
FC	21-Jan-10	5.28	0.000016	0.02	0.000076	1.1	0.00062	0.0002	0.18	< 0.000005	2.2	0.0306	0.000072	0.0012	0.0017
FC	24-Feb-10	5.22		0.044	0.00211	1.11	0.00257	0.00019		< 0.000005	2.22	0.0304	0.000083	0.0016	0.0017
FC	30-Mar-10	5.53	0.000099	0.469	0.00173	1.21	0.0111	0.00028	0.22	< 0.000005	2.33		0.000175	0.0071	0.0025

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Non-metals												Metals	
		Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
	Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
FC	19-May-10	9.1	< 0.005	10.6	8.7	< 0.02			7.47	< 0.5	16	6		0.000045	
FC	3-Aug-10		< 0.005	31.8	16.8	< 0.02			7.39	1.5	30	< 1		0.00001	
FC	3-Nov-10		0.013	22.3	15.7	< 0.02			7.5	1.7	36	< 4		0.000011	0.00001
FC	18-May-11	10	0.03		14.2	< 0.02	20.7	22.9	6.68	< 0.5	28	< 1	0.86	0.00012	0.000112
FC	30-May-12	7	0.0095		9.91	0.0048		10.8			32	10.9	4.54	0.0000706	0.0000505
FC	28-Aug-12				13.6										0.000016
FC	24-Oct-12	16.4	0.013			0.0115		2.38		1.51			0.45		
R6	23-Jan-08	140	< 0.005	272	167	0.22	1	1	6.8	23.3	200	< 1		0.000013	0.000014
R6	20-Feb-08	150	< 0.005	355	159	0.2	1.1	1.4	7.6	23	180	1		0.000013	0.000007
R6	4-Mar-08	159	< 0.01		186				7.8	21.4		< 1	0.64	< 0.0002	< 0.0002
R6	13-Mar-08	150	< 0.005	214	167	0.2	0.8	0.7	6.43	21.7	220	< 1		0.000007	0.000017
R6	28-Apr-08	130	< 0.005		147	0.14	1.1	1.2	7.96	20	180	1		0.000013	0.000049
R6	21-May-08	49	< 0.005	118.2	60.3	0.03	12.2	13	7.91	< 0.5	110	20		0.000074	0.000044
R6	24-Jun-08	68	< 0.005		75.2	0.02	6.4	7	7.44	10	110	27		0.000052	0.000084
R6	22-Jul-08	99	< 0.01		115					17		5		0.000023	0.000014
R6	29-Jul-08	120	< 0.005	260	124	0.11	3.4	3.2	8.34	18	180	2		0.000015	0.000013
R6	19-Aug-08	151	0.01		146				8	18.8			0.37	< 0.0002	< 0.0002
R6	4-Sep-08	110	< 0.01		129					19		3		0.000019	
R6	17-Sep-08	120	< 0.005	270	128	0.09	4.3	3.5	7.79	21	170	2		0.00002	0.000007
R6	8-Oct-08	130	< 0.005	281	144	0.1	1	1.9	8.35	21	160	< 1		0.000016	0.000016
R6	10-Dec-08	150	< 0.005	414	172	0.2	1.8	1.5	7.38	24	210	3		0.000017	
R6	22-Jan-09	150	0.006		164	0.17				24		2		0.000017	0.000017
R6	24-Feb-09	150	0.007		251	0.24					300	< 1		0.000015	0.00001
R6	26-Mar-09	160		296	166	0.22			7.2	25	200	< 1		0.000059	0.000045
R6	20-May-09	88	< 0.005	512	92.6	0.06			7.51	13	110	13			0.000045
R6	23-Jun-09	110	< 0.005	620	109	0.05			7.93	15	130	12		0.000017	0.000669
R6	30-Jul-09	140	0.006	289	156	< 0.02			8.3		170	7		0.000009	0.000009
R6	25-Aug-09	120	< 0.005	252	135	0.04			8.39	16	130	2		0.000089	0.000023
R6	30-Sep-09	120	< 0.005	186.5	133	0.14			8.21	19		< 1		0.000014	0.000014
R6	28-Oct-09	140	< 0.005		157	0.16				21	160	1		0.000032	0.000018
R6	24-Nov-09	150	0.008	4.4	161	0.19			8.05	24	170			0.000034	0.000009
R6	21-Jan-10	150	0.007	178.4	168	0.22				22	200	1		0.000012	< 0.000005
R6	26-Feb-10	150	< 0.005	179.6	160	0.22			8.13	23	200	< 1		0.000008	0.000008
R6	30-Mar-10	150	< 0.005	178	165	0.21			8.34	24	170	< 1		0.000014	0.000036
R6	19-May-10	79	0.023	113	97.4	0.05			7.93	14	120	62		0.000152	
R6	3-Aug-10	160	< 0.005	211	153	0.02			8.46	21	170	< 1		0.000017	
R6	4-Nov-10		0.012	168.7	159	0.16			7.99	22	170	< 4		0.000007	0.000009
R6	19-May-11	43	0.025		47.5	0.04	22.2	22.9	7.5	< 0.5	74	85	6.2	0.000236	0.000055
R6	29-May-12	61.7				0.0518		10.2		8.74	98	8.4	3.4	0.0000615	0.0000283
R6	29-Aug-12				141									0.000015	0.000011
R6	23-Oct-12	147	0.03			0.175		2.17		22.7	192	< 1	0.52		
W10	21-May-08	17	< 0.005	46.8	23.1	< 0.02	11.4	12.1	7.08	< 0.5	44	3		0.000072	0.000077
W10	1-Jun-08		< 0.01		24				7.6	2.97		< 1		< 0.0002	< 0.0002
W10	24-Jun-08	34	< 0.005	86.6	36.7	< 0.02	4.5	4.6	7.46	1.1	66	2		0.000017	0.000025
W10	30-Jul-08	49	< 0.005	123.8	44.9	< 0.02	4.6	4.4	7.41	3.3	66	< 1		0.000021	0.000023
W10	17-Sep-08	45	< 0.005		45	< 0.02	4.9	4.2	7.14	3.9	88	< 1		0.000022	0.000012
W10	29-Sep-08		0.04		49				7.1	3.96		2			< 0.0002
W10	8-Oct-08	48	< 0.005	113.8		< 0.02	3.2	3.4		4.8	74	< 1		0.000048	0.000014

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Metals													
		Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
FC	19-May-10	2.62	0.000105	0.249	0.00105		0.0116	0.00058	0.56	< 0.000005	0.97	0.0173	0.000325	0.0076	
FC	3-Aug-10	5	0.000026	0.04	0.000504	1.05		0.00032	0.16	< 0.000005	2.1	0.0323	0.000115	0.0014	
FC	3-Nov-10	4.56	0.000016	0.021	0.000105			0.00024	0.14	< 0.000005	2.25	0.0293	0.00008	0.0022	0.0017
FC	18-May-11	4.18	0.000123	0.166	0.00252	0.92	0.0145	0.00086	1.36	0.000015	1.22	0.0282	0.000163	0.0304	0.0301
FC	30-May-12	2.95	0.000157		0.017	0.615	0.00925	0.00086	0.66	0.0000352	1.01	0.0191	0.000242	0.0148	0.0174
FC	28-Aug-12	4.02	0.000046	0.0772			0.00232	0.000467	0.156	< 0.000005	1.8	0.025	0.000149	0.00196	0.00194
FC	24-Oct-12														
R6	23-Jan-08	48.3	0.000025	0.117	0.000029	11.3	0.0111	0.00024	1.26	< 0.000005	2.12	0.151	0.00248	0.0008	0.0018
R6	20-Feb-08	46.7	0.000022	0.132	0.000029	10.3	0.00985	0.00022	1.32	< 0.000005	2.22	0.146	0.00244	0.0014	0.0012
R6	4-Mar-08	49.7	< 0.001	0.14		14.9	0.01	< 0.001	1.5	< 0.00025	2.93	0.19	0.0021	< 0.005	< 0.005
R6	13-Mar-08	48.8	0.00002	0.148	0.000054	10.9	0.00945	0.00022	1.33	< 0.000005	2.15	0.148	0.0024	0.0037	0.0054
R6	28-Apr-08	43.1	0.000044	0.281	0.000078	9.63	0.018	0.00022	1.32	< 0.000005	1.94	0.139	0.00225	0.004	0.0058
R6	21-May-08	16.5	0.000264	0.568	0.00048	4.66	0.0398	0.00183	1.39	0.000008	0.75	0.0469	0.000577	0.0053	0.003
R6	24-Jun-08	20.6	0.000231	0.433	0.000575	5.77	0.0342	0.00115	0.69	0.000009	0.97	0.0592	0.00083	0.0034	0.0027
R6	22-Jul-08		0.000064	0.125	0.00009	8.47	0.0128	0.00056	0.76		1.35		0.00117		0.0007
R6	29-Jul-08	34.8	0.000051	0.09	0.000142	9.03	0.0117	0.00042	0.84	< 0.000005	2.18	0.0998	0.00144	0.0015	0.002
R6	19-Aug-08	39	< 0.001	0.2	< 0.001	11.7	0.013	< 0.001		< 0.00025	1.89	0.12	0.0015	< 0.005	< 0.005
R6	4-Sep-08	35.6	0.000055		0.000049	9.7	0.013	0.00052	0.91	< 0.000005	1.63	0.104	0.00145	0.0006	0.0006
R6	17-Sep-08	35.6	0.000049	0.106	0.000057	9.41	0.013	0.00046	0.94	< 0.000005	1.56	0.101	0.00139	0.0006	0.0001
R6	8-Oct-08	39.9	0.000047	0.11	0.000109	10.7	0.0165	0.00041	0.73	0.000005	1.73	0.111	< 0.000002	< 0.0001	0.0016
R6	10-Dec-08	48.8	0.000052	0.134	0.00014	12.3	0.018	0.00034	1.24	< 0.000005	2.01	0.141	0.00235	0.0018	0.0028
R6	22-Jan-09	47.6	0.000039	0.189	0.000174	10.9	0.0189	0.00026	1.23	< 0.000005	2.88	0.148	0.00244	0.0023	0.0043
R6	24-Feb-09	74.6	0.000038	0.037	0.000204	15.8	0.0316	0.00083	1.68		4.9	0.251	0.00238		0.0078
R6	26-Mar-09	48	0.00003	0.177		11.1	0.0123	0.00024	1.29	< 0.000005	2.02	0.15	0.00256	0.0013	0.0007
R6	20-May-09	25.5	0.000166	0.396		7.01	0.0421	0.0011	1.18	< 0.000005	1.06	0.0739	0.00112	0.0023	0.0013
R6	23-Jun-09	30.5	0.000065	0.162	0.000341	8.03	0.0127	0.00058	0.84	< 0.000005	1.54	0.0851	0.00129	0.0026	0.0067
R6	30-Jul-09	44.3	0.000046	0.154	0.000057	11	0.0129	0.0003	1.14	< 0.000005		0.125	0.00197	0.0004	0.0006
R6	25-Aug-09	37.6	0.000059		0.000142	9.91	0.0177	0.00055	1.02	< 0.000005	1.85	0.113	0.00166	0.001	0.0007
R6	30-Sep-09	37.8	0.000045	0.136	0.00003	9.39	0.0184	0.00038	0.98	< 0.000005	1.77	0.113	0.00178	0.0006	0.0023
R6	28-Oct-09	45	0.000037	0.135	0.00177	10.9	0.0182	0.00036	1.15		1.94	0.127	0.00206	0.0017	
R6	24-Nov-09	46.1	0.00003		0.000172	11.2	0.00609	0.00035	1.19	< 0.000005	2.11	0.134	0.00219	0.0027	0.0024
R6	21-Jan-10	49.1	0.000033	0.118	0.000016	11	0.0149	0.00026	1.31	< 0.000005	2.16	0.141	0.00233	0.0006	0.0008
R6	26-Feb-10	46.9	0.000026	0.112	0.000042	10.3	0.0106	0.00024	1.24	< 0.000005	2.02	0.142	0.00241	0.0007	0.0009
R6	30-Mar-10	48	0.000021	0.124	0.000025	11	0.00846	0.00019	1.3	< 0.000005	2.22		0.00261	0.0006	0.0022
R6	19-May-10	26.7	0.000985	2.2	0.00155	7.49	0.149	0.00315	1.16	< 0.000005	1.21	0.0804	0.0014	0.0114	
R6	3-Aug-10	42.9	0.000038	0.169	0.000053	11.3	0.0129	0.0004		< 0.000005	1.84	0.128		0.0003	
R6	4-Nov-10	45.2		0.083	0.000025	11.3		0.00032	1.14	< 0.000005	1.96	0.135	0.00223	0.0004	0.0014
R6	19-May-11	12.8	0.00127	3.15	0.00157	3.8	0.166	0.0046	1.8	0.000037	0.6	0.0418	0.000592	0.015	0.0063
R6	29-May-12	18.5	0.000145	0.369	0.000189	4.99	0.0337	0.00103	1.24	0.0000104	0.806	0.0571	0.000647	0.00208	0.0035
R6	29-Aug-12	38.9	0.000056	0.144	0.000033	10.5	0.0145	0.000579	1.08	< 0.000005	1.73	0.112	0.0015	0.00047	0.00044
R6	23-Oct-12														
W10	21-May-08	7.47	0.000112	0.149	0.00229	1.09	0.0119	0.00072	1.09	0.000018	0.83		0.000122	0.0164	0.0161
W10	1-Jun-08	7.88	< 0.001	< 0.05	< 0.001	1.04	< 0.001	< 0.001	0.4	< 0.00025	1.4	0.027	< 0.0005	< 0.005	< 0.005
W10	24-Jun-08	12.1	0.000027	0.024	0.000155	1.59	0.00035	0.00049	0.41	< 0.000005	1.54	0.0434	0.000114	0.0023	0.0026
W10	30-Jul-08	14.9	0.000025	0.02	0.000344	1.88	0.00046	0.00043	0.39	< 0.000005	2.89	0.0532	0.000126	0.0045	0.0038
W10	17-Sep-08	14.9	0.000025	0.018	0.000085	1.92	0.00035	0.00042	0.45	< 0.000005	1.68	0.0501	0.000113	0.0018	0.0005
W10	29-Sep-08	16	< 0.001	< 0.05	< 0.001	2.14		< 0.001	0.5	< 0.00025	1.95	0.056	< 0.0005	< 0.005	0.015
W10	8-Oct-08	14.9	0.000022	0.017	0.000304	1.98	0.00043	0.00037	0.05	0.0504	1.62	0.0504	< 0.000002	0.0001	0.0026

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Non-metals												Metals	
		Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
	Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
W10	4-May-09	15	0.06	41	21.2		23.5	19.8		< 0.5	40	< 1		0.000166	0.000152
W10	10-Jun-09	33	< 0.005	59	29.6		5.6	5.2	7	1.4	56	< 1		0.000013	0.000014
W10	14-Jul-09	52		100	53.1		3.2	2.9	8.5	6.5	54	7		0.000011	0.000025
W10	3-Sep-09	65	< 0.01		62.5		3.1	3.1	7.96	3.8	72			0.000018	0.00002
W10	5-Oct-09	60	0.03	70	58.6		2.7	2.7	7.4	3.5		< 4		0.000022	0.000058
W10	3-May-10	38	0.038	109	38.9		12.1	11.2	7.71	0.3	50	< 1		0.000064	
W10	5-Jun-10	38		68	35.8		5.2	5	7.76	1.9	60	< 1		0.000025	0.000032
W10	10-Jul-10	52		101	52.4		4.1	4	8.08	1	40	< 1		0.000016	0.000071
W10	19-May-11	16	0.019			< 0.02	30.3	27.8	7.4	< 0.5	46	1	0.67	0.000139	0.000141
W10	30-May-12	22.4	0.013		24.4			9.61		< 0.5	42	12.9	1.43	0.0000495	0.0000315
W10	28-Aug-12				63.4									0.000024	0.000016
W10	24-Oct-12	57.5	0.019			< 0.002		3.08		3.98	80		0.24		
n		209	225	164	237	166	149	151	184	234	202	227	67	212	199
minimum		5.1	<0.005	4.4	8.2	<0.002	<0.5	<0.5	5.23	0.3	16	<1	<0.1	<0.000005	<0.000005
maximum		160	0.36	620	251	0.24	30.3	27.8	9.15	25	300	400	6.2	0.000348	0.000669
median		40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
mean [a]		55.1	0.018	137	64.2	0.06	4.4	4.2	7.65	8.0	82	7	0.77	0.0000256	0.000024
standard deviation (SD) [a]		43.3	0.033	101	48.4	0.06	5.8	5.4	0.56	6.0	50	32	1.02	0.0000396	0.000052
max detection limit		-	0.05	-	-	0.02	0.5	0.5	-	0.5	-	4	0.25	0.00001	0.000026
# < detection limit		-	117	-	-	63	3	4	-	19	-	143	9	25	25
% < detection limit		-	52%	-	-	38%	2%	3%	-	8%	-	63%	13%	12%	13%
95th percentile		150	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
5th percentile		10.0	<0.005	25.5	13.4	0.02	0.8	0.7	6.6	<0.5	28	<1	<0.1	<0.000005	<0.000005
background benchmark		10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]		-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	218	-	25	4.23	0.000086	-
source [b]		-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion		-	1	-	-	0	8	7	1	0	-	11	2	13	-
% > current water quality criterion		-	0%	-	-	0%	5%	5%	1%	0%	-	5%	3%	6%	-
# < current water quality criterion		-	-	-	-	-	3	4	8	-	-	-	-	-	-
% < current water quality criterion		-	-	-	-	-	2%	3%	4%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.9: Water quality data and summary statistics for all reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

Station	Date	Metals													
		Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
W10	4-May-09	6.56	0.000072	0.133	0.00234	0.99	0.00445		1.48	0.000022	0.45	0.0234	0.000062	0.0389	0.0386
W10	10-Jun-09	10.2	0.000023	0.03		1.3	0.00083	0.00049	0.38	< 0.000005	1.38	0.0362	0.000137	0.0046	0.0027
W10	14-Jul-09	15.6	0.000028	0.018	0.000164	2.16	0.00037	0.00038	0.43	< 0.000005	1.76	0.0555	0.000116	0.001	0.0023
W10	3-Sep-09	19.6	0.000024	0.022	0.000461	2.68	0.00072	0.00037	0.51	< 0.000005	2	0.0673	0.000161	0.0015	
W10	5-Oct-09	19.3	0.000019	0.014	0.000165	2.54	0.00027	0.0003		< 0.000005	1.84	0.0635		0.001	0.0034
W10	3-May-10	12.6			0.000755	1.83	0.00317	0.00065	1	0.000006	1.18	0.0431	0.000106	0.0148	0.0118
W10	5-Jun-10		0.000033		0.000717	1.72	0.00081	0.00061		< 0.000005	1.62	0.0406	0.000133	0.0036	0.0114
W10	10-Jul-10	14.4	0.000021	0.013	0.000196	2.21	0.00026	0.00038	0.43	< 0.000005	1.83	0.0575		0.0017	
W10	19-May-11	7.96	0.000098	0.145	0.00189	1.16	0.00558	0.00075	2.18	0.000024	0.55	0.0282	0.000069		0.0362
W10	30-May-12		0.0000697	0.119	0.000803	1.1	0.00251	0.000655	0.714			0.028	0.000162		0.00698
W10	28-Aug-12	21	0.000024	0.0358	0.000259	2.67	0.000941	0.000373	0.536	< 0.000005	1.92		0.000153	0.00157	
W10	24-Oct-12														
n		230	207	227	228	228	229	230	221	200	226	222	225	230	222
minimum		2.47	0.000006	<0.001	<0.000005	0.27	<0.00005	0.00015	<0.05	<0.000005	<0.05	0.0168	<0.000002	<0.0001	0.0001
maximum		74.6	0.00127	3.15	0.017	15.8	0.212	0.0107	2.18	0.0005	4.9	0.251	0.00619	0.0389	0.197
median		14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
mean [a]		19.0	0.0000756	0.15	0.000600	3.86	0.0126	0.00052	0.67	0.000009	1.86	0.0781	0.000975	0.0039	0.0056
standard deviation (SD) [a]		13.8	0.000168	0.31	0.00152	3.37	0.0230	0.00092	0.41	0.00005	0.66	0.0466	0.000907	0.0057	0.014
max detection limit		-	0.0001	0.05	0.001	-	0.001	0.001	0.05	0.00001	0.05	-	0.0005	0.005	0.0328
# < detection limit		-	1	9	18	-	3	22	2	160	1	-	9	20	20
% < detection limit		-	0.5%	4%	8%	-	1%	10%	1%	80%	0.4%	-	4%	9%	9%
95th percentile		45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
5th percentile		3.92	0.000011	0.006	0.0000257	0.77	0.000264	0.00017	0.16	<0.000005	0.81	0.0235	0.0000694	0.00040	0.00052
background benchmark		45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]		-	0.0025	1	0.005	-	0.8	0.055	373	0.0001	-	-	0.015	0.03	-
source [b]		-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion		-	0	4	3	-	0	0	0	2	-	-	0	4	-
% > current water quality criterion		-	0%	2%	1%	-	0%	0%	0%	1%	-	-	0%	2%	-
# < current water quality criterion		-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion		-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.10: Water quality data and summary statistics for station V1 (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
23-Jan-08	42	< 0.005	126.4	51.3	0.11	1.5	0.8	7.28	12.2	58	< 1		0.000008	0.000018
21-Feb-08	48	< 0.005	126.5	54.6	0.12	0.7	0.7	6.86	12.2	82	< 1		0.000006	< 0.000005
10-Mar-08	49.4	< 0.01		59				7.2	12.3		< 1	< 0.1	< 0.0002	< 0.0002
11-Mar-08	47	< 0.005	125.4	54.1	0.13	0.8	0.8	6.3	11.9	88	< 1		0.000006	0.000009
29-Apr-08	45	< 0.005	129	51.2	0.12	0.8	0.9	7.82	11	86	< 1		0.000007	0.000007
22-May-08	22	< 0.005	70.1		< 0.02		9.4	7.7	1.4	60	< 1		0.000114	0.000026
24-May-08	15	0.13		23.1	< 0.02		8		1.6	52	16		0.000047	
10-Jun-08	16.2	0.02		17				7.5	4.25		< 1	0.5	< 0.0002	< 0.0002
25-Jun-08	12	< 0.005	48.8	16.5	< 0.02	3	3	6.76	3.8	38	2		< 0.000005	0.00001
29-Jul-08	27	< 0.005	92.3	32.2	< 0.02	2.5	2.4		7.3	58	< 1		0.000011	0.000014
2-Sep-08	28.2	< 0.01							7.22		6	0.3	< 0.0002	< 0.0002
17-Sep-08	29	< 0.005	83.4	30.3	< 0.02	2.6	2.9	6.93	7.7	72	< 1		0.000009	0.000017
7-Oct-08	29	< 0.005		29.9	0.04	1.6			9.6	58	3		< 0.000005	
2-Dec-08	40.8	0.02							10.8		< 1	0.11	< 0.0002	< 0.0002
11-Dec-08	44	< 0.005	303	51.3	0.06	1.6	1.5		11	100	1		0.000009	0.000006
22-Jan-09	48	< 0.005		50.6	0.08				11	60	< 1		0.000007	0.000009
25-Feb-09	50	< 0.005		52.8	0.12				12		< 1		0.000021	0.000015
4-Mar-09	51	< 0.01	95	55.7		1.5	1	8.2	12	96	< 1		0.000009	0.000007
26-Mar-09	51	0.027		52.8	0.14					66	< 1		0.000006	0.000007
8-Apr-09	52	< 0.01	69.3	57.2		1.9	2	6.95	13	90	< 1		0.000009	< 0.000005
5-May-09	13	0.05	39	16		10.4	10.6	7.16	< 0.5	38	5		0.000041	0.000026
10-Jun-09				18.8		2.9	2.5	7.7	6.2	36	< 1		0.000008	0.00001
13-Jul-09	31	< 0.01		36.4		2.3	2.1	8.2	7.6	54	< 1		0.000009	0.000006
10-Aug-09	26	0.06	54	35.2		2.6		8.1	7.8	74	< 1		0.000011	0.000015
10-Sep-09	23	< 0.01	50	28.8		2.2	2.2	7.8	8.1	66	< 1		0.000006	0.000012
7-Oct-09	24	< 0.01	53	29.6		2.3	1.9	7.67	8.9	66	< 1		0.000006	0.000009
9-Nov-09	38	< 0.01	110	42.1		0.9	0.7		9.5	64	< 1		< 0.000005	0.000014
15-Dec-09	42	0.02	123	48.9		< 0.5	< 0.5	7.87	10	52				
7-Jan-10	45	< 0.01	140	53.4		1	0.8	7.76	10	68	< 4		< 0.000005	< 0.000005
18-Feb-10	49	0.03	80	50.8		0.8	< 0.5	8.34	11	68	< 1		< 0.000005	< 0.000005
29-Mar-10		< 0.01	122	51.5		1.6	1.4	7.91	12		< 1		< 0.000005	0.000006
20-Apr-10	46	0.02	101	48		1.5	1	7.9	12	46	< 1		0.000007	0.000006
12-May-10	39	< 0.01	99	44.3			4.5	7.94	7.6	62	< 1		0.000008	0.000011
16-Jun-10	17	< 0.05	54	20.1		2.2	1.8	7.16	5.5	30	2		0.000012	0.000042
14-Jul-10	26	< 0.05	60	27.2		1.1	1.8	8.2	6.8	38	< 1		0.000008	0.000024
4-Aug-10	35	< 0.05		37.3		1.6	1.7	8.29	10	64	< 1		0.000008	0.000014
7-Sep-10	29		30	33.7		1.8	1.8	8.38	9.1	62	< 1	0.2	0.000008	0.000007
5-Oct-10	34	0.36	103	39.9	0.03	1.1	1.7	5.23	9.6	82	< 1	0.2	0.000007	0.000015
1-Nov-10	38	0.008		39.1	0.04	1	0.9	8.67	12	60		0.15	0.000011	< 0.000005
1-Dec-10	39	< 0.05	140	48.5	0.07	< 0.5	< 0.5		13	56		1	0.000014	
24-Jan-11	47	0.036	192	59.7	0.12	27.1	0.7	7.93	11	62	< 1	< 0.25	0.000013	0.000038
17-Feb-11	45	< 0.005	134	49	0.13	0.9	1.1	7.84	11	62	< 4	< 0.25	< 0.000005	0.000007
22-Mar-11	45	0.013	137	50.7	0.15	0.7	0.6	8.03	12	66	< 1		0.00001	< 0.000005
21-Apr-11	46	0.019	90	56.5	0.15	0.8	0.7	8.52	15	64	< 1	< 0.25	< 0.000005	0.000017
17-May-11	36		88	40.7	< 0.02	12.1	11.7	8.08	7.5	42	< 1	0.5	0.000018	0.000022
15-Jun-11	14	0.024	38	17.6	< 0.02	3	2.3	7.62	6.9		< 1	< 0.25	< 0.000005	0.000006
13-Jul-11	24	0.02		30.2	< 0.02	1.9	2.3	7.65	9.2	48	< 1		0.000008	0.000009
10-Aug-11	26	< 0.005	73	31.3	< 0.02	2.5	2.3	7.68	7.9	64	< 1	0.34	0.000011	0.000007

Table B.10: Water quality data and summary statistics for station V1 (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Jan-08	16.1	0.000013	0.007	0.000027	2.68	0.00056	0.0002	0.52	< 0.000005	2.08	0.0843	0.0012	0.0005	0.0031
21-Feb-08	17.4	0.000011	0.006	0.00001	2.69	0.00062	0.00021	0.58	< 0.000005	2.31	0.0823	0.00135	0.0005	0.0004
10-Mar-08	18.5	< 0.001	< 0.05	< 0.001	3.06	< 0.001	< 0.001	0.7	< 0.00025	2.58	0.094	0.0014	< 0.005	< 0.005
11-Mar-08	17.1	0.000013	0.005	0.000035	2.77	0.00062	0.00024	0.59	< 0.000005	2.28	0.0819	0.00147	0.0041	0.0048
29-Apr-08	16.3	0.000012	0.005	0.000059	2.54	0.00061	0.00025	0.58	< 0.000005	2.08	0.0817	0.00144	0.004	0.0046
22-May-08	9.36	0.000116	0.168	0.00123	1.46	0.0228	0.00099	1.43	0.000007	1.35	0.0444	0.000459	0.0166	0.0058
24-May-08	7.4	0.000255	0.344	0.000748		0.0471	0.00082	0.98	0.000009	0.96	0.0378	0.000613	0.0058	
10-Jun-08	5.56	< 0.001	0.09	< 0.001	0.87	0.023	< 0.001	0.4	0.0005	1.05	0.028	< 0.0005	< 0.005	< 0.005
25-Jun-08	5.38	0.000038	0.055	0.000136	0.75	0.00259	0.0003	0.31	< 0.000005	0.96	0.0289	0.000399	0.0012	0.0021
29-Jul-08	10.4	0.000021	0.031	0.000112	1.5	0.00083	0.00028	0.37	< 0.000005	2.32	0.0515	0.000374	0.0016	0.0023
2-Sep-08		< 0.001	< 0.05	< 0.001	1.11	0.001	< 0.001	0.3	< 0.00025	1.48	0.042	< 0.0005	< 0.005	0.03
17-Sep-08	9.76	0.000023	0.027	0.000195	1.44	0.00116	0.00025	0.38	< 0.000005	1.53	0.0496	0.000343	0.0032	0.0013
7-Oct-08			< 0.001	< 0.000005	0.27	< 0.00005	0.0107		0.0561		< 0.00005	< 0.000002	< 0.0001	0.002
2-Dec-08	16.8	< 0.001	< 0.05	< 0.001	2.88	0.001	< 0.001	0.6	< 0.00025	2.3	0.072	0.0007	< 0.005	< 0.005
11-Dec-08	16.2	0.000014	0.008	0.000192	2.62	0.00021	0.00025	0.53	< 0.000005	1.95	0.077	0.000918	0.0015	
22-Jan-09	16.2	0.00001		0.000104	2.48	0.00028	0.00018	0.53	< 0.000005	2.72	0.0789	0.00132	0.0024	0.0029
25-Feb-09	16.9	0.00001	0.005	0.000201	2.56	0.00066	0.00019	0.55	< 0.000005	1.83		0.00151	0.0014	0.0029
4-Mar-09	17.4	0.000011	0.005	0.000023	2.96	0.00016	0.00021			2.07	0.0863		0.0006	0.0005
26-Mar-09	16.7	0.000011	0.002	0.000008	2.72	0.00014	0.00017			1.9	0.0848	0.00172		0.0144
8-Apr-09	18	0.000006	0.004	0.000025	2.96	0.00018		0.6	< 0.000005	2.14	0.0808	0.00165	0.0007	0.0014
5-May-09	5.01	0.000111		0.000331	0.85	0.0147	0.00061	1.41	0.000006	0.79	0.0278	0.000554	0.004	0.004
10-Jun-09		0.00003	0.047	0.000061	0.86	0.00111	0.00022	0.34		0.98		0.000388	0.0005	
13-Jul-09	10.7	0.000021	0.018	0.000188	1.56	0.00047	0.00026				0.0531	0.000366	0.0009	0.0032
10-Aug-09	11.4	0.000051		0.000798	1.62	0.00299	0.00046	0.46	< 0.000005	1.85	0.0569	0.000377	0.0349	0.0116
10-Sep-09	9.25	0.000029		0.000162	1.38	0.00161	0.00018	0.33	< 0.000005	1.74	0.049	0.000343	0.0034	0.004
7-Oct-09	9.23	0.00002	0.027	0.000311	1.43	0.00186	0.00025	0.31	< 0.000005		0.0488		0.0019	0.0056
9-Nov-09	13.3		0.013	0.000209	2.14	0.00037	0.00023		< 0.000005	1.89	0.0662	0.000602	0.0029	0.0017
15-Dec-09	15.5		0.008	0.000162		0.00035		0.51	< 0.000005	2.04	0.0743	0.00088	0.0005	0.0007
7-Jan-10	15.5	0.000012	0.007	0.00014	2.53	0.00024	0.00026	0.5	< 0.000005	1.97	0.0774	0.00105	0.0008	0.0024
18-Feb-10	16.3	0.000012	0.005	0.000087	2.68	0.00028	0.00021	0.54	< 0.000005	2	0.0743	0.00125	0.0008	0.0007
29-Mar-10	15.4	0.000012	0.003	0.000104	2.77	0.00022	0.00018	0.51	< 0.000005	2.13	0.0761	0.00147	0.001	0.0011
20-Apr-10	14.6	0.000019	0.007	0.000373	2.43	0.00064	0.00018		< 0.000005	1.76	0.0793		0.0008	0.0026
12-May-10	13.9		0.111	0.000107		0.00188	0.00052	0.78	< 0.000005	1.74	0.07	0.00064	0.0034	0.0061
16-Jun-10	6.39	0.00003	0.032	0.000977	1	0.00258	0.00027	0.31	< 0.000005	1.29		0.000331	0.0046	0.0414
14-Jul-10	7.76	0.000017	0.022	0.000087	1.07	0.00114	0.00018	0.29		1.22	0.0436	0.00029	0.0008	0.0145
4-Aug-10		0.000034	0.011	0.000108	1.79		0.00025	0.41	< 0.000005	1.81	0.0608	0.000391	0.0059	0.005
7-Sep-10	11	0.000011	0.024	0.000091	1.5	0.00064	0.00016	0.33	< 0.000005	1.69	0.0564	0.000328	0.0011	0.0034
5-Oct-10	12.3	0.000017	0.016	0.000105	1.9	0.00076	0.0002	0.42	< 0.000005	1.94	0.0601	0.000526	0.0008	0.0075
1-Nov-10		0.000015	0.008	0.000962	2.15	0.00053	0.0002	0.42	< 0.000005	1.94	0.0687	0.000556	0.0021	
1-Dec-10	14.9	0.000033		0.00138	2.47	0.00328	0.00029	0.52	< 0.000005	2.04	0.0767	0.000761	0.0064	0.002
24-Jan-11	17.6	0.000018	0.009	0.000514	2.85	0.00063	0.00024	0.64	0.000014		0.0829		0.0021	0.0103
17-Feb-11	15	0.00001	0.004	0.000062	2.84	0.00026	0.00023			2.18	0.0818			0.0004
22-Mar-11	14.5	0.000011	0.006	0.000278	2.94	0.00142		0.58	< 0.000005	2.22	0.0842	0.00155	0.0029	0.0022
21-Apr-11	17.9	0.000014	0.007	0.000605	2.88	0.00057	0.0013	0.54	< 0.000005	2.18	0.0857	0.00172	0.0005	0.0045
17-May-11	12.5	0.000059	0.081	0.000215	2.15	0.00385		1.12		1.45	0.0598	0.000673	0.0017	0.0017
15-Jun-11	5.65	0.000023	0.03	0.000087	0.83	0.001	0.00025	0.31	< 0.000005	1.13	0.0312	0.000325	0.0004	0.0043
13-Jul-11	9.7		0.027	0.000109		0.00113		0.36	< 0.000005	1.56	0.0511	0.00032	0.0005	0.0007
10-Aug-11	10	0.000022	0.027	0.000299	1.51	0.00069	0.0003		< 0.000005	1.62	0.0523	0.000333	0.0028	0.0019

Table B.10: Water quality data and summary statistics for station V1 (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
13-Sep-11	26	0.047	61	30.6	< 0.02	2.2	1.8	7.75		44	< 1	0.17	0.000008	0.000018
18-Oct-11	36	0.032	110	41.8	< 0.02	1.6	1.5	7.78	10.8	54	< 1	< 0.1		0.000008
23-Nov-11	40.1	0.028	127	53.9		2.34	1.28	8.41	17.9	58	< 1	< 0.1	< 0.000005	0.000014
8-Dec-11	42.8	0.071	104	47.7	0.073	1.04	1.23	7.89	13.4	64	< 4	< 0.1	0.000006	0.000006
25-Jan-12	47.7	0.055	90	49.6	0.12	1.17	1.08	8.04	11.6	76	< 1		0.000016	0.000019
27-Feb-12	46	0.023	125	54.1	0.121		0.91	7.97	11.1	64	< 1	0.12	0.00001	< 0.000005
7-Mar-12	47.4	0.023	113	51.6	0.137	< 0.5	0.65	7.71	11.9	84	< 1	< 0.1	< 0.000005	0.000006
26-Apr-12			147									0.26		
22-May-12	39.6	0.022	179	46.7	0.026	9.3	7.37	8.29	8.04	74	< 1		0.000021	0.0000232
2-Jun-12	27.8	< 0.005		37.7	0.0067	< 6.06			7.43		2.2		0.0000114	< 0.0000101
19-Jun-12	14.2	0.0097		17.3	< 0.02	3.94	3.43	7.59	4.3	26	1.2		0.0000109	0.0000224
18-Jul-12		0.015	65	27.9	< 0.02	3.2	2.63		6.41	40	< 1	0.33	0.000009	0.0000131
14-Aug-12	22.1	0.0057	92	27			2.27	7.69	6.2	60	< 1	0.25	0.000006	
12-Sep-12	23.9	0.0066	85	29.3	< 0.02	2.38	2.47	7.6	8.77	50	< 1		< 0.000005	0.000006
23-Sep-12	20.8			26.4	0.0136	2.34			9.28	41	< 1	-3.8	< 0.00001	< 0.00001
15-Oct-12	28.7	0.01	56	34	0.03	1.93	1.6	8.22	9.59	42	< 1	0.16		< 0.000005
13-Nov-12		0.008		43.1	0.055	1.96	0.62	8.01	10.5	74	< 1	0.12		0.000006
11-Dec-12	42.4	0.0069	137	53.9	0.088	0.97		7.7	10.9	88	< 1	0.16	< 0.000005	0.000009
n	61	61	48	62	40	52	53	51	63	57	62	26	57	56
minimum	12	<0.005	30	16	0.0067	<0.5	<0.5	5.23	<0.5	26	<1	<0.1	<0.000005	<0.000005
maximum	52	0.36	303	59.7	0.15	27.1	11.7	8.67	17.9	100	16	1	0.000114	0.000042
median	38	0.010	97	42.0	0.04	1.7	1.7	7.80	9.6	62	<1	0.20	0.0000080	0.0000090
mean [a]	35	0.023	101	40.3	0.06	2.7	2.3	7.72	9.3	61	1	0.22	0.0000110	0.000012
standard deviation (SD) [a]	12	0.049	47	12.8	0.05	4.1	2.5	0.59	3.2	17	2	0.20	0.0000160	0.0000085
max detection limit	-	0.05	-	-	0.02	0.5	0.5	-	0.5	-	4	0.25	0.00001	0.000010
# < detection limit	-	30	-	-	14	3	3	-	1	-	53	9	14	10
% < detection limit	-	49%	-	-	35%	6%	6%	-	2%	-	85%	35%	25%	18%
95th percentile	50	0.060	168	56.5	0.14	9.8	8.6	8.4	13.0	88	4	0.50	0.0000250	0.000026
5th percentile	14.2	<0.005	42	17.3	0.02	0.6	0.6	6.8	3.8	38	<1	<0.1	<0.000005	<0.000005
background benchmark	10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	218	-	25	4.23	0.000077	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	1	-	-	0	1	0	0	0	-	0	0	1	-
% > current water quality criterion	-	2%	-	-	0%	2%	0%	0%	0%	-	0%	0%	2%	-
# < current water quality criterion	-	-	-	-	-	3	3	2	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	6%	6%	4%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.10: Water quality data and summary statistics for station V1 (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
13-Sep-11		0.00002	0.025	0.000591	1.44	0.00121	0.00027	0.38		1.61	0.0534	0.000376	0.002	0.0056
18-Oct-11	13.3	0.000016			2.09	0.00042	0.00024	0.46	< 0.000005	1.84	0.0658	0.000618	0.0008	0.0018
23-Nov-11	17.3	0.000019	0.009	0.000182	2.6	0.00059	0.00022	0.53	< 0.000005	2.14		0.000798	0.0008	0.003
8-Dec-11	14.8	0.000013	0.006	0.000009	2.58	0.00034	0.0002	0.54	< 0.000005		0.0781	0.000905	0.0012	0.0011
25-Jan-12	15.3	0.00001	0.004	0.000093	2.76	0.00021	0.0003	0.57	< 0.000005	2.11	0.0795	0.00112	0.0016	0.0022
27-Feb-12	17	0.000018	0.015		2.87	0.00065	0.00027		< 0.000005	2.2	0.0819	0.00136	0.0028	0.0014
7-Mar-12	15.6	0.000978	0.02	0.000128	2.65	0.00044		0.55	< 0.000005	2.17	0.0819		0.0009	
26-Apr-12														
22-May-12	14.7	0.0000357	0.0384	0.0000478	2.36	0.00183	0.000549		< 0.000005	1.91	0.0721		0.00068	0.00666
2-Jun-12	10.5	0.0000468	0.117	0.000116	1.59	0.00495		0.843	< 0.000005		0.0478	0.000401		< 0.00371
19-Jun-12	5.74	0.0000456	0.068	0.000396	0.726	0.00226	0.000356	0.372	0.0000092	0.915		0.000318		0.00658
18-Jul-12	9	0.0000371	0.0382	0.000123	1.31	0.00128	0.000284	0.312	< 0.000005	1.31	0.0453	0.000339	0.00098	0.00221
14-Aug-12	8.04	0.000019	0.0288	0.000047	1.23	0.00104	0.000234	0.281	< 0.000005	1.44	0.0529	0.00045	0.00035	0.197
12-Sep-12	9.58			0.000018	1.29	0.00167	0.000283	0.308	< 0.000005	1.54	0.0472	0.000373	0.00047	0.0009
23-Sep-12			0.034	< 0.00005	1.23		< 0.0005	0.323	< 0.00001	1.64	0.0464	0.000316	0.0053	0.0014
15-Oct-12	10.1	0.000022	0.0167	0.000061	1.67	0.000606	0.000213		< 0.000005	1.7	0.0555	0.000412	0.00072	0.00092
13-Nov-12	13.6	0.000017	0.0071		2.26	0.000188	0.000236	0.484	< 0.000005	1.94	0.074	0.0007	0.00076	0.00058
11-Dec-12	16.6	0.000011		0.000078	2.73	0.000224	0.000289	0.555	< 0.000005	2.09	0.0783	0.000903	0.00083	0.00087
n	58	54	57	62	61	63	58	54	53	59	59	58	61	60
minimum	5.01	0.000006	<0.001	<0.000005	0.27	<0.00005	0.00016	0.281	<0.000005	0.79	0.0278	<0.000002	<0.0001	0.0004
maximum	18.5	0.000978	0.344	0.00138	3.06	0.0471	0.0107	1.43	0.0005	2.72	0.094	0.00172	0.0349	0.197
median	14.2	0.0000185	0.02	0.000126	2.15	0.00066	0.00025	0.51	<0.000005	1.89	0.0687	0.000579	0.0014	0.0029
mean [a]	12.9	0.0000464	0.03	0.000257	2.00	0.0027	0.00050	0.53	0.000013	1.79	0.0643	0.000738	0.0027	0.0077
standard deviation (SD) [a]	4.0	0.000135	0.05	0.000303	0.76	0.0071	0.0014	0.24	0.000068	0.43	0.0175	0.000467	0.0048	0.026
max detection limit	-	-	0.05	0.001	-	0.001	0.001	-	0.00001	-	-	0.0005	0.005	0.005
# < detection limit	-	-	4	6	-	2	5	-	47	-	-	3	5	4
% < detection limit	-	-	7%	10%	-	3%	9%	-	89%	-	-	5%	8%	7%
95th percentile	17.6	0.000113	0.11	0.00100	2.9	0.014	0.0010	1.03	0.000010	2.31	0.0849	0.00157	0.0059	0.015
5th percentile	5.64	0.000010	0.0038	0.0000104	0.83	0.00018	0.00018	0.31	<0.000005	0.96	0.0310	0.000318	0.00047	0.00058
background benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]	-	0.0025	1	0.004	-	0.8	0.049	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	0	-	0	0	0	1	-	-	0	1	-
% > current water quality criterion	-	0%	0%	0%	-	0%	0%	0%	2%	-	-	0%	2%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.11: Water quality data and summary statistics for station VR (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
24-Jan-08	36	< 0.005	188	39	0.08	1.6	1.7		5.9	30	96		0.000067	0.000017
21-Feb-08	40	< 0.005	88.7	40.5	0.06	1.6	1.2	7.7	8.1	64	< 1		0.000016	0.000016
11-Mar-08	41	< 0.005	113.1	42.6	0.08	1.8	1.8	7.43	6.6	76	1		0.000015	0.000019
29-Apr-08	41	0.006	112.5	44.9	0.07	2.4	2.6	7.45	7.2	66	4		0.000048	0.000033
22-May-08	12	< 0.005	188.8		< 0.02	16.4	16.5	7.1	< 0.5	38	41		0.000113	0.000061
24-May-08	7.7	< 0.01		16.4	< 0.02	11.9	12.2		3.4	34	100		0.000127	
25-Jun-08	9.6	< 0.005		14.6	< 0.02	4.6	5	6.73	< 0.5	32	3		0.000015	0.000015
29-Jul-08	21	< 0.005	63.8	22.9	< 0.02	4.4	4.4	6.61	4.1	40	< 1		0.000016	
19-Aug-08	25	< 0.01		26.6	< 0.02	4.2			4.6	60	< 1		0.000013	0.000013
17-Sep-08	21	< 0.005	56.5	22.8	< 0.02		4.1	6.37	4.4	50	< 1		0.000011	0.000006
7-Oct-08	25	< 0.005	68.5	25.1	< 0.02	1.8	2.9	6.8	6.9	28	< 1		0.000009	0.000008
11-Dec-08	33	< 0.005	78.3	35.3		2.9	2.6		6.3	44	2		0.000017	0.000018
22-Jan-09	35	< 0.005		33.7	0.04				7.8	62	19		0.000026	0.000029
25-Feb-09	38	0.006		42.1	0.09				7.6	78	400			0.000026
20-May-09	23			24.3	< 0.02			6.32	1.3	38	11		0.000043	0.00003
23-Jun-09	24	< 0.005	163	24.9	< 0.02			7.67	2.4		1		0.000107	0.000135
30-Jul-09	30	0.008	76.3	32.6	< 0.02			7.49	3.5	64	< 1		0.000023	0.000022
25-Aug-09		< 0.005	72.5	30.2	0.02			7.82	4.3	52	< 1		0.000013	0.00001
30-Sep-09	29		77.9	28	< 0.02			7.35	5.3	42	< 1		0.000025	0.000031
21-Oct-09	33	< 0.005		30.8	0.02				5.5	52	< 1		0.000012	0.000009
24-Nov-09	34	< 0.005	25.1	34	0.04			9.15	6.8	48	< 1			< 0.000005
21-Jan-10	39	0.022	52.9	41.5	0.07				6.2		14		0.00008	0.000028
24-Feb-10	41	0.124	60.6	44.8	0.09			8.4	6.1	78	200		0.000348	0.000023
30-Mar-10	40	< 0.005	55.9	44.4	0.08			7.84	7.1	48	46		0.000108	0.000022
3-Nov-10	35	0.014	44.6	34.8	0.02			7.3	6.1	58	< 4		0.000008	0.000005
18-May-11	11	0.025		18.3	< 0.02	25	24.5	6.77	< 0.5	28	9	2.02	0.00013	0.000107
30-May-12	16.9			19.2	0.0314		9.98		0.5	40	4.7	1.21	0.0000345	
30-Aug-12				28.6									0.00001	0.000008
23-Oct-12	29.9	0.013			0.0154				5.96	54	< 1	0.3		
n	27	25	18	27	27	12	13	18	28	26	28	3	26	25
minimum	7.7	<0.005	25.1	14.6	0.0154	1.6	1.2	6.32	<0.5	28	<1	0.3	0.000008	<0.000005
maximum	41	0.124	188.8	44.9	0.09	25	24.5	9.15	8.1	78	400	2.02	0.000348	0.000135
median	30	<0.005	74	30.8	<0.02	3.6	4.1	7.39	5.7	49	3	1.21	0.0000240	0.000019
mean [a]	29	0.011	88	31.2	0.03	6.6	6.9	7.35	4.8	50	34	1.18	0.0000552	0.000028
standard deviation (SD) [a]	10	0.024	48	9.2	0.03	7.4	7.0	0.72	2.5	15	84	0.86	0.0000724	0.000031
max detection limit	-	0.01	-	-	0.02	-	-	-	0.5	-	4	-	-	0.000005
# < detection limit	-	17	-	-	12	-	-	-	3	-	12	-	-	1
% < detection limit	-	68%	-	-	44%	-	-	-	11%	-	43%	-	-	4%
95th percentile	41	0.024	188	44.7	0.09	20.3	19.7	8.5	7.7	78	165	1.94	0.000129	0.000098
5th percentile	10.0	<0.005	42	17.0	<0.02	1.6	1.5	6.4	<0.5	29	<1	0.39	0.00000925	0.0000052
background benchmark	10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	128	-	25	4.23	0.00006	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	1	0	-	6	0	8	-
% > current water quality criterion	-	0%	-	-	0%	8%	8%	6%	0%	-	21%	0%	31%	-
# < current water quality criterion	-	-	-	-	-	0	0	2	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	11%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.11: Water quality data and summary statistics for station VR (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
24-Jan-08	11.9	0.000203	0.255		2.22	0.0376	0.00049	0.41	0.000007	1.64	0.06	0.00112	0.0062	0.0028
21-Feb-08	12.6	0.000025	0.03	0.000129	2.2	0.00119		0.54	< 0.000005	1.79	0.0641	0.000416	0.0012	0.002
11-Mar-08	13.2	0.000015	0.022	0.000117	2.34	0.00081	0.00017	0.52	< 0.000005	1.76	0.0677	0.000423	0.0048	
29-Apr-08	13.8	0.000048	0.058	0.000843	2.52	0.00307	0.00733	1.2	0.000005	2.14	0.0715	0.000507	0.0099	0.0082
22-May-08	6.28	0.000414	0.488	0.00426	1.15	0.0291	0.00107	1.03	0.000029	1	0.0316		0.0127	0.0089
24-May-08	5.09	0.000455	0.488	0.00543	0.89		0.00097		0.000014	0.8	0.0292		0.0137	
25-Jun-08	4.54	0.000043	0.075	0.000275	0.8	0.00164	0.00031	0.24	0.000005	1.03	0.0251	0.000695	0.0021	0.0033
29-Jul-08	7.02		0.026	0.000083	1.3	0.00084	0.00023	0.27	< 0.000005	2.23	0.0376	0.000407	0.0021	0.0043
19-Aug-08	8.15	0.000023	0.021	0.000051	1.52		0.0002	0.29	< 0.000005	1.52	0.0458	0.000397	0.0007	0.0018
17-Sep-08	7.02	0.000022	0.022	0.000066	1.27	0.00069	0.00021	0.31	< 0.000005	1.39		0.000376	0.001	0.0002
7-Oct-08	7.64	0.000019	0.02	0.000322	1.46	0.00077	0.0003	< 0.05	0.0412	1.46	< 0.00005	< 0.000002	0.0002	0.0018
11-Dec-08	10.9	0.000028	0.04	0.000602	2	0.00256	0.00015	0.38	< 0.000005	1.57	0.0556	0.000481		0.0025
22-Jan-09	10.5	0.000051	0.085	0.000632	1.82	0.0107	0.00017	0.4		2.18		0.000605	0.0036	0.0048
25-Feb-09	13.2	0.00118	1.82		2.19		0.00174	0.54	0.00002	1.43	0.0717	0.00619	0.0273	0.0045
20-May-09	7.41	0.000079	0.129	0.00127	1.41	0.00727	0.00049	0.6	0.000008	1.15	0.039	0.000739	0.0042	0.0035
23-Jun-09	7.35	0.000175	0.075	0.000277	1.6	0.00578	0.00041	0.31	0.000009	1.96	0.0359	0.000476	0.0034	0.0039
30-Jul-09	10.2	0.000046	0.057	0.000507	1.73	0.0056	0.00023	0.35		1.53		0.000517	0.0014	0.0015
25-Aug-09	9.17	0.000021	0.027	0.00007	1.78			0.32	< 0.000005	1.58	0.0481	0.000406	0.0012	0.001
30-Sep-09	8.56	0.000021	0.02	0.000272	1.61	0.00155	0.00029	0.31	< 0.000005	1.47	0.0447	0.000355	0.0037	0.0023
21-Oct-09	9.38	0.000014	0.021	0.000156	1.78	0.00096	0.00018	0.32	< 0.000005	1.51		0.000374	0.0017	0.0014
24-Nov-09	10.4	0.000018	0.022		1.98		0.00024	0.34	< 0.000005	1.56	0.055	0.000439	0.002	0.0017
21-Jan-10	12.6	0.000097	0.176	0.00204	2.42	0.0267	0.00045	0.52	< 0.000005	1.83	0.0643	0.000789	0.0153	0.0124
24-Feb-10	13.8	0.000869	1.31	0.0125	2.52	0.212	0.0016	0.79	0.000026	2.18	0.0685	0.00559	0.0309	0.011
30-Mar-10	13.6	0.000274	0.438	0.0026	2.55	0.0469	0.00067	0.57	0.000024	1.78	0.0693	0.00164	0.0108	0.004
3-Nov-10	10.5	0.000017	0.018	0.000083	2.12	0.00135	0.00016	0.34	< 0.000005	1.73	0.0569	0.000457	0.0012	0.0008
18-May-11	5.62	0.000095	0.175	0.00102	1.04	0.0165	0.0006	1.31	0.000011	0.59	0.029	0.000554	0.0124	0.0135
30-May-12	5.9	0.0000833	0.117	0.000584	1.08		0.000455	0.575	0.0000131	1.07	0.0332	0.000727	0.00243	0.00317
30-Aug-12	8.71	0.000017	0.0217	0.000051	1.66	0.000924	0.000196	0.339	< 0.000005	1.51	0.0455	0.000317	0.00074	0.00052
23-Oct-12														
n	28	27	28	25	28	22	26	27	25	28	23	26	27	26
minimum	4.54	0.000014	0.018	0.000051	0.8	0.00069	0.00015	<0.05	<0.000005	0.59	0.0251	<0.000002	0.0002	0.0002
maximum	13.8	0.00118	1.82	0.0125	2.55	0.212	0.00733	1.31	0.000029	2.23	0.0717	0.00619	0.0309	0.0135
median	9.3	0.0000460	0.06	0.000322	1.8	0.00282	0.000305	0.38	<0.000005	1.55	0.0481	0.000479	0.0034	0.0030
mean [a]	9.5	0.000161	0.22	0.00137	1.7	0.0188	0.000743	0.49	0.000008	1.55	0.0500	0.000961	0.0066	0.0041
standard deviation (SD) [a]	2.9	0.000279	0.41	0.00269	0.5	0.0452	0.00141	0.29	0.000008	0.41	0.0154	0.00148	0.0079	0.0037
max detection limit	-	-	-	-	-	-	-	0.05	0.000005	-	-	0.000002	-	-
# < detection limit	-	-	-	-	-	-	-	1	13	-	-	1	-	-
% < detection limit	-	-	-	-	-	-	-	4%	52%	-	-	4%	-	-
95th percentile	13.7	0.000745	1.02	0.00520	2.5	0.0464	0.00171	1.15	0.00003	2.18	0.0713	0.00460	0.024	0.012
5th percentile	5.28	0.0000156	0.02	0.0000540	0.9	0.000772	0.000163	0.25	<0.000005	0.87	0.0290	0.000327	0.00071	0.00059
background benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]	-	0.0025	1	0.004	-	0.7	0.039	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	2	3	-	0	0	0	0	-	-	0	1	-
% > current water quality criterion	-	0%	7%	12%	-	0%	0%	0%	0%	-	-	0%	4%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.12: Water quality data and summary statistics for station USFR (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
24-May-08	7.6	0.16		15.3	< 0.02	6.6	6.7		< 0.5	34	20		0.000033	
19-Aug-08	17	< 0.01		21.5	< 0.02	3.7			4.4	50	< 1		0.000009	0.000007
3-Nov-10		0.015	30.2	30.8	0.04			7.39	7.2	58	< 4		< 0.000005	< 0.000005
18-May-11	16	0.034		20.3	< 0.02	26.8	27.8	7.03	5	32	11		0.000071	0.00006
30-May-12	14.5	0.012		16.8	0.0183				2.5	24		2.25	0.0000235	0.0000115
30-Aug-12				22.6									< 0.000005	< 0.000005
24-Oct-12	26.3	0.016			0.0157		1.63		7.38	42	< 1			
n	5	6	1	6	6	3	3	2	6	6	5	1	6	5
minimum	7.6	<0.01	-	15.3	0.0157	3.7	1.63	7.03	<0.5	24	<1	-	<0.000005	<0.000005
maximum	26.3	0.16	-	30.8	0.04	26.8	27.8	7.39	7.38	58	20	-	0.000071	0.00006
median	16	0.016	-	20.9	<0.02	6.6	6.7	-	4.7	38	<4	-	0.0000163	0.0000070
mean [a]	16.3	0.040	-	21.2	0.02	12.4	12.0	-	4.5	40	7	-	0.0000236	0.000017
standard deviation (SD) [a]	6.7	0.059	-	5.5	0.01	12.6	13.9	-	2.8	13	9	-	0.0000262	0.000024
max detection limit	-	0.01	-	-	0.02	-	-	-	0.5	-	4	-	0.000005	0.000005
# < detection limit	-	1	-	-	3	-	-	-	1	-	3	-	2	2
% < detection limit	-	17%	-	-	50%	-	-	-	17%	-	60%	-	33%	40%
95th percentile	24.4	0.13	-	28.8	0.04	24.8	25.7	-	7.3	56	18	-	0.0000615	0.000050
5th percentile	9.0	0.011	-	15.7	0.02	4.0	2.1	-	1	26	<1	-	<0.000005	<0.000005
background benchmark	10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	128	-	25	4.23	0.000043	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	0	0	1	-
% > current water quality criterion	-	0%	-	-	0%	33%	33%	0%	0%	-	0%	0%	17%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.12: Water quality data and summary statistics for station USFR (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
24-May-08	4.98	0.000144	0.44	0.000719	0.7	0.0445	0.00052		0.000006		0.0293	0.000871	0.0089	
19-Aug-08	6.81	0.00003	0.119	0.000108	1.1	0.00728	0.00033	0.23		1.49	0.0422			0.0017
3-Nov-10	9.61	0.000028	0.087	0.000032	1.64	0.011	0.00016	0.32	< 0.000005	1.86	0.0598	0.000464	0.0003	0.001
18-May-11	6.07	0.000208	0.474	0.000396	1.24	0.0939		2.08	< 0.000005	0.73	0.0345	0.000819	0.0062	0.0085
30-May-12	5.24	0.0000766	0.295	0.000215	0.894	0.0353	0.000402		0.0000061	1.12	0.0365			0.00085
30-Aug-12	7.22	0.000022	0.119	0.000057	1.1	0.00925	0.000901	0.26	< 0.000005	1.41	0.0422	0.000352	0.00041	0.00033
24-Oct-12														
n	6	6	6	6	6	6	5	4	5	5	6	4	4	5
minimum	4.98	0.000022	0.087	0.000032	0.7	0.00728	0.00016	0.23	<0.000005	0.73	0.0293	0.000352	0.0003	0.00033
maximum	9.61	0.000208	0.474	0.000719	1.64	0.0939	0.000901	2.08	0.0000061	1.86	0.0598	0.000871	0.0089	0.0085
median	6.44	0.0000533	0.21	0.000162	1.1	0.0232	0.00040	0.29	<0.000005	1.41	0.0394	0.000642	0.0033	0.0010
mean [a]	6.66	0.0000848	0.26	0.000255	1.1	0.0335	0.00046	0.72	0.000004	1.32	0.0408	0.000627	0.0040	0.0025
standard deviation (SD) [a]	1.69	0.0000761	0.17	0.000264	0.3	0.0333	0.00028	0.91	0.000002	0.42	0.0105	0.000257	0.0043	0.0034
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	3	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	60%	-	-	-	-	-
95th percentile	9.01	0.000192	0.47	0.000638	1.5	0.0816	0.00082	1.82	0.000006	1.79	0.0554	0.000863	0.0085	0.0071
5th percentile	5.05	0.0000235	0.095	0.0000383	0.7	0.00777	0.00019	0.23	<0.000005	0.81	0.0306	0.000369	0.00032	0.00043
background benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]	-	0.0025	1	0.004	-	0.7	0.029	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	0	-	0	0	0	0	-	-	0	0	-
% > current water quality criterion	-	0%	0%	0%	-	0%	0%	0%	0%	-	-	0%	0%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

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[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.13: Water quality data and summary statistics for station R7 (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
8-Jan-08		0.01		119				7.9	9.67		< 1		< 0.0002	< 0.0002
19-Feb-08		0.01		132				8.1	8.99		< 1		< 0.0002	< 0.0002
18-Mar-08		< 0.01		139				7.5	9.94		< 1		< 0.0002	< 0.0002
14-Apr-08		0.02		141				7.7	10.4		< 1		< 0.0002	< 0.0002
15-May-08		0.03		40				8.8	2.2		3		< 0.0002	< 0.0002
25-May-08	17	0.15		25.2	< 0.02	9.6	10.4		< 0.5	52	33		0.000071	
17-Jun-08		0.02		69				8.2	5.76		4		< 0.0002	< 0.0002
15-Jul-08		< 0.01		47				7.8	4.18		43		< 0.0002	< 0.0002
22-Jul-08	58	< 0.01		63.6					6.9				0.000009	0.000007
12-Aug-08		0.01		76				7.6	6.52				< 0.0002	< 0.0002
21-Aug-08	78	< 0.01		80.1	< 0.02	3.7			6.6	98	< 1		0.00001	
4-Sep-08	68	0.04		70.3					7.2		4		0.000017	0.000016
15-Sep-08		0.02		58				7.3	6.76		1		< 0.0002	< 0.0002
15-Oct-08		0.02		79				7.6	7.72		< 1		< 0.0002	
4-Nov-08		0.02		99				8.2	8.48				< 0.0002	< 0.0002
2-Dec-08		0.02		116				7.8	8.96		3		< 0.0002	
13-Jan-09		0.01		131				7.5	10.4		< 1		< 0.0002	
3-Feb-09		0.03		129				7.7	10.8				< 0.0002	< 0.0002
4-Mar-09	130	0.09	226	136		1.4	1.5	8.3	17	160	< 1		0.000007	0.000006
7-Apr-09	140	< 0.01	150.3	136		1.6	1.1		17	170	< 1		0.000006	0.000009
5-May-09	26	0.02	48	29.1		21.8	21.3		< 0.5	54	5		0.000073	0.000059
10-Jun-09	44	< 0.005	85	44.7		3.9	3.7	7.3		60	6			< 0.000005
14-Jul-09	80	0.02	155	80.1		3.2		7.7	8.7	84	< 1		0.000051	0.000061
6-Aug-09	97	< 0.01	182	98		1.8	2.2	7.5	7.6	110			0.000007	0.000045
2-Sep-09	74	< 0.01	110	74.1		2.8	2.8	8.2	6.5	90	< 1		0.000011	
4-Oct-09	82	< 0.01	110	81.8		1.7		8	6	92	< 4		0.000008	0.000006
4-Nov-09			194	108		2.6	2.4	7.54	7.3	120			0.00002	0.00002
2-Dec-09	110		215	129		1.8	1.7		9.6	130			0.000012	0.00001
11-Jan-10		0.02	235	131		0.7	0.9	7.21	11	130	< 1		0.00001	< 0.000005
23-Feb-10		< 0.01	260	138		0.8	0.9	7.95	9.7	160	< 1		< 0.000005	< 0.000005
10-Mar-10	130	< 0.01	239	140		1.1	1.3	7.78	9.7	190	< 1		< 0.000005	< 0.000005
11-Apr-10	140	< 0.01	240	139				7.78	9.9	150	< 1		< 0.000005	0.000009
3-May-10		0.014	91	56.3		16	13.4	7.66	0.3	68	4		0.000034	0.000027
5-Jun-10	52	< 0.05	97	55.2			2.9	7.85	4.5	62	4		0.000012	0.000019
8-Jul-10	64	< 0.05	123			3.5	4	8.04	6.4	76	2		0.000012	0.00002
3-Aug-10	91	< 0.05	183	86			2.2	7.37	6.3	100	< 1		< 0.000005	0.000009
1-Sep-10		0.12	186	87.6	< 0.02	3	2.7	7.84	7.5		< 1	0.9	< 0.000005	0.000021
19-Oct-10	96	0.026		103	0.07	2.5	1.6	7.2	8.1		< 1	1	0.000008	0.000017
10-Nov-10	110	< 0.005	215	118	0.09	1.4	1.5	7.9	10	120	< 1	0.66	0.000009	0.000013
1-Dec-10	120	< 0.05	100	123	0.09	0.9	0.8	7.12	10	120	< 4	1	0.00001	0.000006
20-Jan-11	130	< 0.05	292	149	0.15	1	0.9	7.64	10	150	< 1	0.69	0.00001	< 0.000005
15-Feb-11	130	0.018	285	123	0.16	1.1	1.1	8.01		140	< 1	0.58	0.000009	0.000007

Table B.13: Water quality data and summary statistics for station R7 (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8-Jan-08	36	< 0.001	0.11	< 0.001	7.14	0.008	< 0.001	0.9	< 0.00025	2.66	0.14	0.0018	0.008	< 0.005
19-Feb-08	39.2	< 0.001	< 0.05	0.0005	8.12	0.009	< 0.001	0.8	< 0.00025	3.21	0.17	0.0015	< 0.005	< 0.005
18-Mar-08	40.1	< 0.001	0.05	< 0.001	9.39	0.006	< 0.001	1.1	< 0.00025	3.81	0.17	0.0025	< 0.005	< 0.005
14-Apr-08	42.5	< 0.001	< 0.05	< 0.001	8.37	0.006	< 0.001	1.1	< 0.00025	3.42	0.18	0.0026	< 0.005	< 0.005
15-May-08	12	< 0.001	0.47	< 0.001	2.33	0.038	0.001	1.5	< 0.00025	1.05	0.051	0.0005	0.014	< 0.005
25-May-08	7.87	0.000316	0.89	0.000954	1.34	0.0752	0.00124	0.93	0.000012	0.71	0.0385	0.000385	0.01	
17-Jun-08	19.5	< 0.001	0.18	< 0.001	4.87	0.015	< 0.001	0.6	< 0.00025	1.69	0.071	0.0007	0.008	0.005
15-Jul-08	14.1	< 0.001	0.98	0.001	2.86	0.033	0.002	0.5	0.0004	1.28	0.057	0.0005	0.012	< 0.005
22-Jul-08	18.9	0.000047	0.114			0.0147	0.00038	0.34	< 0.000005	1.37	0.0687	0.000638	0.0008	0.0006
12-Aug-08	22.8	< 0.001	0.22	0.002	4.65	0.021	< 0.001	0.5	< 0.00025	1.78	0.084	0.0007	< 0.005	0.006
21-Aug-08	23.9	0.000038	0.152	0.0003	5	0.0166	0.00039	0.5	< 0.000005	2.04	0.0977	0.000962	0.0016	0.0043
4-Sep-08	21.1	0.000061	0.166	0.00009	4.26	0.0169	0.00038	0.46		1.64	0.0813	0.000794	0.0008	0.0012
15-Sep-08	17.5	< 0.001	0.22	0.003		0.019	< 0.001	0.4	< 0.00025	1.59	0.084	0.0009	< 0.005	< 0.005
15-Oct-08	24.3	< 0.001	0.05	< 0.001	4.49		< 0.001	0.5	< 0.00025	1.67	0.095	0.001	< 0.005	< 0.005
4-Nov-08	29.7	< 0.001	< 0.05	0.0005		0.015	< 0.001	0.7	< 0.00025	2.22	0.12	0.0013	< 0.005	< 0.005
2-Dec-08	35.3	< 0.001	0.09	< 0.001	6.74		< 0.001	0.9	< 0.00025	2.67	0.13	0.0017	0.014	0.013
13-Jan-09	39.3	< 0.001	0.12	< 0.001	8.06	0.017	< 0.001	0.9	< 0.00025	2.86	0.16	0.0024	< 0.005	< 0.005
3-Feb-09	38.6	< 0.001	0.2	< 0.001		0.018	< 0.001	0.9	< 0.00025	2.98	0.18	0.0021	< 0.005	< 0.005
4-Mar-09	41.4	0.000017	0.088	0.000052	7.97	0.0118	0.00017	0.96	< 0.000005	3.1	0.177	0.00261	0.0007	0.0004
7-Apr-09	41.3	0.000016	0.075	0.000022	8.03	0.0101	0.00019	0.99	< 0.000005	3.09	0.178	0.00276	0.0017	0.0006
5-May-09	8.3	0.000108	0.432	0.001	1.66	0.0369	0.00089	1.75		0.66	0.0368		0.0092	
10-Jun-09	12.8	0.000041	0.117		2.68	0.0113	0.00029	0.43	< 0.000005	0.99	0.0498	0.000546	0.0015	0.0011
14-Jul-09	23.3	0.000047	0.14	0.00201	5.05	0.0182	0.00033	0.58	< 0.000005	1.82	0.0874	0.00095	0.0104	0.0109
6-Aug-09	29.5	0.000021	0.127	0.0001	5.89	0.0108	0.00022	0.61	< 0.000005	2.07	0.123	0.00132	0.0007	0.0042
2-Sep-09	20.6	0.000046	0.176	0.0003	3.86	0.0185	0.00023	0.44	< 0.000005	1.69	0.0913	0.000842	0.001	0.0007
4-Oct-09	23.7	0.000043	0.216	0.000261	4.66	0.0263	0.00025	0.51	< 0.000005	2.01		0.00113	0.0023	0.0042
4-Nov-09	33.7	0.000039	0.148	0.00183	5.88	0.0207	0.00047	0.82	< 0.000005		0.129	0.00153	0.0048	0.004
2-Dec-09	34.7	0.000022	0.12	0.000086	6.55	0.0164	0.0002	0.76	< 0.000005		0.149	0.00193	0.0012	0.0013
11-Jan-10	39.6	0.000021	0.091	0.000058	7.81	0.0149	0.00018	0.93	< 0.000005	3.05	0.161	0.00226	0.0006	0.0004
23-Feb-10		0.000011	0.079	0.00001	8.31	0.0101	0.00015	0.95		3.27		0.00262	0.0003	
10-Mar-10	41.2	0.000016	0.082	0.00005	8.09	0.00987	0.00017	0.96	< 0.000005	3.23	0.175	0.00279	0.0004	0.0003
11-Apr-10	42.4	0.000014	0.028	0.000079	8.06	0.00749	0.00018	1.04	< 0.000005	3.3	0.177	0.00282	0.0008	0.0011
3-May-10	16.5	0.000097	0.409	0.000517		0.0399	0.00108	1.3	< 0.000005		0.0724	0.000736	0.004	0.0053
5-Jun-10	16.1	0.00005	0.168	0.00033	3.44	0.0151	0.00044	0.52	< 0.000005		0.0637		0.0029	0.0044
8-Jul-10	16.8	0.00005	0.142	0.000592	4.01	0.0164	0.0004	0.41	< 0.000005	1.61	0.0791	0.000714	0.002	0.0052
3-Aug-10	25.4	0.000026	0.168	0.000391	5.52	0.0134	0.00028	0.56	< 0.000005	2.01	0.107	0.0011	0.0019	0.0021
1-Sep-10	26.5		0.208	0.000105	5.22		0.00025	0.54	< 0.000005	2.02	0.109	0.00107	0.0006	0.0197
19-Oct-10	29.6	0.000034	0.181	0.000281	6.04	0.0196	0.00028	0.64		2.3	0.127		0.0016	0.0072
10-Nov-10	35.4		0.124	0.000454	7.2	0.0173		0.79	< 0.000005	2.74	0.146	0.00171	0.006	0.0213
1-Dec-10	36.9	0.000024	0.145	0.000056	7.2	0.0181	0.00019	0.82	< 0.000005	2.73		0.00183	0.0009	0.0029
20-Jan-11	39.6	0.000022	0.097	0.000545	7.68	0.0112		0.97	< 0.000005	2.83	0.188	0.00251	0.0049	0.0013
15-Feb-11	35.8	0.000036	0.092	0.000272	8.15	0.0101	0.00023		< 0.000005	3.15	0.176	0.00249		0.0021

Table B.13: Water quality data and summary statistics for station R7 (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
16-Mar-11	140	0.021	281	139	0.19	1.4	1	7.73		170	< 1	0.48	0.000014	
12-Apr-11			284	144	0.18	2.5	2.8	8.03	9.2	150		0.53	0.000018	0.000009
9-May-11	95	0.062	217	85.2	0.07	12.1	9.3	7.8	4.2	130	2	2.17	0.000029	0.000021
22-Jun-11	43	0.038	94	46.5		5.4	5.3	7.98		64	6	1.16	0.000014	0.000014
21-Jul-11	59	0.035	123	63.8	< 0.02	5.3	4.7	8.83	6	90	2	0.54	0.00001	
24-Aug-11	68	0.039	140	71.6	< 0.02		3.2	7.6	8.9	86	2	0.34	0.000006	0.000097
22-Sep-11	78	0.037	192	82.1	< 0.02	2.5	1.7	7.52	11	130	< 1	0.63	0.00001	0.000012
19-Oct-11	93		170	101	0.06	1.5	1.9	7.89	8.7		< 1	0.65	0.000015	0.000009
15-Nov-11	105	0.014	220	103	0.124	2.6	2.29	7.36	9.63	116	< 1	0.61	0.000015	0.000019
6-Dec-11	107	0.033	223	110	0.113	2.04	1.46		9.23	120	< 1	1.01	< 0.000005	0.000013
11-Jan-12	114	0.022		112		1.83	1.27	8.25	9.61	130	< 1	0.83	< 0.000005	< 0.000005
14-Feb-12	125	0.021	266	136	0.166	1.64	1.99		8.92	146	< 1	0.87	0.000008	0.000013
6-Mar-12		0.023	241	140	0.18	1.53	1.1	7.84	8.52	146	< 1	1.14	0.00001	0.000007
19-Apr-12			274					7.92				1.08		
17-May-12	83.4	0.03	173	84.8	0.055	7.73	8.37	7.92	2.92	118	2.3		0.0000268	0.0000215
31-May-12	34.7	< 0.005		37.9	0.0089	9.04			2.95	66	7		0.0000254	< 0.0000172
13-Jun-12	39.9	0.012	40	40.9	< 0.02	5.16		7.45	5	60	17.3		0.0000281	0.0000102
11-Jul-12	47.7	0.034	184	53.1	< 0.02	5.37	5.93	7.88	4.06	70	7.4	1.24	0.0000145	0.0000199
8-Aug-12	82.4		140	87.7	< 0.02	3.34	2.78	7.9	7.42	94	< 1	0.56	0.000007	0.000014
6-Sep-12			196	83.8	< 0.02	2.93	2.43	7.72	7.3	110	< 1	0.69	< 0.000005	< 0.000005
20-Sep-12	79.1	< 0.005		86.3	0.005	3.09			7.39	106	1.3		0.000011	< 0.000026
11-Oct-12				85.7	0.053	2.43	2.13	7.9	8.8	126	< 1	0.44	0.000007	0.00003
6-Nov-12		0.018	279	114	0.1	1.19	1.06	7.82	9.54	132	1.3	0.7	0.000011	0.000006
5-Dec-12		0.017	243	134	0.167	1.6	1.9	7.78	10.1	138	< 1	0.68	0.000006	< 0.000005
n	40	58	43	64	29	45	42	55	61	46	57	26	50	46
minimum	17	<0.005	40	25.2	0.005	0.7	0.8	7.12	0.3	52	<1	0.34	<0.000005	<0.000005
maximum	140	0.15	292	149	0.19	21.8	21.3	8.83	17	190	43	2.17	0.000073	0.000097
median	83	0.020	192	93	0.06	2.5	2.2	7.80	8.5	119	<1	0.69	0.0000100	0.000013
mean [a]	87	0.024	186	96	0.07	3.8	3.4	7.79	7.8	113	3	0.81	0.0000144	0.000016
standard deviation (SD) [a]	34	0.026	69	34	0.07	4.2	3.9	0.34	3.2	35	7	0.37	0.0000150	0.000018
max detection limit	-	0.05	-	-	0.02	-	-	-	0.5	-	4	-	0.000005	0.000026
# < detection limit	-	20	-	-	10	-	-	-	2	-	35	-	8	10
% < detection limit	-	34%	-	-	34%	-	-	-	3%	-	61%	-	16%	22%
95th percentile	140	0.066	284	140	0.18	11.6	10.3	8.3	11.0	168	9	1.22	0.0000433	0.000056
5th percentile	34	<0.005	86	40	0.01	0.9	0.9	7.3	2.2	60	<1	0.45	<0.000005	<0.000005
background benchmark	10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.000149	-
source [b]	-	CCME	-	-	CCME	-	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	2	0	0	-
% > current water quality criterion	-	0%	-	-	0%	2%	2%	0%	0%	-	4%	0%	0%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.13: Water quality data and summary statistics for station R7 (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
16-Mar-11	41		0.074	0.000645	8.87	0.00938		1.12	< 0.000005	3.55	0.194		0.0068	0.0065
12-Apr-11	40.4	0.000021	0.208	0.00114	8.03	0.00696	0.00034	1.03	< 0.000005	3.14	0.177	0.00271	0.0023	0.003
9-May-11		0.000048	0.453	0.000264	5.43	0.0231	0.0006	1.54	< 0.000005	2.04	0.117	0.00127	0.0025	0.0103
22-Jun-11	13.9	0.000066	0.186	0.000242	2.85	0.0166	0.00069	0.36	< 0.000005	1.18		0.00045	0.0011	0.0023
21-Jul-11	19.3	0.000046			3.78	0.0171	0.0004	0.33	< 0.000005	1.43	0.0696	0.000532	0.0016	0.0116
24-Aug-11		0.000037	0.145	0.000165	4.09	0.0179	0.00043	0.4		1.53		0.000683	0.0018	
22-Sep-11	24.8	0.000045	0.16	0.000102	4.94	0.0206	0.00031	0.58	< 0.000005	1.82	0.097	0.000981		0.0011
19-Oct-11	28.1	0.000056	0.177	0.000834	5.83	0.0252	0.00028	0.61	0.000036	2.29	0.118	0.00151	0.0103	0.0017
15-Nov-11	30.1			0.000373		0.0167	0.0003	0.78	< 0.000005		0.141	0.0017	0.0034	0.0042
6-Dec-11	33.3		0.176	0.00004	6.45	0.0181	0.00019		< 0.000005	2.46	0.137	0.00181	0.0004	0.0061
11-Jan-12		0.000022	0.149	0.000045	7.23	0.0122	0.00018	0.82	< 0.000005	2.74	0.155	0.002	0.0003	0.0036
14-Feb-12	40.2	0.000018	0.116		7.46	0.0113	0.00021	0.99	< 0.000005	2.96	0.163	0.00209	0.0013	0.0035
6-Mar-12	39.6	0.000028	0.111	0.00016	7.85		0.00044		< 0.000005		0.168	0.00229	0.0022	0.0022
19-Apr-12														
17-May-12	26	0.0000627	0.43	0.000757	4.84	0.021	0.000989	1.28	< 0.000005	1.97	0.105	0.0012	0.00625	0.00633
31-May-12	11.8	0.00011	0.354	0.000246	2.11	0.0258	0.000719	0.957	0.0000052	0.998	0.0462	0.000367	0.00457	< 0.00454
13-Jun-12	11.9	0.000144	0.329	0.000372		0.027	0.000585	0.545	0.0000064		0.0491	0.000401	0.00231	0.00072
11-Jul-12	15.5	0.0000955	0.219	0.000352	3.31	0.0195	0.000598	0.325	< 0.000005	1.37	0.0607	0.000476	0.0033	0.00641
8-Aug-12	26.4	0.000038	0.185	0.000041		0.0225	0.000254	0.495	< 0.000005	1.85		0.000979	0.00036	0.00897
6-Sep-12	25.3	0.000037	0.176	0.000063	5.01	0.0238	0.000296	0.611	< 0.000005	2.05	0.0985	0.000977		0.00109
20-Sep-12	24.5	< 0.0001	0.204	0.000487	4.76	0.026	< 0.0005	0.545	< 0.00001	1.92	0.0972	0.001	< 0.003	< 0.0328
11-Oct-12	25.3	0.000036	0.14	0.000314	5.15	0.0244	0.000253	0.605		1.98	0.104	0.00122	0.00202	0.0297
6-Nov-12	34.7	0.000063	0.187	0.000135		0.0275	0.000385	0.745	< 0.000005		0.139	0.00176	0.00191	0.00108
5-Dec-12	40.6	0.000021	0.1	0.000034	7.85	0.0199	0.000242	0.914	< 0.000005	2.8	0.161	0.00211	0.00176	0.00146
n	61	46	63	61	56	61	62	62	46	57	59	61	62	61
minimum	7.87	0.000011	0.028	0.00001	1.34	0.006	0.00015	0.325	<0.000005	0.66	0.0368	0.000367	0.0003	0.0003
maximum	42.5	0.000316	0.98	0.003	9.39	0.0752	0.002	1.75	0.0004	3.81	0.194	0.00282	0.014	0.0328
median	26.5	0.0000385	0.15	0.000352	5.7	0.0171	0.00039	0.75	<0.000005	2.04	0.118	0.00127	0.0023	0.0044
mean [a]	28.0	0.0000502	0.19	0.000476	5.8	0.0188	0.00044	0.76	0.000012	2.22	0.118	0.00144	0.0034	0.0047
standard deviation (SD) [a]	10.3	0.0000490	0.17	0.000548	2.1	0.0105	0.00031	0.31	0.000059	0.78	0.0455	0.000759	0.0034	0.0055
max detection limit	-	0.0001	0.05	0.001	-	-	0.001	-	0.00001	-	-	-	0.005	0.0328
# < detection limit	-	1	3	9	-	-	13	-	41	-	-	-	10	13
% < detection limit	-	2.2%	5%	15%	-	-	21%	-	89%	-	-	-	16%	21%
95th percentile	41.3	0.000110	0.45	0.00183	8.3	0.0369	0.0010	1.30	0.000012	3.32	0.180	0.00271	0.010	0.020
5th percentile	11.9	0.0000160	<0.05	0.000040	2.3	0.00749	0.00018	0.36	<0.000005	1.00	0.0488	0.000450	0.00040	0.00060
background benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]	-	0.0025	1	0.006	-	1.0	0.090	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	0	-	0	0	0	1	-	-	0	0	-
% > current water quality criterion	-	0%	0%	0%	-	0%	0%	0%	2%	-	-	0%	0%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.14: Water quality data and summary statistics for station FC (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
24-Jan-08	18	< 0.005	74.2	16.7	0.06	1.1	1		1.7	52	< 1			0.000014
21-Feb-08	23	< 0.005	487	17.7	0.08	0.7	< 0.5	7.15	2.4	44	< 1		0.00001	0.000007
11-Mar-08	23	< 0.005	53.3	18.7	0.08	0.9		6.1	2	76	< 1			0.000006
29-Apr-08	24	< 0.005	55	20.4	0.09	1.2	1.2	7.34	2.7	44	< 1		0.000014	0.000011
22-May-08	7.1	< 0.005	23.8	10.1	< 0.02	11.3		6.49	< 0.5	48	3		0.000071	0.000067
25-Jun-08	5.1	< 0.005	27.2	8.2	< 0.02	5	5.2	6.55	< 0.5	16	< 1		0.000019	0.000011
30-Jul-08	13	< 0.005	35.6	11.7	< 0.02	4.2	3.8	6.84	0.6	32	< 1		0.000027	0.000025
22-Aug-08	11	0.02		12.5	< 0.02	3.9			0.9		5		0.000016	
18-Sep-08	9.1	< 0.005	28.9	9.8	< 0.02	3.8	3.8	6.26	0.8	50	2		0.000011	0.000015
7-Oct-08	9.4	< 0.005	30.9	9.7	< 0.02	2.6	2.5	7.52	2.2	22	3		0.000009	0.000009
11-Dec-08	16	< 0.005	103	14.6	0.03	1.5	1.5		1.5	22	1		0.000031	0.000007
22-Jan-09	21	< 0.005		15.9						30	< 1		0.000014	0.00001
25-Feb-09	22			18.1	0.08				2.5	42	< 1		0.000012	
27-Mar-09	24	0.034		19.1	0.1				3		< 1		0.000006	0.000012
20-May-09	9.5	< 0.005	87.3	11	< 0.02			6.61	< 0.5	24	2		0.000062	0.000062
23-Jun-09	10	< 0.005	80.2	11.1	< 0.02			7.97		20	1		0.000013	0.000039
30-Jul-09	20	0.007	21	16.4	< 0.02			7.32	< 0.5	40	< 1		0.000012	
25-Aug-09	17	< 0.005	43	16.3	< 0.02			8.16	0.7		< 1		0.000023	0.000018
30-Sep-09	14	< 0.005	391	12.3	< 0.02			7.8	2.3	30	< 1		0.000017	0.000036
21-Oct-09	16	< 0.005		12.8	< 0.02				1.7	38	< 1		0.000012	0.000013
24-Nov-09	16	< 0.005	25.5	14.5					2.3				< 0.000005	< 0.000005
21-Jan-10	21	< 0.005	24.7	17.7	0.06				2	42	< 1		0.000008	0.000007
24-Feb-10	21	0.009	25.5	18.5	0.06			8.08	1.5	42	< 1		0.000008	0.000008
30-Mar-10	25	0.013	24.6	18.8	0.08			8.18	2	26	11		0.000025	0.000011
19-May-10	9.1	< 0.005	10.6	8.7	< 0.02			7.47	< 0.5	16	6		0.000045	
3-Aug-10		< 0.005	31.8	16.8	< 0.02			7.39	1.5	30	< 1		0.00001	
3-Nov-10		0.013	22.3	15.7	< 0.02			7.5	1.7	36	< 4		0.000011	0.00001
18-May-11	10	0.03		14.2	< 0.02	20.7	22.9	6.68	< 0.5	28	< 1	0.86	0.00012	0.000112
30-May-12	7	0.0095		9.91	0.0048		10.8			32	10.9	4.54	0.0000706	0.0000505
28-Aug-12				13.6										0.000016
24-Oct-12	16.4	0.013			0.0115		2.38		1.51			0.45		
n	28	29	22	30	28	12	11	19	27	25	28	3	27	25
minimum	5.1	<0.005	10.6	8.2	0.0048	0.7	<0.5	6.1	<0.5	16	<1	0.45	<0.000005	<0.000005
maximum	25	0.034	487	20.4	0.1	20.7	22.9	8.18	3	76	11	4.54	0.00012	0.000112
median	16	<0.005	31	14.6	<0.02	3.2	2.5	7.34	1.5	32	<1	0.86	0.0000140	0.000012
mean [a]	16	0.0068	78	14.4	0.03	4.7	5.0	7.23	1.4	35	2	1.95	0.0000252	0.000023
standard deviation (SD) [a]	6	0.0083	120	3.5	0.03	5.8	6.6	0.65	0.9	13	3	2.25	0.0000268	0.000026
max detection limit	-	0.005	-	-	0.02	-	0.5	-	0.5	-	4	-	0.000005	0.000005
# < detection limit	-	20	-	-	16	-	1	-	6	-	18	-	1	1
% < detection limit	-	69%	-	-	57%	-	9%	-	22%	-	64%	-	4%	4%
95th percentile	24	0.026	377	19.0	0.09	15.5	16.9	8.2	2.6	52	9	4.17	0.0000709	0.000066
5th percentile	7	<0.005	21	9.2	0.01	0.8	0.8	6.2	<0.5	17	<1	0.49	0.0000066	0.0000062
background benchmark	10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	128	-	25	4.23	0.000032	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	0	1	5	-
% > current water quality criterion	-	0%	-	-	0%	8%	9%	0%	0%	-	0%	33%	19%	-
# < current water quality criterion	-	-	-	-	-	0	1	3	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	9%	16%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.14: Water quality data and summary statistics for station FC (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
24-Jan-08	5.03	0.000015	0.021			0.00062	0.0002	0.2	< 0.000005	2.23	0.031	0.000071	0.0018	0.0032
21-Feb-08	5.29	0.000015	0.023	0.000097	1.08	0.00115	0.00015	0.21	< 0.000005	2.39		0.000064	0.0015	0.0021
11-Mar-08	5.64	0.000012	0.017		1.12	0.00085	0.00017	0.21	< 0.000005	2.43	0.0342	0.000063	0.0045	0.0055
29-Apr-08	6.02	0.000017	0.018	0.000201	1.29	0.0013	0.00018	0.25	< 0.000005		0.0366	0.000065	0.0053	0.006
22-May-08	3.05	0.000098		0.00195	0.6	0.00999	0.00074	1.11	0.000012	< 0.05	0.019	0.000264	0.0194	0.0182
25-Jun-08	2.47	0.000038	0.055	0.000215	0.49	0.00141	0.00041	0.15	< 0.000005	1.27	0.0168		0.0032	0.0035
30-Jul-08	3.51	0.000051	0.062	0.000403	0.71	0.00238	0.00047	0.12	< 0.000005	2.46	0.0229	0.000192	0.005	0.005
22-Aug-08	3.7	0.000084	0.139	0.000849	0.79	0.00436	0.00051	0.12	< 0.000005		0.0226	0.000195	0.0035	
18-Sep-08	2.95	0.000055	0.096	0.000404	0.59	0.00246	0.00036		< 0.000005	1.5	0.02		0.0025	
7-Oct-08	2.91	0.000044	0.065	0.000324	0.59	0.00208	0.00031	< 0.05	0.000005	1.45	0.0191	< 0.000002	0.0001	0.0025
11-Dec-08	4.35	0.000017	0.032	0.000176	0.91	0.00069	0.00022	0.15	< 0.000005	1.85	0.0271	0.0001	0.0025	0.0031
22-Jan-09	4.84	0.000014	0.022	0.000149	0.93	0.00118	0.00019	0.19	0.000005	2.88	0.0299	0.000081	0.0034	0.004
25-Feb-09	5.44	0.000014	0.02	0.000102	1.09	0.00098	0.00016	0.2	< 0.000005	1.99	0.0344	0.000069	0.0019	0.0019
27-Mar-09	5.61	0.000016	0.015	0.000061	1.23	0.00088	0.00015	0.22	< 0.000005	2.27	0.034	0.000064	0.0011	0.0022
20-May-09	3.31	0.000056		0.00164	0.66	0.00477	0.00067	0.83	0.000005	1.0	0.0211	0.000259	0.014	0.0148
23-Jun-09	3.11	0.000042	0.077	0.0003	0.81	0.00239	0.00045	0.17	< 0.000005	1.76	0.0207	0.000224		0.0048
30-Jul-09	5.03	0.000018	0.029	0.000539	0.94	0.00116	0.00022		< 0.000005	2.05	0.0299	0.000103	0.0015	0.003
25-Aug-09	4.79	0.000045	0.082	0.00236	1.05	0.0029	0.00054	0.18	< 0.000005	2.1	0.03	0.000181	0.0033	0.0031
30-Sep-09	3.68	0.000026	0.049	0.000287	0.76	0.00205	0.00036	0.12		1.67	0.0235	0.000144	0.0024	
21-Oct-09	3.83	0.000025	0.031	0.000068	0.8	0.00093		0.12	< 0.000005	1.71	0.0236	0.00011	0.0014	0.002
24-Nov-09		0.000021	0.035	0.000159	0.89	0.00083	0.00034	0.14	< 0.000005	1.89	0.0269	0.000098	0.0016	0.0021
21-Jan-10	5.28	0.000016	0.02	0.000076	1.1	0.00062	0.0002	0.18	< 0.000005	2.2	0.0306	0.000072	0.0012	0.0017
24-Feb-10	5.22		0.044	0.00211	1.11	0.00257	0.00019		< 0.000005	2.22	0.0304	0.000083	0.0016	0.0017
30-Mar-10	5.53	0.000099	0.469	0.00173	1.21	0.0111	0.00028	0.22	< 0.000005	2.33		0.000175	0.0071	0.0025
19-May-10	2.62	0.000105	0.249	0.00105		0.0116	0.00058	0.56	< 0.000005	0.97	0.0173	0.000325	0.0076	
3-Aug-10	5	0.000026	0.04	0.000504	1.05		0.00032	0.16	< 0.000005	2.1	0.0323	0.000115	0.0014	
3-Nov-10	4.56	0.000016	0.021	0.000105			0.00024	0.14	< 0.000005	2.25	0.0293	0.00008	0.0022	0.0017
18-May-11	4.18	0.000123	0.166	0.00252	0.92	0.0145	0.00086	1.36	0.000015	1.22	0.0282	0.000163	0.0304	0.0301
30-May-12	2.95	0.000157		0.017	0.615	0.00925	0.00086	0.66	0.0000352	1.01	0.0191	0.000242	0.0148	0.0174
28-Aug-12	4.02	0.000046	0.0772			0.00232	0.000467	0.156	< 0.000005	1.8	0.025	0.000149	0.00196	0.00194
24-Oct-12														
n	29	29	27	27	26	28	29	27	29	28	28	28	29	25
minimum	2.47	0.000012	0.015	0.000061	0.49	0.00062	0.00015	<0.05	<0.000005	<0.05	0.0168	<0.000002	0.0001	0.0017
maximum	6.02	0.000157	0.469	0.017	1.29	0.0145	0.00086	1.36	0.0000352	2.88	0.0366	0.000325	0.0304	0.0301
median	4.4	0.0000260	0.04	0.000324	0.9	0.00207	0.00032	0.18	<0.000005	1.94	0.0270	0.000107	0.0025	0.0031
mean [a]	4.3	0.0000452	0.07	0.00131	0.9	0.00348	0.00037	0.30	0.000005	1.82	0.0263	0.000134	0.0051	0.0058
standard deviation (SD) [a]	1.1	0.0000383	0.10	0.00323	0.2	0.00393	0.00021	0.32	0.000007	0.60	0.00580	0.0000777	0.0066	0.007
max detection limit	-	-	-	-	-	-	-	0.05	0.000005	0.05	-	0.000002	-	-
# < detection limit	-	-	-	-	-	-	-	1	23	1	-	1	-	-
% < detection limit	-	-	-	-	-	-	-	4%	79%	3.6%	-	4%	-	-
95th percentile	5.6	0.000116	0.22	0.00247	1.2	0.0114	0.00081	1.03	0.000014	2.45	0.0343	0.000262	0.018	0.018
5th percentile	2.7	0.0000140	0.02	0.0000704	0.6	0.000645	0.00015	0.12	<0.000005	0.98	0.0179	0.0000634	0.0011	0.0017
background benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]	-	0.0025	1	0.004	-	0.7	0.025	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	1	-	0	0	0	0	-	-	0	1	-
% > current water quality criterion	-	0%	0%	4%	-	0%	0%	0%	0%	-	-	0%	3%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.15: Water quality data and summary statistics for station R6 (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
23-Jan-08	140	< 0.005	272	167	0.22	1	1	6.8	23.3	200	< 1		0.000013	0.000014
20-Feb-08	150	< 0.005	355	159	0.2	1.1	1.4	7.6	23	180	1		0.000013	0.000007
4-Mar-08	159	< 0.01		186				7.8	21.4		< 1	0.64	< 0.0002	< 0.0002
13-Mar-08	150	< 0.005	214	167	0.2	0.8	0.7	6.43	21.7	220	< 1		0.000007	0.000017
28-Apr-08	130	< 0.005		147	0.14	1.1	1.2	7.96	20	180	1		0.000013	0.000049
21-May-08	49	< 0.005	118.2	60.3	0.03	12.2	13	7.91	< 0.5	110	20		0.000074	0.000044
24-Jun-08	68	< 0.005		75.2	0.02	6.4	7	7.44	10	110	27		0.000052	0.000084
22-Jul-08	99	< 0.01		115					17		5		0.000023	0.000014
29-Jul-08	120	< 0.005	260	124	0.11	3.4	3.2	8.34	18	180	2		0.000015	0.000013
19-Aug-08	151	0.01		146				8	18.8			0.37	< 0.0002	< 0.0002
4-Sep-08	110	< 0.01		129					19		3		0.000019	
17-Sep-08	120	< 0.005	270	128	0.09	4.3	3.5	7.79	21	170	2		0.00002	0.000007
8-Oct-08	130	< 0.005	281	144	0.1	1	1.9	8.35	21	160	< 1		0.000016	0.000016
10-Dec-08	150	< 0.005	414	172	0.2	1.8	1.5	7.38	24	210	3		0.000017	
22-Jan-09	150	0.006		164	0.17				24		2		0.000017	0.000017
24-Feb-09	150	0.007		251	0.24					300	< 1		0.000015	0.00001
26-Mar-09	160		296	166	0.22			7.2	25	200	< 1		0.000059	0.000045
20-May-09	88	< 0.005	512	92.6	0.06			7.51	13	110	13			0.000045
23-Jun-09	110	< 0.005	620	109	0.05			7.93	15	130	12		0.000017	0.000669
30-Jul-09	140	0.006	289	156	< 0.02			8.3		170	7		0.000009	0.000009
25-Aug-09	120	< 0.005	252	135	0.04			8.39	16	130	2		0.000089	0.000023
30-Sep-09	120	< 0.005	186.5	133	0.14			8.21	19		< 1		0.000014	0.000014
28-Oct-09	140	< 0.005		157	0.16				21	160	1		0.000032	0.000018
24-Nov-09	150	0.008	4.4	161	0.19			8.05	24	170			0.000034	0.000009
21-Jan-10	150	0.007	178.4	168	0.22				22	200	1		0.000012	< 0.000005
26-Feb-10	150	< 0.005	179.6	160	0.22			8.13	23	200	< 1		0.000008	0.000008
30-Mar-10	150	< 0.005	178	165	0.21			8.34	24	170	< 1		0.000014	0.000036
19-May-10	79	0.023	113	97.4	0.05			7.93	14	120	62		0.000152	
3-Aug-10	160	< 0.005	211	153	0.02			8.46	21	170	< 1		0.000017	
4-Nov-10		0.012	168.7	159	0.16			7.99	22	170	< 4		0.000007	0.000009
19-May-11	43	0.025		47.5	0.04	22.2	22.9	7.5	< 0.5	74	85	6.2	0.000236	0.000055
29-May-12	61.7				0.0518		10.2		8.74	98	8.4	3.4	0.0000615	0.0000283
29-Aug-12				141									0.000015	0.000011
23-Oct-12	147	0.03			0.175		2.17		22.7	192	< 1	0.52		
n	32	31	21	32	29	11	13	25	31	27	31	5	30	27
minimum	43	<0.005	4.4	47.5	<0.02	0.8	0.7	6.43	<0.5	74	<1	0.37	0.000007	<0.000005
maximum	160	0.03	620	251	0.24	22.2	22.9	8.46	25	300	85	6.2	0.000236	0.000669
median	140	<0.005	252	150	0.14	1.8	2.2	7.93	21.0	170	2	0.64	0.0000170	0.000016
mean [a]	125	0.006	256	142	0.13	5.0	5.4	7.83	18.5	166	9	2.23	0.0000364	0.000047
standard deviation (SD) [a]	34	0.007	137	39	0.08	6.7	6.5	0.51	6.4	46	19	2.55	0.0000489	0.00013
max detection limit	-	0.01	-	-	0.02	-	-	-	0.5	-	4	-	-	0.000005
# < detection limit	-	21	-	-	1	-	-	-	2	-	12	-	-	1
% < detection limit	-	68%	-	-	3%	-	-	-	6%	-	39%	-	-	4%
95th percentile	159	0.024	512	178	0.22	17.2	17.0	8.4	24.0	217	45	5.64	0.000124	0.000075
5th percentile	56	<0.005	113	68	<0.02	0.9	0.9	6.9	4.6	102	<1	0.4	0.00000745	0.0000070
background benchmark	10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.000222	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	3	1	1	-
% > current water quality criterion	-	0%	-	-	0%	9%	8%	0%	0%	-	10%	20%	3%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	4%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.15: Water quality data and summary statistics for station R6 (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
23-Jan-08	48.3	0.000025	0.117	0.000029	11.3	0.0111	0.00024	1.26	< 0.000005	2.12	0.151	0.00248	0.0008	0.0018
20-Feb-08	46.7	0.000022	0.132	0.000029	10.3	0.00985	0.00022	1.32	< 0.000005	2.22	0.146	0.00244	0.0014	0.0012
4-Mar-08	49.7	< 0.001	0.14		14.9	0.01	< 0.001	1.5	< 0.00025	2.93	0.19	0.0021	< 0.005	< 0.005
13-Mar-08	48.8	0.00002	0.148	0.000054	10.9	0.00945	0.00022	1.33	< 0.000005	2.15	0.148	0.0024	0.0037	0.0054
28-Apr-08	43.1	0.000044	0.281	0.000078	9.63	0.018	0.00022	1.32	< 0.000005	1.94	0.139	0.00225	0.004	0.0058
21-May-08	16.5	0.000264	0.568	0.00048	4.66	0.0398	0.00183	1.39	0.000008	0.75	0.0469	0.000577	0.0053	0.003
24-Jun-08	20.6	0.000231	0.433	0.000575	5.77	0.0342	0.00115	0.69	0.000009	0.97	0.0592	0.00083	0.0034	0.0027
22-Jul-08		0.000064	0.125	0.00009	8.47	0.0128	0.00056	0.76		1.35		0.00117		0.0007
29-Jul-08	34.8	0.000051	0.09	0.000142	9.03	0.0117	0.00042	0.84	< 0.000005	2.18	0.0998	0.00144	0.0015	0.002
19-Aug-08	39	< 0.001	0.2	< 0.001	11.7	0.013	< 0.001		< 0.00025	1.89	0.12	0.0015	< 0.005	< 0.005
4-Sep-08	35.6	0.000055		0.000049	9.7	0.013	0.00052	0.91	< 0.000005	1.63	0.104	0.00145	0.0006	0.0006
17-Sep-08	35.6	0.000049	0.106	0.000057	9.41	0.013	0.00046	0.94	< 0.000005	1.56	0.101	0.00139	0.0006	0.0001
8-Oct-08	39.9	0.000047	0.11	0.000109	10.7	0.0165	0.00041	0.73	0.000005	1.73	0.111	< 0.000002	< 0.0001	0.0016
10-Dec-08	48.8	0.000052	0.134	0.00014	12.3	0.018	0.00034	1.24	< 0.000005	2.01	0.141	0.00235	0.0018	0.0028
22-Jan-09	47.6	0.000039	0.189	0.000174	10.9	0.0189	0.00026	1.23	< 0.000005	2.88	0.148	0.00244	0.0023	0.0043
24-Feb-09	74.6	0.000038	0.037	0.000204	15.8	0.0316	0.00083	1.68		4.9	0.251	0.00238		0.0078
26-Mar-09	48	0.00003	0.177		11.1	0.0123	0.00024	1.29	< 0.000005	2.02	0.15	0.00256	0.0013	0.0007
20-May-09	25.5	0.000166	0.396		7.01	0.0421	0.0011	1.18	< 0.000005	1.06	0.0739	0.00112	0.0023	0.0013
23-Jun-09	30.5	0.000065	0.162	0.000341	8.03	0.0127	0.00058	0.84	< 0.000005	1.54	0.0851	0.00129	0.0026	0.0067
30-Jul-09	44.3	0.000046	0.154	0.000057	11	0.0129	0.0003	1.14	< 0.000005		0.125	0.00197	0.0004	0.0006
25-Aug-09	37.6	0.000059		0.000142	9.91	0.0177	0.00055	1.02	< 0.000005	1.85	0.113	0.00166	0.001	0.0007
30-Sep-09	37.8	0.000045	0.136	0.00003	9.39	0.0184	0.00038	0.98	< 0.000005	1.77	0.113	0.00178	0.0006	0.0023
28-Oct-09	45	0.000037	0.135	0.00177	10.9	0.0182	0.00036	1.15		1.94	0.127	0.00206	0.0017	
24-Nov-09	46.1	0.00003		0.000172	11.2	0.00609	0.00035	1.19	< 0.000005	2.11	0.134	0.00219	0.0027	0.0024
21-Jan-10	49.1	0.000033	0.118	0.000016	11	0.0149	0.00026	1.31	< 0.000005	2.16	0.141	0.00233	0.0006	0.0008
26-Feb-10	46.9	0.000026	0.112	0.000042	10.3	0.0106	0.00024	1.24	< 0.000005	2.02	0.142	0.00241	0.0007	0.0009
30-Mar-10	48	0.000021	0.124	0.000025	11	0.00846	0.00019	1.3	< 0.000005	2.22		0.00261	0.0006	0.0022
19-May-10	26.7	0.000985	2.2	0.00155	7.49	0.149	0.00315	1.16	< 0.000005	1.21	0.0804	0.0014	0.0114	
3-Aug-10	42.9	0.000038	0.169	0.000053	11.3	0.0129	0.0004		< 0.000005	1.84	0.128		0.0003	
4-Nov-10	45.2		0.083	0.000025	11.3		0.00032	1.14	< 0.000005	1.96	0.135	0.00223	0.0004	0.0014
19-May-11	12.8	0.00127	3.15	0.00157	3.8	0.166	0.0046	1.8	0.000037	0.6	0.0418	0.000592	0.015	0.0063
29-May-12	18.5	0.000145	0.369	0.000189	4.99	0.0337	0.00103	1.24	0.0000104	0.806	0.0571	0.000647	0.00208	0.0035
29-Aug-12	38.9	0.000056	0.144	0.000033	10.5	0.0145	0.000579	1.08	< 0.000005	1.73	0.112	0.0015	0.00047	0.00044
23-Oct-12														
n	32	30	30	30	33	32	33	31	28	32	31	32	31	30
minimum	12.8	0.00002	0.037	0.000016	3.8	0.00609	0.00019	0.69	<0.000005	0.6	0.0418	<0.000002	<0.0001	0.0001
maximum	74.6	0.00127	3.15	0.00177	15.8	0.166	0.0046	1.8	0.000037	4.9	0.251	0.00261	0.015	0.0078
median	43.0	0.0000465	0.14	0.0000995	10.5	0.0138	0.00041	1.19	<0.000005	1.92	0.125	0.00188	0.0015	0.0021
mean [a]	39.8	0.000135	0.35	0.000291	9.9	0.0260	0.00071	1.17	0.000005	1.88	0.120	0.00174	0.0024	0.0025
standard deviation (SD) [a]	12.3	0.000279	0.66	0.000478	2.6	0.0357	0.00091	0.26	0.000007	0.77	0.0423	0.000698	0.0032	0.0021
max detection limit	-	-	-	0.001	-	-	0.001	-	0.000005	-	-	0.000002	0.005	0.0050
# < detection limit	-	-	-	1	-	-	2	-	23	-	-	1	3	2
% < detection limit	-	-	-	3%	-	-	6%	-	82%	-	-	3%	10%	7%
95th percentile	49.4	0.000661	1.47	0.00156	13.3	0.0902	0.0024	1.59	0.000010	2.90	0.171	0.00252	0.0084	0.0065
5th percentile	17.6	0.0000215	0.086	0.0000250	4.9	0.00900	0.00022	0.75	<0.000005	0.78	0.0520	0.000585	0.00035	0.00051
background benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]	-	0.0025	1	0.007	-	1.3	0.13	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	2	0	-	0	0	0	0	-	-	0	0	-
% > current water quality criterion	-	0%	7%	0%	-	0%	0%	0%	0%	-	-	0%	0%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.16: Water quality data and summary statistics for station W10 (reference), Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
21-May-08	17	< 0.005	46.8	23.1	< 0.02	11.4	12.1	7.08	< 0.5	44	3		0.000072	0.000077
1-Jun-08		< 0.01		24				7.6	2.97		< 1		< 0.0002	< 0.0002
24-Jun-08	34	< 0.005	86.6	36.7	< 0.02	4.5	4.6	7.46	1.1	66	2		0.000017	0.000025
30-Jul-08	49	< 0.005	123.8	44.9	< 0.02	4.6	4.4	7.41	3.3	66	< 1		0.000021	0.000023
17-Sep-08	45	< 0.005		45	< 0.02	4.9	4.2	7.14	3.9	88	< 1		0.000022	0.000012
29-Sep-08		0.04		49				7.1	3.96		2			< 0.0002
8-Oct-08	48	< 0.005	113.8		< 0.02	3.2	3.4		4.8	74	< 1		0.000048	0.000014
4-May-09	15	0.06	41	21.2		23.5	19.8		< 0.5	40	< 1		0.000166	0.000152
10-Jun-09	33	< 0.005	59	29.6		5.6	5.2	7	1.4	56	< 1		0.000013	0.000014
14-Jul-09	52		100	53.1		3.2	2.9	8.5	6.5	54	7		0.000011	0.000025
3-Sep-09	65	< 0.01		62.5		3.1	3.1	7.96	3.8	72			0.000018	0.00002
5-Oct-09	60	0.03	70	58.6		2.7	2.7	7.4	3.5		< 4		0.000022	0.000058
3-May-10	38	0.038	109	38.9		12.1	11.2	7.71	0.3	50	< 1		0.000064	
5-Jun-10	38		68	35.8		5.2	5	7.76	1.9	60	< 1		0.000025	0.000032
10-Jul-10	52		101	52.4		4.1	4	8.08	1	40	< 1		0.000016	0.000071
19-May-11	16	0.019			< 0.02	30.3	27.8	7.4	< 0.5	46	1	0.67	0.000139	0.000141
30-May-12	22.4	0.013		24.4			9.61		< 0.5	42	12.9	1.43	0.0000495	0.0000315
28-Aug-12				63.4									0.000024	0.000016
24-Oct-12	57.5	0.019			< 0.002		3.08		3.98	80		0.24		
n	16	15	11	16	7	14	16	14	18	15	16	3	16	15
minimum	15	<0.005	41	21.2	<0.002	2.7	2.7	7	0.3	40	<1	0.24	0.000011	0.000012
maximum	65	0.06	123.8	63.4	0.02	30.3	27.8	8.5	6.5	88	12.9	1.43	0.000166	0.000152
median	42	<0.01	87	41.9	<0.02	4.8	4.5	7.44	2.4	56	<1	0.67	0.0000230	0.0000250
mean [a]	40	0.016	84	41.4	0.01	8.5	7.7	7.54	2.4	59	2	0.78	0.0000455	0.0000474
standard deviation (SD) [a]	16	0.018	28	14.4	0.003	8.4	7.1	0.43	1.9	15	3	0.60	0.0000459	0.0000452
max detection limit	-	0.01	-	-	0.02	-	-	-	0.5	-	4	-	-	-
# < detection limit	-	8	-	-	7	-	-	-	4	-	10	-	-	-
% < detection limit	-	53%	-	-	100%	-	-	-	22%	-	63%	-	-	-
95th percentile	61	0.046	119	62.7	<0.02	25.9	21.8	8.2	5.1	82	8	1.35	0.000146	0.000144
5th percentile	16	<0.005	44	22.6	<0.02	3.0	2.9	7.1	0.47	40	<1	0.28	0.0000125	0.0000134
background benchmark	10.0 - 150.0	0.054	292	159	0.20	0.8 -19.0	0.7 - 15.0	6.6 - 8.4	21.5	180	20	2.23	0.000107	0.000067
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	218	-	25	4.23	0.000077	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	2	2	0	0	-	0	0	2	-
% > current water quality criterion	-	0%	-	-	0%	14%	13%	0%	0%	-	0%	0%	13%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was at the 95th percentile of pooled reference station data; therefore the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table B.16: Water quality data and summary statistics for station W10 (reference), Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
21-May-08	7.47	0.000112	0.149	0.00229	1.09	0.0119	0.00072	1.09	0.000018	0.83		0.000122	0.0164	0.0161
1-Jun-08	7.88	< 0.001	< 0.05	< 0.001	1.04	< 0.001	< 0.001	0.4	< 0.00025	1.4	0.027	< 0.0005	< 0.005	< 0.005
24-Jun-08	12.1	0.000027	0.024	0.000155	1.59	0.00035	0.00049	0.41	< 0.000005	1.54	0.0434	0.000114	0.0023	0.0026
30-Jul-08	14.9	0.000025	0.02	0.000344	1.88	0.00046	0.00043	0.39	< 0.000005	2.89	0.0532	0.000126	0.0045	0.0038
17-Sep-08	14.9	0.000025	0.018	0.000085	1.92	0.00035	0.00042	0.45	< 0.000005	1.68	0.0501	0.000113	0.0018	0.0005
29-Sep-08	16	< 0.001	< 0.05	< 0.001	2.14		< 0.001	0.5	< 0.00025	1.95	0.056	< 0.0005	< 0.005	0.015
8-Oct-08	14.9	0.000022	0.017	0.000304	1.98	0.00043	0.00037	0.05	0.0504	1.62	0.0504	< 0.000002	0.0001	0.0026
4-May-09	6.56	0.000072	0.133	0.00234	0.99	0.00445		1.48	0.000022	0.45	0.0234	0.000062	0.0389	0.0386
10-Jun-09	10.2	0.000023	0.03		1.3	0.00083	0.00049	0.38	< 0.000005	1.38	0.0362	0.000137	0.0046	0.0027
14-Jul-09	15.6	0.000028	0.018	0.000164	2.16	0.00037	0.00038	0.43	< 0.000005	1.76	0.0555	0.000116	0.001	0.0023
3-Sep-09	19.6	0.000024	0.022	0.000461	2.68	0.00072	0.00037	0.51	< 0.000005	2	0.0673	0.000161	0.0015	
5-Oct-09	19.3	0.000019	0.014	0.000165	2.54	0.00027	0.0003		< 0.000005	1.84	0.0635		0.001	0.0034
3-May-10	12.6			0.000755	1.83	0.00317	0.00065	1	0.000006	1.18	0.0431	0.000106	0.0148	0.0118
5-Jun-10		0.000033		0.000717	1.72	0.00081	0.00061		< 0.000005	1.62	0.0406	0.000133	0.0036	0.0114
10-Jul-10	14.4	0.000021	0.013	0.000196	2.21	0.00026	0.00038	0.43	< 0.000005	1.83	0.0575		0.0017	
19-May-11	7.96	0.000098	0.145	0.00189	1.16	0.00558	0.00075	2.18	0.000024	0.55	0.0282	0.000069		0.0362
30-May-12		0.0000697	0.119	0.000803	1.1	0.00251	0.000655	0.714			0.028	0.000162		0.00698
28-Aug-12	21	0.000024	0.0358	0.000259	2.67	0.000941	0.000373	0.536	< 0.000005	1.92		0.000153	0.00157	
24-Oct-12														
n	16	15	16	17	18	17	17	16	14	17	16	16	16	15
minimum	6.56	0.000019	0.013	0.000085	0.99	0.00026	0.0003	0.05	<0.000005	0.45	0.0234	<0.000002	0.0001	0.0005
maximum	21	0.000112	0.149	0.00234	2.68	0.0119	0.001	2.18	0.000024	2.89	0.0673	<0.0005	0.0389	0.0386
median	14.7	0.000025	0.027	0.000461	1.9	0.000810	0.00049	0.48	<0.000005	1.62	0.0468	0.000124	0.0030	<0.005
mean [a]	13.5	0.000042	0.05	0.000702	1.8	0.00199	0.00049	0.68	0.000007	1.56	0.0452	0.000130	0.0062	0.0104
standard deviation (SD) [a]	4.5	0.000031	0.05	0.000740	0.6	0.00301	0.00014	0.53	0.000008	0.58	0.0137	0.0000621	0.0099	0.0120
max detection limit	-	-	0.05	0.001	-	0.001	0.001	-	0.000005	-	-	0.0005	0.005	0.005
# < detection limit	-	-	2	2	-	1	2	-	10	-	-	3	2	1
% < detection limit	-	-	13%	12%	-	6%	12%	-	71%	-	-	19%	13%	7%
95th percentile	20.0	0.00010	0.15	0.00230	2.7	0.00684	0.0010	1.66	0.00002	2.18	0.0645	<0.0005	0.022	0.0369
5th percentile	7.2	0.000020	0.014	0.000141	1.0	0.000268	0.00036	0.30	<0.000005	0.53	0.0261	0.0000470	0.00078	0.00176
background benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
current water quality criterion [b]	-	0.0025	1	0.004	-	0.8	0.049	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	0	-	0	0	0	0	-	-	0	1	-
% > current water quality criterion	-	0%	0%	0%	-	0%	0%	0%	0%	-	-	0%	6%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
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[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

ATTACHMENT C

WATER QUALITY DATA,
MINE-INFLUENCED STATIONS

Table C.1: Water quality summary statistics for station V27 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	46	21	140	84	83	35
	Ammonia-N	mg/L	51	<0.005	0.14	0.010	0.018	0.022
	Conductivity, Field	µS/cm	42	70	1700	513	523	277
	Hardness, Total ($CaCO_3$)	mg/L	53	34.9	482	270	255	116
	Nitrate-N	mg/L	34	<0.02	1.46	0.60	0.57	0.40
	Organic carbon, Dissolved	mg/L	40	<0.5	9.2	1.6	2.1	1.7
	Organic carbon, Total	mg/L	44	<0.5	9.3	1.7	2.3	1.9
	pH, Field	pH units	45	5.75	8.68	8.05	7.87	0.59
	Sulfate	mg/L	52	32.6	380	163	161	84.4
	Total dissolved solids	mg/L	43	86	660	340	335	150
	Total suspended solids	mg/L	48	<1	61	<1	2	9
	Turbidity, Lab	NTU	24	0.08	1.3	0.25	0.28	0.26
Metals	Cadmium, Total	mg/L	49	<0.000005	0.000717	0.0000660	0.000110	0.000129
	Cadmium, Dissolved	mg/L	51	<0.000005	0.000773	0.000064	0.00010	0.00013
	Calcium, Total	mg/L	51	13.4	138	65.0	63.2	29.5
	Cobalt, Total	mg/L	46	<0.000005	0.00293	0.0000330	0.000145	0.000437
	Iron, Total	mg/L	46	0.005	1.33	0.035	0.077	0.20
	Lead, Total	mg/L	49	<0.000005	0.0244	0.000389	0.00108	0.00347
	Magnesium, Total	mg/L	51	0.4	50.3	24.0	23.1	11.4
	Manganese, Total	mg/L	50	<0.00005	1.03	0.00368	0.0469	0.157
	Nickel, Total	mg/L	49	0.00039	0.301	0.00076	0.0070	0.043
	Potassium, Total	mg/L	49	<0.05	1.5	0.86	0.84	0.28
	Silver, Total	mg/L	46	<0.000005	0.000019	<0.000005	0.000004	0.000003
	Sodium, Total	mg/L	49	1.1	4.51	3.14	2.92	0.88
	Strontium, Total	mg/L	49	0.0574	0.453	0.230	0.226	0.0970
	Uranium, Total	mg/L	50	<0.000002	0.00876	0.00339	0.00387	0.00249
	Zinc, Total	mg/L	51	<0.0001	0.138	0.031	0.035	0.021
	Zinc, Dissolved	mg/L	48	0.001	0.104	0.030	0.036	0.018

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.2: Water quality summary statistics for station V4 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	42	83	340	280	269	58
	Ammonia-N	mg/L	44	<0.005	0.23	0.031	0.040	0.048
	Conductivity, Field	µS/cm	39	188.8	908	545	555	150
	Hardness, Total ($CaCO_3$)	mg/L	47	13.3	437	336	319	91
	Nitrate-N	mg/L	29	<0.02	0.19	0.07	0.07	0.06
	Organic carbon, Dissolved	mg/L	42	2	12.8	4.3	4.9	2.2
	Organic carbon, Total	mg/L	41	2.1	13.2	4.5	5.0	1.9
	pH, Field	pH units	44	7.19	8.5	8.02	7.97	0.33
	Sulfate	mg/L	46	3.4	92	56.8	57.6	19.7
	Total dissolved solids	mg/L	39	130	490	372	366	79
	Total suspended solids	mg/L	46	<1	120	1.95	7.4	20
	Turbidity, Lab	NTU	18	0.69	3.13	1.60	1.64	0.63
Metals	Cadmium, Total	mg/L	42	<0.000005	0.0000806	0.0000215	0.0000239	0.0000153
	Cadmium, Dissolved	mg/L	45	<0.000005	0.000069	0.000020	0.000023	0.000014
	Calcium, Total	mg/L	46	2.91	107	83.0	74.9	24.6
	Cobalt, Total	mg/L	41	<0.000005	0.000729	0.0000700	0.000103	0.000124
	Iron, Total	mg/L	42	0.013	1.58	0.24	0.31	0.31
	Lead, Total	mg/L	44	<0.000005	0.0135	0.000223	0.000914	0.00254
	Magnesium, Total	mg/L	47	0.45	39.8	30.2	28.3	9.8
	Manganese, Total	mg/L	44	<0.00005	0.492	0.0454	0.0562	0.0716
	Nickel, Total	mg/L	47	0.00017	0.0088	0.00083	0.0011	0.0012
	Potassium, Total	mg/L	46	0.64	1.63	1.06	1.08	0.23
	Silver, Total	mg/L	43	<0.000005	0.000025	<0.000005	0.000003	0.000002
	Sodium, Total	mg/L	44	0.97	4.87	3.17	3.17	0.94
	Strontium, Total	mg/L	45	0.0993	0.432	0.337	0.323	0.0827
	Uranium, Total	mg/L	47	<0.000002	0.0176	0.00992	0.00987	0.00446
	Zinc, Total	mg/L	44	0.00051	0.0607	0.0036	0.0058	0.0097
	Zinc, Dissolved	mg/L	41	<0.0001	0.0195	0.0036	0.0044	0.0042

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.3: Water quality summary statistics for station VGMAIN (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	20	39	213	134	127	54
	Ammonia-N	mg/L	21	0.009	0.045	0.011	0.017	0.013
	Conductivity, Field	µS/cm	4	121	700	325	368	243
	Hardness, Total ($CaCO_3$)	mg/L	20	53.8	415	235	243	109
	Nitrate-N	mg/L	6	0.06	0.42	0.23	0.25	0.15
	Organic carbon, Dissolved	mg/L	4	2.5	19.4	12.6	11.8	8.0
	Organic carbon, Total	mg/L	6	1.9	20.4	8.7	10.2	7.6
	pH, Field	pH units	17	7.4	8.4	8.1	8.0	0.3
	Sulfate	mg/L	21	24	340	130	129	69
	Total dissolved solids	mg/L	6	70	560	255	281	183
	Total suspended solids	mg/L	19	<1	190	<1	15	44
	Turbidity, Lab	NTU	16	<0.1	80	0.30	5.90	19.8
Metals	Cadmium, Total	mg/L	18	0.000052	0.0005	<0.0002	0.000149	0.000128
	Cadmium, Dissolved	mg/L	18	0.000042	0.0003	<0.0002	0.000099	0.000054
	Calcium, Total	mg/L	21	13.6	119	64.8	60.1	26.3
	Cobalt, Total	mg/L	19	0.000083	0.00473	<0.001	0.000697	0.000991
	Iron, Total	mg/L	21	0.029	6.1	0.07	0.46	1.35
	Lead, Total	mg/L	19	0.000077	0.0464	<0.001	0.00357	0.0105
	Magnesium, Total	mg/L	18	4.79	39.1	20.2	22.9	11.3
	Manganese, Total	mg/L	20	0.004	0.318	0.00800	0.0380	0.0746
	Nickel, Total	mg/L	19	0.000685	0.0158	0.0016	0.0022	0.0034
	Potassium, Total	mg/L	20	0.6	1.9	1.04	1.06	0.33
	Silver, Total	mg/L	7	<0.000005	0.000126	0.000008	0.000026	0.000045
	Sodium, Total	mg/L	21	0.9	4.99	2.67	2.89	1.21
	Strontium, Total	mg/L	19	0.0563	0.401	0.259	0.235	0.101
	Uranium, Total	mg/L	19	0.0011	0.0099	0.00360	0.00478	0.00298
	Zinc, Total	mg/L	21	<0.005	0.128	0.023	0.027	0.025
	Zinc, Dissolved	mg/L	18	<0.005	0.026	0.012	0.014	0.0068

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.4: Water quality summary statistics for station VW3 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	4	28	65	56	51	18
	Ammonia-N	mg/L	4	<0.005	0.04	0.018	0.020	0.016
	Conductivity, Field	µS/cm	1	-	-	-	-	-
	Hardness, Total ($CaCO_3$)	mg/L	4	69.2	88.5	72.1	75.5	8.9
	Nitrate-N	mg/L	4	0.156	0.21	0.17	0.18	0.02
	Organic carbon, Dissolved	mg/L	1	-	-	-	-	-
	Organic carbon, Total	mg/L	3	2.66	20.6	10.7	11.3	9.0
	pH, Field	pH units	1	-	-	-	-	-
	Sulfate	mg/L	4	28	53	33.5	37.0	11.0
	Total dissolved solids	mg/L	3	100	140	120	120	20
	Total suspended solids	mg/L	4	1.6	39	11.2	15.3	17.7
	Turbidity, Lab	NTU	3	0.54	12.8	4.03	5.79	6.32
Metals	Cadmium, Total	mg/L	4	0.000031	0.00112	0.000209	0.000392	0.000513
	Cadmium, Dissolved	mg/L	4	0.000024	0.00114	0.00017	0.00037	0.00053
	Calcium, Total	mg/L	3	18.3	26.1	19.5	21.3	4.2
	Cobalt, Total	mg/L	4	0.000031	0.00219	0.000291	0.000701	0.00102
	Iron, Total	mg/L	4	0.0905	1.31	0.23	0.46	0.58
	Lead, Total	mg/L	4	0.000212	0.0113	0.00128	0.00352	0.00526
	Magnesium, Total	mg/L	4	4.96	6.1	5.9	5.7	0.5
	Manganese, Total	mg/L	3	0.00587	0.0394	0.0132	0.0195	0.0176
	Nickel, Total	mg/L	2	0.000407	0.0018	0.0011	0.0011	0.00098
	Potassium, Total	mg/L	4	0.36	1.7	0.56	0.79	0.63
	Silver, Total	mg/L	4	<0.000005	0.000036	0.0000095	0.000014	0.000016
	Sodium, Total	mg/L	3	0.6	1.89	0.96	1.15	0.67
	Strontium, Total	mg/L	4	0.0755	0.11	0.0909	0.0918	0.0141
	Uranium, Total	mg/L	4	0.000462	0.00178	0.00107	0.00110	0.000539
	Zinc, Total	mg/L	4	0.0149	1.24	0.24	0.43	0.58
	Zinc, Dissolved	mg/L	3	0.0119	1.38	0.41	0.60	0.70

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.5: Water quality summary statistics for station VW1 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	10	55	290	152	158	66
	Ammonia-N	mg/L	10	<0.005	0.089	0.018	0.036	0.033
	Conductivity, Field	µS/cm	5	9.5	339	267	220	127
	Hardness, Total ($CaCO_3$)	mg/L	8	154	391	197	227	76
	Nitrate-N	mg/L	10	0.05	0.19	0.12	0.12	0.04
	Organic carbon, Dissolved	mg/L	0	-	-	-	-	-
	Organic carbon, Total	mg/L	3	3.88	24.4	10.6	13.0	10.5
	pH, Field	pH units	5	7.93	8.69	8.01	8.14	0.31
	Sulfate	mg/L	10	27	110	46.2	51.7	23.4
	Total dissolved solids	mg/L	9	130	440	220	244	96
	Total suspended solids	mg/L	10	<4	1500	7.5	177	468
	Turbidity, Lab	NTU	2	0.46	756	-	-	-
Metals	Cadmium, Total	mg/L	9	0.000007	0.000245	0.0000150	0.0000427	0.0000769
	Cadmium, Dissolved	mg/L	10	0.000007	0.000164	0.000013	0.000034	0.000050
	Calcium, Total	mg/L	10	29.7	96.1	47.0	53.3	19.1
	Cobalt, Total	mg/L	9	0.000068	0.0259	0.000110	0.003109	0.008558
	Iron, Total	mg/L	9	0.106	44.9	0.13	5.30	14.9
	Lead, Total	mg/L	9	0.000058	0.0609	0.000222	0.00706	0.0202
	Magnesium, Total	mg/L	9	9.1	36.7	17.3	18.8	7.9
	Manganese, Total	mg/L	10	0.0314	1.07	0.0689	0.166	0.319
	Nickel, Total	mg/L	9	0.0005	0.0815	0.00058	0.010	0.027
	Potassium, Total	mg/L	10	0.67	5.1	0.89	1.35	1.35
	Silver, Total	mg/L	10	<0.000005	0.000441	<0.000005	0.000050	0.00014
	Sodium, Total	mg/L	10	1.55	7.16	3.23	3.50	1.60
	Strontium, Total	mg/L	9	0.137	0.424	0.203	0.233	0.0840
	Uranium, Total	mg/L	10	0.0014	0.00557	0.00260	0.00291	0.00118
	Zinc, Total	mg/L	10	0.002	0.213	0.0034	0.041	0.079
	Zinc, Dissolved	mg/L	8	0.0018	0.123	0.0032	0.020	0.042

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.6: Water quality summary statistics for station VW2 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	8	88	320	305	266	85
	Ammonia-N	mg/L	9	<0.005	0.04	<0.005	0.013	0.016
	Conductivity, Field	µS/cm	5	9.7	685	422	385	242
	Hardness, Total ($CaCO_3$)	mg/L	9	129	436	391	352	98
	Nitrate-N	mg/L	8	<0.02	0.32	0.16	0.17	0.09
	Organic carbon, Dissolved	mg/L	1	-	-	-	-	-
	Organic carbon, Total	mg/L	3	3	24.2	7.0	11.4	11.3
	pH, Field	pH units	6	7.98	8.41	8.2	8.2	0.1
	Sulfate	mg/L	9	28	120	95.6	92.5	28.3
	Total dissolved solids	mg/L	9	180	530	430	404	106
	Total suspended solids	mg/L	7	<1	130	2	21	48
	Turbidity, Lab	NTU	3	0.13	24.6	0.56	8.43	14.01
Metals	Cadmium, Total	mg/L	9	0.000071	0.000911	0.000115	0.000204	0.000267
	Cadmium, Dissolved	mg/L	9	0.0000478	0.000179	0.00011	0.00011	0.000040
	Calcium, Total	mg/L	9	32.1	109	96.3	87.7	24.5
	Cobalt, Total	mg/L	8	0.000009	0.00206	0.0000155	0.000274	0.000722
	Iron, Total	mg/L	6	0.006	4.31	0.012	0.73	1.75
	Lead, Total	mg/L	8	0.000014	0.00658	0.0000610	0.000889	0.00230
	Magnesium, Total	mg/L	9	12	39.9	36.1	32.5	8.9
	Manganese, Total	mg/L	8	0.00012	0.0825	0.000441	0.0107	0.0290
	Nickel, Total	mg/L	9	0.000807	0.0099	0.0012	0.0022	0.0029
	Potassium, Total	mg/L	9	0.92	2.1	1.04	1.15	0.36
	Silver, Total	mg/L	8	<0.000005	0.000187	<0.000005	0.000026	0.000065
	Sodium, Total	mg/L	9	0.9	2.7	2.53	2.27	0.59
	Strontium, Total	mg/L	7	0.127	0.341	0.327	0.290	0.0793
	Uranium, Total	mg/L	9	0.00151	0.0092	0.00721	0.00646	0.00260
	Zinc, Total	mg/L	8	0.00268	0.043	0.0048	0.010	0.014
	Zinc, Dissolved	mg/L	9	0.00268	0.0111	0.0063	0.0065	0.0028

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.7: Water quality summary statistics for station V5 (mine exposed), Faro Mine, Yukon

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	50	68	340	200	204	66
	Ammonia-N	mg/L	50	<0.005	0.31	0.022	0.036	0.054
	Conductivity, Field	µS/cm	45	29	1717	501	555	293
	Hardness, Total ($CaCO_3$)	mg/L	55	112	581	274	301	112
	Nitrate-N	mg/L	26	<0.02	0.22	0.09	0.10	0.07
	Organic carbon, Dissolved	mg/L	40	1.51	25.9	4.3	5.6	5.5
	Organic carbon, Total	mg/L	40	2.3	27.2	3.7	5.4	5.3
	pH, Field	pH units	52	6.68	8.86	8.18	8.03	0.43
	Sulfate	mg/L	52	24	210	80.5	92.0	47.5
	Total dissolved solids	mg/L	42	150	650	325	343	123
	Total suspended solids	mg/L	50	1.3	1730	23	119	328
	Turbidity, Lab	NTU	33	0.55	730	5.6	42.7	129
Metals	Cadmium, Total	mg/L	48	0.000031	0.00182	0.0000705	0.000168	0.000359
	Cadmium, Dissolved	mg/L	47	0.000021	0.00021	0.000045	0.000056	0.000035
	Calcium, Total	mg/L	50	29.6	130	65.5	70.9	24.7
	Cobalt, Total	mg/L	51	0.000062	0.0257	0.000408	0.00162	0.00430
	Iron, Total	mg/L	52	0.037	42.4	0.24	2.06	6.38
	Lead, Total	mg/L	53	0.000175	0.0633	0.00109	0.00410	0.0113
	Magnesium, Total	mg/L	52	9.28	62.3	24.9	28.6	12.1
	Manganese, Total	mg/L	52	0.0116	1.16	0.0362	0.0943	0.197
	Nickel, Total	mg/L	48	0.001	0.0873	0.0023	0.0065	0.014
	Potassium, Total	mg/L	54	0.68	5	1.20	1.35	0.69
	Silver, Total	mg/L	39	<0.000005	0.000477	<0.000005	0.000038	0.00011
	Sodium, Total	mg/L	51	1.03	5.86	3.54	3.55	1.12
	Strontium, Total	mg/L	48	0.115	0.495	0.264	0.282	0.0847
	Uranium, Total	mg/L	53	0.00118	0.00777	0.00378	0.00417	0.00174
	Zinc, Total	mg/L	54	0.0018	0.21	0.0089	0.019	0.037
	Zinc, Dissolved	mg/L	49	0.0013	0.0789	<0.005	0.0080	0.013

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.8: Water quality summary statistics for station V8 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	61	53	250	152	158	60
	Ammonia-N	mg/L	66	<0.005	0.2	0.020	0.027	0.036
	Conductivity, Field	µS/cm	43	182	833	552	539	166
	Hardness, Total ($CaCO_3$)	mg/L	68	88.8	471	301	288	110
	Nitrate-N	mg/L	33	0.05	0.6	0.15	0.22	0.16
	Organic carbon, Dissolved	mg/L	43	1.2	22.6	2.9	5.0	5.8
	Organic carbon, Total	mg/L	46	1.3	23.8	2.9	5.0	5.5
	pH, Field	pH units	60	5.98	8.75	8.04	8.01	0.42
	Sulfate	mg/L	64	23	240	122	126	55
	Total dissolved solids	mg/L	48	120	580	360	357	130
	Total suspended solids	mg/L	68	<1	1500	4.1	53	190
	Turbidity, Lab	NTU	39	0.22	683	1.5	29	115
Metals	Cadmium, Total	mg/L	65	0.000035	0.00181	0.0000780	0.000131	0.000231
	Cadmium, Dissolved	mg/L	58	0.000019	0.000294	0.000063	0.000071	0.000042
	Calcium, Total	mg/L	63	22.8	113	69.5	67.5	24.5
	Cobalt, Total	mg/L	65	0.000046	0.0221	0.000200	0.000874	0.00293
	Iron, Total	mg/L	65	0.03	33	0.12	1.14	4.62
	Lead, Total	mg/L	65	0.000074	0.0821	<0.001	0.00306	0.0106
	Magnesium, Total	mg/L	64	7.75	49.2	24.9	26.9	11.5
	Manganese, Total	mg/L	67	0.00458	1.13	0.0160	0.0552	0.149
	Nickel, Total	mg/L	62	0.001	0.0729	0.0020	0.0040	0.0098
	Potassium, Total	mg/L	62	0.59	4	1.09	1.19	0.51
	Silver, Total	mg/L	49	<0.000005	0.0004	<0.000005	0.000020	0.000064
	Sodium, Total	mg/L	60	1.21	5.72	3.55	3.48	1.29
	Strontium, Total	mg/L	61	0.0903	0.43	0.275	0.271	0.101
	Uranium, Total	mg/L	64	0.00129	0.0104	0.00410	0.00508	0.00275
	Zinc, Total	mg/L	66	0.007	0.269	0.014	0.028	0.047
	Zinc, Dissolved	mg/L	61	0.005	0.0497	0.012	0.014	0.0066

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.9: Water quality summary statistics for station R8 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	39	24	140	93	91	35
	Ammonia-N	mg/L	49	<0.005	0.1	0.020	0.022	0.018
	Conductivity, Field	µS/cm	44	30	295	179	171	70
	Hardness, Total ($CaCO_3$)	mg/L	59	25.7	159	97	95	37
	Nitrate-N	mg/L	26	<0.02	0.18	0.08	0.08	0.06
	Organic carbon, Dissolved	mg/L	42	<0.5	21.3	2.2	3.4	3.9
	Organic carbon, Total	mg/L	42	<0.5	19.4	2.2	3.2	3.5
	pH, Field	pH units	49	6.91	8.7	7.76	7.74	0.32
	Sulfate	mg/L	56	<0.5	14	8.1	7.7	2.7
	Total dissolved solids	mg/L	39	48	200	114	112	38
	Total suspended solids	mg/L	54	<1	69	<1	4	12
	Turbidity, Lab	NTU	23	0.45	2.14	0.77	0.86	0.42
Metals	Cadmium, Total	mg/L	42	<0.000005	0.000116	0.0000090	0.000015	0.000019
	Cadmium, Dissolved	mg/L	43	<0.000005	0.000121	0.000010	0.000016	0.000023
	Calcium, Total	mg/L	56	7.29	47.4	29.6	28.2	10.8
	Cobalt, Total	mg/L	44	0.000013	0.001	0.0000355	0.000073	0.000156
	Iron, Total	mg/L	58	0.032	1.73	0.14	0.19	0.24
	Lead, Total	mg/L	57	0.000017	0.021	0.000487	0.000985	0.00282
	Magnesium, Total	mg/L	53	1.64	9.8	5.7	5.8	2.1
	Manganese, Total	mg/L	56	0.00083	0.0606	0.0164	0.0178	0.0101
	Nickel, Total	mg/L	53	0.00018	0.004	0.00037	0.00053	0.00060
	Potassium, Total	mg/L	53	0.306	1.75	0.79	0.78	0.33
	Silver, Total	mg/L	41	<0.000005	0.00001	<0.000005	0.000003	0.000002
	Sodium, Total	mg/L	57	0.73	4.35	2.20	2.30	0.80
	Strontium, Total	mg/L	56	0.0371	0.2	0.120	0.119	0.0471
	Uranium, Total	mg/L	55	0.000305	0.00284	0.00139	0.00145	0.000784
	Zinc, Total	mg/L	57	0.0004	0.03	0.0025	0.0036	0.0048
	Zinc, Dissolved	mg/L	55	0.0003	0.022	0.0041	0.0040	0.0039

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.10: Water quality summary statistics for station R9 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	38	25	150	97	96	34
	Ammonia-N	mg/L	54	<0.005	0.13	0.021	0.026	0.025
	Conductivity, Field	µS/cm	40	58	293	202	197	70
	Hardness, Total ($CaCO_3$)	mg/L	56	31	155	108	105	38
	Nitrate-N	mg/L	25	<0.02	0.29	0.13	0.13	0.10
	Organic carbon, Dissolved	mg/L	44	<0.5	22.4	2.1	3.4	4.0
	Organic carbon, Total	mg/L	39	<0.5	21.2	2	2.9	3.5
	pH, Field	pH units	58	7.11	8.4	7.73	7.73	0.25
	Sulfate	mg/L	59	<0.5	22	13.3	13.1	5.5
	Total dissolved solids	mg/L	40	58	220	130	123	40
	Total suspended solids	mg/L	56	<1	440	<1	11	59
	Turbidity, Lab	NTU	25	0.39	2.48	0.70	0.84	0.45
Metals	Cadmium, Total	mg/L	41	<0.000005	0.0000470	0.0000110	0.0000141	0.0000103
	Cadmium, Dissolved	mg/L	42	<0.000005	0.00014	0.000012	0.000019	0.000025
	Calcium, Total	mg/L	53	9.31	46.8	33.6	31.0	11.3
	Cobalt, Total	mg/L	40	0.000017	0.000357	0.0000425	0.000058	0.000069
	Iron, Total	mg/L	57	<0.05	1.55	0.14	0.19	0.22
	Lead, Total	mg/L	59	0.000055	0.0170	0.000522	0.000989	0.00235
	Magnesium, Total	mg/L	56	1.88	11	6.61	6.52	2.42
	Manganese, Total	mg/L	56	0.00779	0.0682	0.0176	0.0193	0.0100
	Nickel, Total	mg/L	53	0.0002	0.012	0.00042	0.00072	0.0017
	Potassium, Total	mg/L	54	0.36	1.8	0.84	0.85	0.31
	Silver, Total	mg/L	35	<0.000005	0.0000158	<0.000005	0.000003	0.000003
	Sodium, Total	mg/L	54	0.75	3.97	2.20	2.28	0.77
	Strontium, Total	mg/L	51	0.0413	0.193	0.133	0.129	0.0483
	Uranium, Total	mg/L	55	0.000332	0.00309	0.00145	0.00157	0.000832
	Zinc, Total	mg/L	53	0.0006	0.026	0.0038	0.0044	0.0050
	Zinc, Dissolved	mg/L	56	0.0006	0.0526	0.0049	0.0053	0.0075

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.11: Water quality summary statistics for station R10 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	39	29.9	140	98	96	32
	Ammonia-N	mg/L	54	<0.005	0.15	0.020	0.022	0.024
	Conductivity, Field	µS/cm	43	60	350	207	202	71
	Hardness, Total ($CaCO_3$)	mg/L	55	32.9	165	104	103	37
	Nitrate-N	mg/L	27	<0.02	0.291	0.13	0.13	0.10
	Organic carbon, Dissolved	mg/L	39	0.9	14.7	2.3	3.1	2.7
	Organic carbon, Total	mg/L	42	0.9	14.5	2.35	3.1	2.7
	pH, Field	pH units	52	7.06	8.15	7.68	7.69	0.26
	Sulfate	mg/L	54	<0.5	22	12.8	13.2	5.6
	Total dissolved solids	mg/L	42	38	200	129	126	40
	Total suspended solids	mg/L	53	<1	73	<1	3	10
	Turbidity, Lab	NTU	24	0.44	2.71	0.79	0.88	0.51
Metals	Cadmium, Total	mg/L	42	0.000006	0.000123	0.0000140	0.0000195	0.0000188
	Cadmium, Dissolved	mg/L	41	<0.000005	0.000124	0.000019	0.000025	0.000022
	Calcium, Total	mg/L	51	9.93	44.6	31.8	30.3	10.4
	Cobalt, Total	mg/L	48	0.000031	0.001	0.0000565	0.000189	0.000224
	Iron, Total	mg/L	54	<0.05	1.68	0.14	0.18	0.23
	Lead, Total	mg/L	55	0.000052	0.02	0.000388	0.000910	0.00268
	Magnesium, Total	mg/L	52	2.07	11	6.11	6.31	2.33
	Manganese, Total	mg/L	46	0.0113	0.051	0.0181	0.0206	0.00836
	Nickel, Total	mg/L	51	0.00026	0.004	0.00048	0.00059	0.00055
	Potassium, Total	mg/L	55	0.365	1.82	0.81	0.83	0.30
	Silver, Total	mg/L	41	<0.000005	0.0004	<0.000005	0.000013	0.000062
	Sodium, Total	mg/L	53	1.07	4.07	2.27	2.36	0.77
	Strontium, Total	mg/L	52	0.0413	0.204	0.133	0.130	0.047
	Uranium, Total	mg/L	50	0.000304	0.00303	0.00151	0.00159	0.000839
	Zinc, Total	mg/L	50	0.0028	0.0798	0.0068	0.010	0.011
	Zinc, Dissolved	mg/L	52	0.0037	0.082	0.0084	0.012	0.015

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.12: Water quality summary statistics for station NF1 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	12	24	140	83	86	42
	Ammonia-N	mg/L	15	<0.005	0.05	0.020	0.018	0.013
	Conductivity, Field	µS/cm	12	89	421	187	213	109
	Hardness, Total ($CaCO_3$)	mg/L	16	30	176	91	102	53
	Nitrate-N	mg/L	0	-	-	-	-	-
	Organic carbon, Dissolved	mg/L	13	<0.5	18	3.2	4.8	5.1
	Organic carbon, Total	mg/L	15	1.1	17.1	3.2	4.6	4.5
	pH, Field	pH units	16	7.1	8	7.5	7.6	0.2
	Sulfate	mg/L	17	0.3	48	12	15	12
	Total dissolved solids	mg/L	14	60	240	120	135	68
	Total suspended solids	mg/L	15	<1	26	<4	7	7
	Turbidity, Lab	NTU	0	-	-	-	-	-
Metals	Cadmium, Total	mg/L	13	0.00002	0.000313	0.0000430	0.0000809	0.0000902
	Cadmium, Dissolved	mg/L	17	0.000009	0.000367	0.000033	0.000079	0.000098
	Calcium, Total	mg/L	14	8.61	52.2	30.6	30.9	15.6
	Cobalt, Total	mg/L	16	0.00008	0.00419	0.000398	0.000756	0.00117
	Iron, Total	mg/L	17	0.084	6.25	0.30	0.82	1.58
	Lead, Total	mg/L	16	0.000128	0.0125	0.00188	0.00311	0.00331
	Magnesium, Total	mg/L	15	1.98	12.2	5.22	6.16	3.39
	Manganese, Total	mg/L	16	0.009	2.03	0.0722	0.249	0.534
	Nickel, Total	mg/L	16	0.00047	0.00846	0.00093	0.0017	0.0026
	Potassium, Total	mg/L	16	0.48	1.7	0.76	0.89	0.38
	Silver, Total	mg/L	11	<0.000005	0.000018	<0.000005	0.000004	0.000005
	Sodium, Total	mg/L	14	0.61	3.72	2.11	2.26	0.97
	Strontium, Total	mg/L	16	0.038	0.235	0.110	0.125	0.068
	Uranium, Total	mg/L	15	0.000266	0.00303	0.000945	0.00131	0.000993
	Zinc, Total	mg/L	17	0.006	0.262	0.019	0.045	0.070
	Zinc, Dissolved	mg/L	16	0.005	0.135	0.017	0.029	0.040

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.13: Water quality summary statistics for station NF2 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	51	16	160	96	93	38
	Ammonia-N	mg/L	52	<0.005	0.16	0.014	0.024	0.033
	Conductivity, Field	µS/cm	52	56	422	221	213	81
	Hardness, Total ($CaCO_3$)	mg/L	57	14.6	188	109	102	42
	Nitrate-N	mg/L	36	<0.02	0.56	0.19	0.16	0.13
	Organic carbon, Dissolved	mg/L	52	<0.5	18.3	2.2	3.1	3.1
	Organic carbon, Total	mg/L	52	0.8	19.2	2.1	3.3	3.5
	pH, Field	pH units	50	6.19	8.18	7.50	7.50	0.37
	Sulfate	mg/L	56	<0.5	38	15.8	14.5	7.2
	Total dissolved solids	mg/L	52	22	220	137	130	46
	Total suspended solids	mg/L	54	<1	12	<1	2	3
	Turbidity, Lab	NTU	24	0.45	2.63	0.83	0.96	0.49
Metals	Cadmium, Total	mg/L	54	0.000008	0.000168	0.0000240	0.0000328	0.0000305
	Cadmium, Dissolved	mg/L	53	0.000008	0.000164	0.000020	0.000026	0.000027
	Calcium, Total	mg/L	55	8.79	54.6	30.1	30.2	11.8
	Cobalt, Total	mg/L	51	0.000045	0.000515	0.000118	0.000145	0.000091
	Iron, Total	mg/L	56	0.056	0.844	0.16	0.20	0.14
	Lead, Total	mg/L	56	0.000147	0.0216	0.000932	0.00164	0.00310
	Magnesium, Total	mg/L	56	1.83	12.7	6.72	6.55	2.50
	Manganese, Total	mg/L	53	0.00857	0.158	0.0286	0.0346	0.0260
	Nickel, Total	mg/L	56	0.00037	0.00164	0.00058	0.00069	0.00033
	Potassium, Total	mg/L	55	0.3	1.66	0.86	0.85	0.32
	Silver, Total	mg/L	48	<0.000005	0.000029	<0.000005	0.000004	0.000005
	Sodium, Total	mg/L	53	<0.05	5.59	2.50	2.47	0.91
	Strontium, Total	mg/L	55	0.0407	0.239	0.142	0.134	0.053
	Uranium, Total	mg/L	49	<0.000002	0.00367	0.00152	0.00160	0.000965
	Zinc, Total	mg/L	54	<0.0001	0.122	0.011	0.018	0.021
	Zinc, Dissolved	mg/L	51	0.0045	0.124	0.012	0.017	0.019

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.14: Water quality summary statistics for station X2 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	50	26	140	94	93	36
	Ammonia-N	mg/L	65	<0.005	0.17	0.015	0.021	0.028
	Conductivity, Field	µS/cm	42	52	330	204	199	77
	Hardness, Total ($CaCO_3$)	mg/L	66	26.3	172	108	109	42
	Nitrate-N	mg/L	31	0.0064	0.36	0.14	0.13	0.11
	Organic carbon, Dissolved	mg/L	43	0.9	19.7	2.3	3.4	3.7
	Organic carbon, Total	mg/L	44	0.83	18.4	2.3	3.2	3.3
	pH, Field	pH units	58	6.8	8.4	7.61	7.64	0.33
	Sulfate	mg/L	68	<0.25	44	17.1	19.0	10.4
	Total dissolved solids	mg/L	50	40	240	130	129	45
	Total suspended solids	mg/L	61	<1	30	1	2	4
	Turbidity, Lab	NTU	45	0.41	5.32	0.92	1.22	0.88
Metals	Cadmium, Total	mg/L	54	0.00001	0.0003	0.0000260	0.0000389	0.0000497
	Cadmium, Dissolved	mg/L	53	<0.000005	0.0002	0.000022	0.000032	0.000038
	Calcium, Total	mg/L	65	8.27	51.7	30.8	30.3	12.4
	Cobalt, Total	mg/L	47	0.000065	0.00049	0.000167	0.000173	0.000090
	Iron, Total	mg/L	67	0.07	0.834	0.19	0.23	0.14
	Lead, Total	mg/L	68	0.000145	0.00747	<0.001	0.00146	0.00162
	Magnesium, Total	mg/L	61	1.68	12.9	6.47	7.10	3.09
	Manganese, Total	mg/L	56	0.0113	0.22	0.0623	0.0648	0.0442
	Nickel, Total	mg/L	66	0.00044	0.0025	0.00087	0.00093	0.00049
	Potassium, Total	mg/L	67	0.417	2	0.90	0.89	0.31
	Silver, Total	mg/L	50	<0.000005	0.0000308	<0.000005	0.000005	0.000006
	Sodium, Total	mg/L	66	0.893	4.41	2.16	2.35	0.90
	Strontium, Total	mg/L	61	0.0405	0.224	0.124	0.130	0.054
	Uranium, Total	mg/L	62	0.000273	0.0034	0.00133	0.00152	0.000916
	Zinc, Total	mg/L	67	0.0063	0.2	0.024	0.039	0.040
	Zinc, Dissolved	mg/L	65	0.0045	0.392	0.023	0.040	0.057

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.15: Water quality summary statistics for station R1 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	29	24	170	89	91	39
	Ammonia-N	mg/L	29	<0.005	0.115	0.018	0.030	0.031
	Conductivity, Field	µS/cm	17	15.6	516	198	223	134
	Hardness, Total ($CaCO_3$)	mg/L	26	32.3	248	97	102	51
	Nitrate-N	mg/L	25	0.0138	0.27	0.07	0.08	0.07
	Organic carbon, Dissolved	mg/L	9	1.4	19.9	3.9	6.1	6.0
	Organic carbon, Total	mg/L	10	1.2	21.4	2.8	6.1	6.6
	pH, Field	pH units	16	6.37	8.94	7.78	7.65	0.65
	Sulfate	mg/L	26	<0.5	43	20	19	11
	Total dissolved solids	mg/L	24	64	270	140	140	54
	Total suspended solids	mg/L	26	<1	210	3	22	52
	Turbidity, Lab	NTU	4	0.46	5.03	2.90	2.82	1.87
Metals	Cadmium, Total	mg/L	26	<0.000005	0.000171	0.0000205	0.0000291	0.0000348
	Cadmium, Dissolved	mg/L	25	<0.000005	0.000335	0.000018	0.000033	0.000066
	Calcium, Total	mg/L	25	9.72	80.3	28.0	31.3	16.7
	Cobalt, Total	mg/L	25	0.000027	0.00244	0.0000980	0.000279	0.000500
	Iron, Total	mg/L	26	0.091	8.39	0.38	0.92	1.80
	Lead, Total	mg/L	28	0.000036	0.00886	0.000388	0.00114	0.00195
	Magnesium, Total	mg/L	27	1.95	11.5	5.69	5.89	2.09
	Manganese, Total	mg/L	24	0.0159	0.555	0.0607	0.103	0.126
	Nickel, Total	mg/L	30	0.00028	0.006	0.00055	0.00087	0.0011
	Potassium, Total	mg/L	28	0.19	2.16	0.95	1.12	0.55
	Silver, Total	mg/L	26	<0.000005	0.000042	<0.000005	0.000005	0.000008
	Sodium, Total	mg/L	26	0.7	4.87	2.27	2.36	1.04
	Strontium, Total	mg/L	29	0.0485	0.368	0.151	0.161	0.082
	Uranium, Total	mg/L	24	0.000337	0.00391	0.00173	0.00186	0.000958
	Zinc, Total	mg/L	29	<0.0001	0.0369	0.0050	0.0073	0.0090
	Zinc, Dissolved	mg/L	27	0.0007	0.0194	0.0040	0.0054	0.0053

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.16: Water quality summary statistics for station X3 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	37	30.3	150	97	94	34
	Ammonia-N	mg/L	53	0.0062	0.77	0.030	0.051	0.11
	Conductivity, Field	µS/cm	44	65	347	222	210	79
	Hardness, Total ($CaCO_3$)	mg/L	59	35	172	115	112	41
	Nitrate-N	mg/L	24	<0.02	0.29	0.15	0.13	0.09
	Organic carbon, Dissolved	mg/L	44	1	14.9	2.3	2.9	2.6
	Organic carbon, Total	mg/L	42	0.9	16.4	2.2	3.0	2.8
	pH, Field	pH units	52	6.86	8.3	7.68	7.69	0.32
	Sulfate	mg/L	57	5.4	40	20	20	9
	Total dissolved solids	mg/L	44	40	210	132	133	44
	Total suspended solids	mg/L	53	<1	13	<1	2	3
	Turbidity, Lab	NTU	37	0.13	3.5	0.82	0.93	0.59
Metals	Cadmium, Total	mg/L	46	<0.000005	0.0003	0.0000180	0.0000262	0.0000436
	Cadmium, Dissolved	mg/L	55	<0.000005	0.0003	0.000021	0.000046	0.000051
	Calcium, Total	mg/L	53	10.6	48	33.5	32.0	11.9
	Cobalt, Total	mg/L	40	0.000047	0.000313	0.000102	0.000107	0.000051
	Iron, Total	mg/L	58	0.07	0.86	0.17	0.21	0.15
	Lead, Total	mg/L	59	0.00011	0.00338	0.000600	0.000619	0.000606
	Magnesium, Total	mg/L	57	2	12.1	7.17	7.18	2.94
	Manganese, Total	mg/L	57	0.0138	0.16	0.0505	0.0555	0.0339
	Nickel, Total	mg/L	55	0.000365	0.00202	0.00062	0.00072	0.00041
	Potassium, Total	mg/L	48	0.5	1.6	1.00	0.96	0.30
	Silver, Total	mg/L	36	<0.000005	0.000013	<0.000005	0.000003	0.000002
	Sodium, Total	mg/L	51	0.78	4.27	2.44	2.47	0.86
	Strontium, Total	mg/L	56	0.0514	0.216	0.157	0.147	0.049
	Uranium, Total	mg/L	52	<0.0005	0.0033	0.00171	0.00176	0.000812
	Zinc, Total	mg/L	56	0.00322	0.14	0.014	0.027	0.031
	Zinc, Dissolved	mg/L	55	0.0029	0.159	0.015	0.030	0.033

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.17: Water quality summary statistics for station X10 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	70	<0.5	160	109	101	39
	Ammonia-N	mg/L	65	<0.005	0.14	0.020	0.024	0.025
	Conductivity, Field	µS/cm	53	73	406	216	221	80
	Hardness, Total ($CaCO_3$)	mg/L	68	37.6	185	130	123	42
	Nitrate-N	mg/L	38	<0.02	0.3	0.16	0.13	0.11
	Organic carbon, Dissolved	mg/L	50	0.8	18.6	2.2	3.1	3.2
	Organic carbon, Total	mg/L	48	0.7	18	2.4	3.0	3.1
	pH, Field	pH units	64	6.36	8.6	7.80	7.80	0.39
	Sulfate	mg/L	69	<0.5	44.9	23.2	22.2	10.2
	Total dissolved solids	mg/L	56	38	220	148	146	49
	Total suspended solids	mg/L	63	<1	27	<1	2	5
	Turbidity, Lab	NTU	37	0.37	3	0.92	1.09	0.61
Metals	Cadmium, Total	mg/L	72	<0.000005	0.0004	<0.00002	0.0000459	0.0000700
	Cadmium, Dissolved	mg/L	64	0.000009	0.000702	0.0000225	0.0000555	0.000106
	Calcium, Total	mg/L	68	10.3	51.3	36.3	34.1	12.1
	Cobalt, Total	mg/L	53	0.000017	0.000582	0.0000810	0.000103	0.000088
	Iron, Total	mg/L	69	0.07	0.932	0.24	0.27	0.16
	Lead, Total	mg/L	71	0.000076	0.0101	0.000479	0.000768	0.00136
	Magnesium, Total	mg/L	67	2.28	13	8.74	8.45	3.01
	Manganese, Total	mg/L	66	0.011	0.0986	0.0353	0.0410	0.0220
	Nickel, Total	mg/L	65	0.00036	0.00216	0.00075	0.00082	0.00040
	Potassium, Total	mg/L	67	0.31	1.44	1.00	0.94	0.29
	Silver, Total	mg/L	55	<0.000005	0.0003	<0.000005	0.000009	0.000040
	Sodium, Total	mg/L	63	0.9	3.99	2.39	2.41	0.81
	Strontium, Total	mg/L	68	0.0498	0.225	0.164	0.151	0.053
	Uranium, Total	mg/L	65	<0.000002	0.0032	0.00174	0.00176	0.000845
	Zinc, Total	mg/L	70	<0.0001	0.13	0.029	0.042	0.033
	Zinc, Dissolved	mg/L	68	0.00779	0.15	0.031	0.039	0.030

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.18: Water quality summary statistics for station W8 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	4	43	67	57	56	10
	Ammonia-N	mg/L	5	<0.01	0.1	0.020	0.025	0.017
	Conductivity, Field	µS/cm	3	76	120	110	102	23
	Hardness, Total ($CaCO_3$)	mg/L	6	25	72.1	53	51	16
	Nitrate-N	mg/L	0	-	-	-	-	-
	Organic carbon, Dissolved	mg/L	4	2.3	5.2	2.9	3.3	1.3
	Organic carbon, Total	mg/L	4	1.6	4.7	2.7	2.9	1.4
	pH, Field	pH units	6	7	8.1	7.63	7.51	0.44
	Sulfate	mg/L	6	2.99	8.6	6.7	6.5	1.9
	Total dissolved solids	mg/L	3	52	86	68	69	17
	Total suspended solids	mg/L	5	<1	4	<1	1	2
	Turbidity, Lab	NTU	0	-	-	-	-	-
Metals	Cadmium, Total	mg/L	4	0.000035	0.000133	0.0000430	0.0000635	0.0000467
	Cadmium, Dissolved	mg/L	2	0.000047	0.000049	-	-	-
	Calcium, Total	mg/L	6	8.29	21.4	16.8	16.0	4.7
	Cobalt, Total	mg/L	4	0.00004	0.000339	0.000040	0.000115	0.000150
	Iron, Total	mg/L	5	0.053	1.79	0.07	0.41	0.77
	Lead, Total	mg/L	6	0.000263	0.00729	0.00136	0.00226	0.00266
	Magnesium, Total	mg/L	5	1.09	3.29	2.56	2.36	0.89
	Manganese, Total	mg/L	6	0.00779	0.155	0.0114	0.0358	0.0586
	Nickel, Total	mg/L	6	0.00036	0.001	0.00058	0.00057	0.00024
	Potassium, Total	mg/L	5	0.5	0.83	0.70	0.70	0.13
	Silver, Total	mg/L	3	<0.000005	0.000014	<0.000005	0.000006	0.000007
	Sodium, Total	mg/L	6	1.48	2.06	1.86	1.80	0.24
	Strontium, Total	mg/L	6	0.028	0.0781	0.0627	0.0578	0.0181
	Uranium, Total	mg/L	6	0.000151	0.0005	0.000219	0.000214	0.0000399
	Zinc, Total	mg/L	5	0.0144	0.04	0.017	0.024	0.011
	Zinc, Dissolved	mg/L	5	0.0099	0.024	0.013	0.017	0.006

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.19: Water quality summary statistics for station X14 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	186	<0.5	240	97	110	53
	Ammonia-N	mg/L	179	<0.005	0.57	0.078	0.11	0.10
	Conductivity, Field	µS/cm	155	117	1935	500	582	360
	Hardness, Total ($CaCO_3$)	mg/L	191	43.5	1110	217	282	199
	Nitrate-N	mg/L	88	<0.02	0.226	0.06	0.09	0.07
	Organic carbon, Dissolved	mg/L	135	0.8	19.6	2.6	3.5	2.9
	Organic carbon, Total	mg/L	135	0.8	19	2.6	3.4	2.7
	pH, Field	pH units	193	6.36	9	7.89	7.84	0.35
	Sulfate	mg/L	176	19	940	130	179	159
	Total dissolved solids	mg/L	141	62	1600	310	399	281
	Total suspended solids	mg/L	175	<1	55	2	4	7
	Turbidity, Lab	NTU	115	0.09	12	1.80	2.39	2.15
Metals	Cadmium, Total	mg/L	179	0.000013	0.000209	0.0000600	0.0000679	0.0000350
	Cadmium, Dissolved	mg/L	143	0.000014	0.000186	0.000046	0.000054	0.000029
	Calcium, Total	mg/L	183	14.9	322	61.2	80.4	56.9
	Cobalt, Total	mg/L	178	0.000266	0.0504	0.00171	0.00355	0.00582
	Iron, Total	mg/L	183	0.13	3.84	0.38	0.45	0.36
	Lead, Total	mg/L	178	0.000094	0.0144	0.000775	0.00121	0.00186
	Magnesium, Total	mg/L	182	2.72	70.6	14.5	17.6	12.0
	Manganese, Total	mg/L	183	0.2	25.5	1.27	2.63	3.59
	Nickel, Total	mg/L	179	0.00088	0.0562	0.0032	0.0060	0.0077
	Potassium, Total	mg/L	182	0.32	4.2	1.38	1.66	0.84
	Silver, Total	mg/L	148	<0.000005	0.0003	<0.000005	0.000008	0.000025
	Sodium, Total	mg/L	175	0.95	21.6	4.34	6.04	4.53
	Strontium, Total	mg/L	179	0.0468	0.867	0.224	0.265	0.161
	Uranium, Total	mg/L	180	0.000481	0.00524	0.00140	0.00187	0.00121
	Zinc, Total	mg/L	263	0.0101	0.189	0.049	0.058	0.036
	Zinc, Dissolved	mg/L	243	0.007	0.89	0.040	0.053	0.064

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.20: Water quality summary statistics for station R4 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	25	37	160	113	109	37
	Ammonia-N	mg/L	23	<0.005	0.055	<0.010	0.015	0.016
	Conductivity, Field	µS/cm	15	7.9	847	411	423	248
	Hardness, Total ($CaCO_3$)	mg/L	26	60.6	400	156	180	79
	Nitrate-N	mg/L	20	0.03	0.3	0.12	0.14	0.09
	Organic carbon, Dissolved	mg/L	9	1.1	21.3	1.7	5.7	7.0
	Organic carbon, Total	mg/L	12	1.2	23.1	2.7	5.6	6.6
	pH, Field	pH units	18	6.43	8.3	7.44	7.60	0.48
	Sulfate	mg/L	25	24	270	56	75	54
	Total dissolved solids	mg/L	20	100	360	247	230	81
	Total suspended solids	mg/L	25	<1	71	<1	7	15
	Turbidity, Lab	NTU	5	0.2	5.97	0.51	2.22	2.61
Metals	Cadmium, Total	mg/L	22	0.000007	0.000156	0.0000320	0.0000411	0.0000371
	Cadmium, Dissolved	mg/L	26	0.000006	0.00038	0.000031	0.000060	0.000083
	Calcium, Total	mg/L	24	17.9	121	45.0	53.1	24.1
	Cobalt, Total	mg/L	24	0.000028	0.00364	0.000339	0.000553	0.000769
	Iron, Total	mg/L	23	0.017	1.27	0.15	0.20	0.28
	Lead, Total	mg/L	23	0.000025	0.0109	0.00038	0.00131	0.00291
	Magnesium, Total	mg/L	25	3.86	23.6	9.7	10.5	4.6
	Manganese, Total	mg/L	26	0.0216	2.01	0.314	0.378	0.442
	Nickel, Total	mg/L	26	0.00036	0.0067	0.0015	0.0018	0.0014
	Potassium, Total	mg/L	26	0.53	2.38	1.28	1.31	0.41
	Silver, Total	mg/L	23	<0.000005	0.000031	<0.000005	0.000005	0.000008
	Sodium, Total	mg/L	26	1.32	9.45	3.38	3.78	1.90
	Strontium, Total	mg/L	26	0.0702	0.383	0.157	0.178	0.076
	Uranium, Total	mg/L	25	<0.000002	0.00307	0.00114	0.00145	0.000817
	Zinc, Total	mg/L	25	<0.0001	0.066	0.014	0.017	0.015
	Zinc, Dissolved	mg/L	24	0.0034	0.035	0.013	0.013	0.007

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.21: Water quality summary statistics for station A1 (mine exposed), Faro Mine, Yukon.

Analyte		Units	n	Minimum	Maximum	Median	Mean [a]	Standard deviation [a]
Non-Metals	Alkalinity, Total	mg/L	27	39	150	120	110	35
	Ammonia-N	mg/L	24	<0.005	0.049	<0.005	0.009	0.012
	Conductivity, Field	µS/cm	20	10.45	643	243	274	161
	Hardness, Total ($CaCO_3$)	mg/L	26	22.8	224	161	147	47
	Nitrate-N	mg/L	28	<0.02	0.27	0.10	0.13	0.09
	Organic carbon, Dissolved	mg/L	11	0.8	24.4	3.6	5.9	7.4
	Organic carbon, Total	mg/L	11	1	23.2	3.9	6.8	7.0
	pH, Field	pH units	18	6.44	8.42	7.91	7.80	0.52
	Sulfate	mg/L	28	15	88	43	44	18
	Total dissolved solids	mg/L	27	7.8	290	180	180	59
	Total suspended solids	mg/L	28	<1	180	4	24	44
	Turbidity, Lab	NTU	3	1.17	18.4	13.9	11.2	8.9
Metals	Cadmium, Total	mg/L	26	0.000006	0.000173	0.0000295	0.0000486	0.0000465
	Cadmium, Dissolved	mg/L	23	<0.000005	0.000319	0.000021	0.000036	0.000064
	Calcium, Total	mg/L	27	5.8	68	43.2	42.1	14.4
	Cobalt, Total	mg/L	26	0.00002	0.00164	0.000125	0.000306	0.000411
	Iron, Total	mg/L	26	0.018	2.08	0.15	0.33	0.48
	Lead, Total	mg/L	26	0.000033	0.00468	0.000305	0.000801	0.00124
	Magnesium, Total	mg/L	27	2	13.2	10.4	9.3	2.8
	Manganese, Total	mg/L	27	0.00414	0.524	0.0468	0.0961	0.126
	Nickel, Total	mg/L	24	0.00033	0.00653	0.0010	0.0016	0.0015
	Potassium, Total	mg/L	26	0.59	1.86	1.42	1.34	0.27
	Silver, Total	mg/L	27	<0.000005	0.000026	<0.000005	0.000006	0.000007
	Sodium, Total	mg/L	27	0.8	4.24	2.77	2.72	0.92
	Strontium, Total	mg/L	27	0.0325	0.214	0.154	0.139	0.044
	Uranium, Total	mg/L	27	0.000684	0.00279	0.00178	0.00182	0.000635
	Zinc, Total	mg/L	29	0.0001	0.0324	0.0048	0.0072	0.0074
	Zinc, Dissolved	mg/L	27	0.0013	0.0091	0.0036	0.0042	0.0022

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

Table C.22: Water quality data and summary statistics for mine exposed station V27, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
23-Jan-08	100	< 0.005		241	0.6	0.8	0.6	7.39	130	320	< 1		0.000047	0.000045
20-Feb-08	110	< 0.005	535	254	0.62	1.2	0.9	8.4	132	320	< 1		0.000047	0.000042
13-Mar-08	120	< 0.005	498	286	0.77	1.1	1.5	6.4	170	400	< 1		0.000059	0.000057
28-Apr-08	100	< 0.005	567	302	0.7	0.7	0.7		170	390	6		0.000073	0.000059
21-May-08	41	< 0.005	191.3	90.7	< 0.02	9.2	9.3	7.22	47	140	61		0.000406	0.0001
19-Jun-08		0.01		121				8.1	88.5		3	0.7	0.0003	0.0002
24-Jun-08	21	< 0.005	186.2	76	0.06	3.1	3.1	7.19	50	120	12		0.000182	0.000236
29-Jul-08	54	< 0.005		283	0.18	3		8.13	220	370	< 1		0.000439	0.000419
19-Aug-08		0.02		323				7.7	249		< 1	0.3	< 0.0002	< 0.0002
23-Sep-08		0.01		116				8	65		< 1	0.43	< 0.0002	< 0.0002
7-Oct-08	72	< 0.005	377	34.9	0.32	2.1		7.06	85				< 0.000005	< 0.000005
10-Dec-08	120	< 0.005	642	326	0.99	0.7	0.8	7.6	170	460	1		0.000068	0.000065
22-Jan-09	130	< 0.005		361	1.15				200		2		0.000071	0.000076
24-Feb-09	140	0.006		395	1.46				250	490	< 1		0.00008	0.000078
13-Jul-09	54	0.04	768	429			2.3	7.7	350		< 1		0.000288	0.000223
11-Aug-09	63	0.04	510	268		1.5	1.9	7.7	190		< 1			0.00013
10-Sep-09		< 0.01	1700	328			5.2	8.2	89	190	< 1		0.000027	0.000016
8-Oct-09	68	< 0.01		186		1.4	1.9	8.11	110	270	< 1		0.000053	0.000056
11-Dec-09	100	< 0.01	460	269			1.4	8.39	150	360	< 1		0.000049	0.000056
18-Jan-10	110	< 0.01	630	300		1.4	1.7		170		< 1			0.000055
24-Feb-10	130	< 0.01	565	342			0.8	6.94	190	470	< 1		0.000044	0.000052
29-Mar-10	130	0.02	666	370		1	0.9	8.68	170	440	< 1		0.000053	0.000053
20-Apr-10	110	< 0.01	666	399		1.4	2.2	8.3	290	520	3		0.000122	0.000124
12-May-10	80	< 0.005	431	213		3.8	5.2	8.35	130	260	< 1		0.000072	0.00005
16-Jun-10	35	< 0.05	168	75		2.2	2.1	8.07	47	92	< 1		0.000035	0.000038
14-Jul-10	40	< 0.05		472		1.1	1.2	7.94	380	640	< 1		0.000255	0.000411
4-Aug-10	64	< 0.05	291	148		1.7	2.8	8.14	95	210	< 1		0.000059	0.000072
7-Sep-10	53	0.14	290	119	0.24		2.4	5.75	86	180	< 1		0.000034	0.000045
5-Oct-10	74	< 0.05	411	198	0.47	2.2	1.5	8.67	130		< 1	0.2	0.00004	0.000077
1-Nov-10	87	< 0.005	434	231	0.61	1	1.1	8.3	140	290	< 1	0.25	0.000048	0.000041
1-Dec-10		< 0.05	330	264	0.73	< 0.5	< 0.5	8.03	170	340	< 1	1.3	0.000055	0.000046
25-Jan-11	110	< 0.005		333	1.01	0.8	1.2	7.21	180	400	< 1	< 0.25	0.000072	0.000057
17-Feb-11	120		713	326	1.03	1.3	0.9		190	420	< 4	< 0.25	0.000058	0.000061
28-Mar-11	120	0.009	713	355	1.05	1	1.7	8.39	190		< 1	< 0.25	0.000083	0.000074
21-Apr-11	120	0.027	780	359	0.98	1.2	1	8.21	220	450	< 1		0.000076	0.000077
12-May-11	130	0.039	973	482	1.23		4	8.3	330	660	< 1	0.32	0.000121	0.000095
16-Jun-11	33			67.9	0.08	2.2	2.6	8.27	39	86	< 1	0.25	0.000023	0.000033
11-Jul-11	42	0.044	558	321	0.12	3.5	3.3			420	< 1	< 0.25		0.000206
10-Aug-11	49	0.026	234	120		2.7	2.2	7.59	70	170	< 1	0.29	0.000072	0.000063
12-Sep-11	45	0.031	750	422	0.13	2.6	2.2		320	590	< 1	0.36	0.000264	
18-Oct-11	78	0.01	477	204		1.3	1.4	8.27	119	240		0.17	0.000066	0.000097
24-Nov-11	96.2	0.027	530	279	0.57		1.45		151	294	< 1	0.12	0.000068	0.000071
12-Dec-11	99.9	0.015	515	270	0.592	1.93		7.67	158	334	< 1	< 0.1	0.000058	0.000061
25-Jan-12		0.055	320	277	0.775	1.48	1.43	8.11	188	356	< 1		0.00006	0.000069

Table C.22: Water quality data and summary statistics for mine exposed station V27, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Jan-08	59.8	0.00002	0.012	0.000212	22.3	0.0019	0.00058	0.78	< 0.000005	3.26	0.229	0.00528	0.0254	0.0248
20-Feb-08	63.6	0.000022	0.012	0.000166	23.2	0.00214	0.00063	0.84	< 0.000005	3.64	0.23	0.00523	0.0284	0.0283
13-Mar-08	70.2	0.00002	0.007	0.00012	27	0.00134	0.00064	0.9	< 0.000005	3.96	0.241	0.0059	0.0313	0.0314
28-Apr-08	76.2	0.000044	0.031	0.000655	27.1	0.00407	0.00085	1.02	< 0.000005	3.37	0.272	0.00532	0.0362	0.0313
21-May-08	23.3	0.00293	1.33	0.0244	7.89	0.279	0.00359	1.47	0.000019	1.6	0.0871	0.00163	0.138	0.0424
19-Jun-08	35.6	< 0.001	0.12	0.001	7.76	0.21	< 0.001	0.6	< 0.00025	1.38	0.13	0.0008	0.046	0.03
24-Jun-08	21.6	0.000331	0.258		5.34	0.123	0.0011	0.44	0.000014	1.1	0.086	0.000819	0.038	0.0267
29-Jul-08	82	0.000397	0.051	0.00052	19	0.317	0.00133	0.81	< 0.000005	3.14	0.298	0.00184	0.0707	0.0706
19-Aug-08	95.3	< 0.001		< 0.001	20.5	0.013	< 0.001	1.1	< 0.00025	2.97	0.37	0.002	0.053	0.025
23-Sep-08	29.3		0.06	< 0.001	10.4	0.007	< 0.001		< 0.00025	2.06	0.14	0.0024	0.032	
7-Oct-08	13.4	< 0.000005		< 0.000005	0.4	< 0.00005	0.301	< 0.05	0.119		< 0.00005	< 0.000002	< 0.0001	0.001
10-Dec-08	76.5	0.000022	0.014	0.000191	32.7	0.00123	0.00092	0.94	< 0.000005	3.49	0.272	0.00692	0.0384	0.038
22-Jan-09	86.6	0.000016		0.000215	35.1	0.00138	0.00075	0.95	< 0.000005	4.51	0.293	0.0078	0.032	0.0348
24-Feb-09	91.7	0.000018	0.006	0.000119	40.2	0.00103	0.0008	1.05		3.76	0.335	0.00876		
13-Jul-09	125	0.000105	0.034	0.000867	25.4	0.00858	0.00108	1.2	0.000009	2.7	0.452	0.00211	0.0562	0.0548
11-Aug-09	69.5	0.000053	0.043		18.6	0.00597	0.0008	0.8	< 0.000005	2.69	0.241	0.0024	0.0309	0.0311
10-Sep-09	82	0.000064	0.244	0.000248	30		0.00084	1.02	< 0.000005	3.16	0.329	0.00822	0.0024	0.0022
8-Oct-09	44.4	0.000045	0.05	0.00036	16.6	0.00814	0.00067	0.61	< 0.000005	2.49	0.156	0.00292	0.0259	0.0258
11-Dec-09	61	0.000019	0.013	0.000272	26.7	0.00206	0.00069	0.76	< 0.000005	3.17	0.211	0.0053	0.0257	0.0269
18-Jan-10	68.3	0.000027	0.011		29.6	0.00164	0.00076	0.85	< 0.000005	3.3	0.235	0.00589	0.0273	0.027
24-Feb-10	72.4	0.000014		0.000168	33.6	0.00046	0.00071	0.86	< 0.000005	3.58	0.26	0.00673	0.023	0.0252
29-Mar-10	83.6	0.000013	0.005	0.000097	39.1	0.00034	0.00072	0.97	< 0.000005	4.1	0.285		0.025	0.0266
20-Apr-10	82	0.000207	0.167	0.00334	37.9	0.0122	0.00158	1.22	0.000007	3.67	0.291		0.064	0.0579
12-May-10	51.6	0.000158	0.145	0.00274	20.5	0.0131	0.00093	1.03	< 0.000005	2.5	0.169		0.029	0.0307
16-Jun-10	17.9	0.000033	0.036		7.36	0.00383	0.00046	0.44	< 0.000005	1.62	0.0753	0.00113	0.0156	
14-Jul-10	138		0.046	0.000763		0.106		1.09	< 0.000005		0.453	0.00102	0.0437	0.0684
4-Aug-10	33.8	0.000103	0.032	0.000957	13.2	0.0116	0.00069	0.58	< 0.000005		0.133	0.00196	0.0427	0.0415
7-Sep-10	29.7	0.000021	0.024	0.000205	10.8	0.00312	0.00039	0.5	< 0.000005	2.12	0.119	0.00167	0.0167	
5-Oct-10	46.5	0.000027	0.02	0.000367	20	0.00353	0.00063	0.66	< 0.000005	2.87	0.169	0.00328	0.0223	0.0338
1-Nov-10	52.9	0.000023	0.012	0.000515	24	0.00232	0.00075		< 0.000005	3.16	0.193	0.004	0.0231	0.0244
1-Dec-10	62.4	0.00002	0.01	0.00055	28.5	0.00137	0.00071	0.85	< 0.000005	3.4	0.223	0.00466	0.0273	0.0257
25-Jan-11	75.1	0.000033	0.014	0.000847	35.2	0.00292	0.00074	1	0.000008		0.264	0.00654	0.0315	
17-Feb-11	71.2	0.000019	0.009	0.000455	35.9	0.0009	0.00073	0.95	< 0.000005	3.85	0.26	0.00683	0.0279	0.0285
28-Mar-11	79.8	0.000022	0.011	0.000684	37.8	0.00135	0.00087	1.01	< 0.000005	3.9	0.277	0.00693	0.0319	0.0319
21-Apr-11	81.2	0.000025		0.00306	37.9	0.00115	0.00082		< 0.000005	4.1	0.301	0.00732	0.0296	0.029
12-May-11	95.2	0.000055		0.000536	50.3	0.0114	0.00148	1.5	< 0.000005	4.32	0.322	0.0082	0.0357	0.0367
16-Jun-11	16.4	0.000043	0.04	0.000455	6.12	0.0031	0.00058		< 0.000005	1.45	0.067	0.000989	0.0142	0.0157
11-Jul-11	96.4		0.042	0.000406	19.6		0.00108	0.84	< 0.000005	2.28	0.325	0.00132	0.0524	0.0532
10-Aug-11	29.7	0.000055	0.055	0.000387	11.1	0.00438	0.00069	0.52	< 0.000005	2.14	0.118	0.00149	0.0348	0.0439
12-Sep-11	117		0.063	0.000337		0.0823	0.00102	1	< 0.000005	2.73	0.423	0.00154	0.0673	0.0705
18-Oct-11	49.1	0.000039	0.042	0.000389	19.7	0.0046	0.00073	0.69	< 0.000005	2.76	0.173	0.0035	0.0439	0.0565
24-Nov-11	67.8		0.016	0.000613	26.6	0.00308		0.85	< 0.000005	3.37	0.203	0.00464	0.0362	0.104
12-Dec-11	60.1	0.000018	0.01	0.000114	29.2	0.00116	0.00072	0.89		3.67	0.213	0.00521	0.0298	0.0325
25-Jan-12	61.5	0.000012	0.005	0.000085	30.1	0.0008	0.00079	0.91	< 0.000005	3.54	0.229	0.00595	0.0299	0.0299

Table C.22: Water quality data and summary statistics for mine exposed station V27, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
21-Feb-12	116	0.019	640	326	0.689	1.81	1.46	8.02	178	406	< 1	0.08	0.000056	0.000064
7-Mar-12	119	0.029	291	303	0.818	< 0.5	1.69	8.65	200	416		0.1	0.000059	0.000061
30-Apr-12			676					7.93				0.11		
23-May-12	100	0.012	678	261	0.589	7.79	9.1	8.05	168	372	1.8		0.0000921	0.000128
19-Jun-12	27.8	0.045	70	54.7	0.084	2.89	4.09	7.38	32.6	122	5.1		0.0000646	0.0000544
18-Jul-12	39.6	0.029	216	101	0.104	2.84	2.81	7.94	66.9	144		0.35	0.0000824	0.0000857
14-Aug-12		0.013	810	413	0.129	1.97	2.37	8.12	344	618	< 1	0.15	0.000717	0.000773
11-Sep-12	46.6	< 0.005	310	139		2.14	2.62	7.51	102	220	4	0.3	0.000062	0.000057
25-Sep-12	46.2	< 0.005		121	0.167	1.73			68.5	166	< 1			< 0.000053
17-Oct-12	70.3	0.018	379	181	0.279		1.58	8.21	121	260		0.36	0.000039	
n	46	51	42	53	34	40	44	45	52	43	48	24	49	51
minimum	21	<0.005	70	34.9	<0.02	<0.5	<0.5	5.75	32.6	86	<1	0.08	<0.000005	<0.000005
maximum	140	0.14	1700	482	1.46	9.2	9.3	8.68	380	660	61	1.3	0.000717	0.000773
median	84	0.010	513	270	0.60	1.6	1.7	8.05	163	340	<1	0.25	0.0000660	0.000064
mean [a]	83	0.018	523	255	0.57	2.1	2.3	7.87	161	335	2	0.28	0.000110	0.00010
standard deviation (SD) [a]	35	0.022	277	116	0.40	1.7	1.9	0.59	84.4	150	9	0.26	0.000129	0.00013
max detection limit	-	0.05	-	-	0.02	0.5	0.5	-	-	-	4	0.25	0.0002	0.0002
# < detection limit	-	26	-	-	1	2	1	-	-	-	38	5	3	4
% < detection limit	-	51%	-	-	3%	5%	2%	-	-	-	79%	21%	6%	8%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	4%	79%	74%	71%	0%	0%	7%	100%	79%	2%	0%	24%	47%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	5%	2%	4%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	0	1	1	1	0	0	1	1	1	0	0	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00036	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	0	0	0	0	-	1	0	3	-
% > current water quality criterion	-	0%	-	-	0%	0%	0%	0%	0%	-	2%	0%	6%	-
# < current water quality criterion	-	-	-	-	-	2	1	2	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	5%	2%	4%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.22: Water quality data and summary statistics for mine exposed station V27, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
21-Feb-12	73.9	0.000015	0.006	0.0001	34.2	0.00044	0.00069	1.01	< 0.000005	3.95	0.258	0.00658		0.0298
7-Mar-12	65			0.000283	31.7	0.00057	0.00067	0.89	< 0.000005	3.65	0.246	0.0057	0.0261	0.03
30-Apr-12														
23-May-12		0.000106	0.116	0.000989	28.3	0.0071		1.19	< 0.000005	2.9		0.0049	0.0434	0.043
19-Jun-12	13.7		0.111	0.00123	4.98		0.000801	0.494	0.000006	1.16	0.0574	0.000851	0.0234	0.0225
18-Jul-12		0.0000894	0.053	0.000917	8.58	0.0156	0.000783	0.459	< 0.000005	1.74	0.101	0.00113	0.0309	0.0298
14-Aug-12	117	0.000235	0.0463	0.000306	29.6	1.03	0.0012	0.971	< 0.000005	2.53		0.00143	0.0573	0.065
11-Sep-12	35.4	0.000057	0.0562	0.000326	12.3	0.0197		0.524	< 0.000005	2.04		0.00174	0.0231	0.0257
25-Sep-12	30.6	< 0.0001	0.04	0.000288	11	0.00467	< 0.0005	0.499	0.000012	2.09	0.116	0.00168	0.0171	< 0.034
17-Oct-12	41.7	0.000028	0.0346	0.000247	17	0.00386	0.00055	0.72		2.37	0.159	0.00302	0.0191	0.026
n	51	46	46	49	51	50	49	49	46	49	49	50	51	48
minimum	13.4	<0.000005	0.005	<0.000005	0.4	<0.00005	0.00039	<0.05	<0.000005	1.1	0.0574	<0.000002	<0.0001	0.001
maximum	138	0.00293	1.33	0.0244	50.3	1.03	0.301	1.5	0.000019	4.51	0.453	0.00876	0.138	0.104
median	65.0	0.0000330	0.035	0.000389	24.0	0.00368	0.00076	0.86	<0.000005	3.14	0.230	0.00339	0.031	0.030
mean [a]	63.2	0.000145	0.077	0.00108	23.1	0.0469	0.0070	0.84	0.000004	2.92	0.226	0.00387	0.035	0.036
standard deviation (SD) [a]	29.5	0.000437	0.20	0.00347	11.4	0.157	0.043	0.28	0.000003	0.88	0.0970	0.00249	0.021	0.018
max detection limit	-	0.001	-	0.001	-	0.00005	0.001	0.05	0.000005	-	-	0.000002	0.0001	0.034
# < detection limit	-	4	-	3	-	1	4	1	39	-	-	1	1	1
% < detection limit	-	9%	-	6%	-	2%	8%	2%	85%	-	-	2%	2%	2%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	71%	11%	2%	8%	80%	14%	14%	4%	0%	51%	65%	56%	94%	94%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	0	1	1	0	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.8	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	1	1	1	-	0	1	0	0	-	-	0	26	-
% > current water quality criterion	-	2%	2%	2%	-	0%	2%	0%	0%	-	-	0%	51%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.23: Water quality data and summary statistics for mine exposed station V4, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
23-Jan-08	310	0.015	736		0.12	3.3	3.3	7.19	72.1	430	< 1		0.000018	0.000018
20-Feb-08	340	< 0.005		429	0.09	3.9	4.1	7.2	79.6	450	2		0.000017	0.000017
13-Mar-08	320	0.025	718	410	0.09	3.5	4.4		72	470	< 1		0.000025	0.000025
28-Apr-08	280	< 0.005	653	345	0.07	3.6	3.6	7.76	60	370	2		0.000028	0.000028
21-May-08	83		188.8	106	0.03	12.5		8.16	3.4	130	120			0.000048
19-Jun-08		0.01		237				8.3	37.3		< 1	0.8	< 0.0002	< 0.0002
24-Jun-08	170	< 0.005	344		< 0.02	8.7	8.6	8.06	30	230	17		0.000045	0.000045
29-Jul-08	220	< 0.005	465	260	0.02	6.7	6.9	8.45	36		1		0.000016	0.000016
19-Aug-08		0.01		292				8	38.1		< 1	1.6		< 0.0002
23-Sep-08		0.02		267				8	38.8		< 1	0.69	< 0.0002	< 0.0002
7-Oct-08	250	< 0.005	569	13.3	0.02			7.2		370	1		< 0.000005	< 0.000005
10-Dec-08	290	0.011	908	363	0.12	4.2	3.5		53	400	2		0.000024	
22-Jan-09	310	0.028		387	0.14				64	370	4		0.000021	0.000024
24-Feb-09	320			372	0.19				65	430	49			0.000028
13-Jul-09	270	< 0.01	521	322		4	4.2	8.1	51	350	17		0.000023	0.000018
11-Aug-09	280	< 0.01	578	334		4.4	4.4	7.7	51	370	2		0.000022	0.000069
10-Sep-09	280	< 0.01	520	141		2	2.1	8.5	54	350	< 1		0.000047	0.000043
8-Oct-09	280	< 0.01	510	311		4.8	5.1	8.23	50		3		0.000008	< 0.000005
11-Dec-09	320	0.04		385		3.8	3.8	8.15	70	420			0.000008	0.00001
18-Jan-10	330	0.05	810	401		4	4.8	7.89	77	490	< 1		0.000029	0.000016
24-Feb-10	340	0.06	638	421		2.8	2.8	7.32	85	440	< 1		0.000011	0.000009
29-Mar-10	330	0.07	724	392		4.3	4.6		86	430	10		0.000018	0.000016
20-Apr-10	240	0.04	491	299		7	7.1	8.3	52	290	2		0.000016	0.000017
12-May-10	170	0.011	312	194		6.5	7.5	8.03	31	210	9			0.000006
16-Jun-10	250	< 0.05	545	278		6	5.3	8.37	49		< 1			0.000034
14-Jul-10	280	0.08	609	336		4.7	4.7	8.31	55	350	< 1		0.00003	0.00002
4-Aug-10	290	< 0.05		360		4.3	4.6	8.33	67	410	4		0.000013	0.000045
7-Sep-10	290	0.21	690	344	0.05	4.5	4.5		92	400	< 1	2	0.000013	0.000009
5-Oct-10		0.23	652	379	0.08	4.5	4.4	8.43	75	420	3		0.000015	0.000021
1-Nov-10	310		636	389	0.13	3.5	3.5	8.11	76	390	< 1		0.000018	0.000012
1-Dec-10		< 0.05	430	378		2.9	4.1	7.88	79	390	2	2.6	0.000074	0.00001
25-Jan-11	330	0.009		437	0.13	3.1	4.4	7.41			3	1.59	0.000023	0.000024
17-Feb-11		0.072	761	407	0.15	3.5	3.8	8.1	82	440	< 4	1.41	0.000015	0.000025
16-Jun-11	230	0.034	405	266	0.03	6.4	7.3	7.96	51		28	1.04	0.000013	0.000014
11-Jul-11	230	0.12	452	278	< 0.02	6.8	6.6	7.63	44	320			0.00003	0.000031
10-Aug-11	260	0.036	529	320	< 0.02	4.7		8.08	56	340	< 1	1.89	0.000028	0.00002
12-Sep-11	260	0.033	529	302	< 0.02	5	5.1	8.07		340	< 1	1.07	0.000017	0.000019
18-Oct-11	270	0.03	669	338	0.05	3.5	4.3	7.77	57.6	340	2	1.83	0.000024	0.000022
24-Nov-11	308	0.047		429		4.07	4.58	8.01	72.5	374	2.8	2.11	0.000024	0.000018
12-Dec-11		0.064	640	390	0.094	4.12	4.3	7.69	62.1	400		1.91	0.000024	0.00002
25-Jan-12	317	0.072	410	353	0.155	3.56	3.78	7.86	79.4	420	< 1		0.000029	0.000021
21-Feb-12	316	0.087		411		3.81	3.84	8.01	78.9		1.4	3.13	0.000018	0.000013
7-Mar-12	322	0.056	691	397	0.174	2.19	3.94	8.1	80.7	442	< 1	1.2	0.000019	0.00002
30-Apr-12			453					7.86				2.09		

Table C.23: Water quality data and summary statistics for mine exposed station V4, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Jan-08	102	0.000061	0.04	0.000023	36.5	0.083	0.00073	1.26	< 0.000005	4.04	0.411	0.0147	0.0014	0.0014
20-Feb-08	107	0.000036	0.033		39.4	0.0353	0.00067	1.49	< 0.000005	4.87	0.395	0.016	0.0016	0.0016
13-Mar-08	101	0.000043	0.029	0.000048	38.3	0.0449	0.00068	1.34	< 0.000005	4.63	0.417	0.0173	0.0049	0.0049
28-Apr-08	86.4	0.000062	0.244	0.000177	31.4	0.0602	0.00075	1.35	< 0.000005	3.4	0.358	0.0132	0.0062	
21-May-08	27	0.000193	1.28	0.00245	9.29		0.00157	1.2	0.00001	0.97	0.0993	0.00122	0.0043	0.0043
19-Jun-08	62.5	< 0.001	0.22	< 0.001	19.6	0.016	0.001	0.9	< 0.00025	2.03	0.25	0.0052	< 0.005	< 0.005
24-Jun-08	49.4	0.000045	0.295	0.000129	16.6	0.0143	0.00128	0.64	< 0.000005	1.79	0.206	0.0042	0.0028	0.0028
29-Jul-08	66.9	0.000044	0.132	0.000052	22.4	0.0165	0.00084	0.75	< 0.000005	3.12	0.28	0.00558	0.0037	0.0037
19-Aug-08	68.7	< 0.001	0.33	< 0.001	29.2	0.032		1	< 0.00025	2.96	0.33	0.0056	< 0.005	
23-Sep-08		< 0.001	0.15	< 0.001	24.8	0.027	< 0.001	0.8	< 0.00025	2.42	0.33	0.008	< 0.005	< 0.005
7-Oct-08	4.58	< 0.000005	0.013	< 0.000005	0.45	< 0.00005	0.0088				< 0.00005	< 0.000002		< 0.0001
10-Dec-08	88	0.000074	0.255	0.000188	34.8	0.0524	0.00084	1.12	< 0.000005	3.38	0.366	0.00958	0.0035	0.0027
22-Jan-09	97.6	0.000075	0.267	0.00015	34.8		0.00078	1.16	< 0.000005	4.44	0.371	0.0119	0.0035	0.0042
24-Feb-09	92.7	0.000729	1.58		34.1	0.492	0.00205	1.24	< 0.000005	3.37	0.411	0.0127	0.0217	0.0027
13-Jul-09	73.9	0.000068	0.172	0.000436	26	0.0444	0.00083	0.82	< 0.000005	2.86	0.303	0.00835	0.0037	0.0014
11-Aug-09	82	0.000088	0.259	0.00027	30.2		0.00094	0.95	< 0.000005	3.41	0.326	0.00884	0.0106	0.0036
10-Sep-09	35.7	0.000044	0.218	0.000442	12.2	0.00902	0.00057		< 0.000005	2.32	0.131	0.00195	0.0244	0.0195
8-Oct-09	77.4	0.000051		0.00004	28.6	0.0398	0.00073	0.92	< 0.000005	2.96	0.304	0.00847	0.0014	0.0017
11-Dec-09	90.9	0.000066		0.000071	34.4	0.0792	0.00066	1.06	< 0.000005	3.68	0.375	0.0125	0.0016	0.0015
18-Jan-10	94.2	0.000061	0.183	0.0108	36.2		0.00069	1.26	< 0.000005	3.87	0.387	0.0132	0.0078	0.0023
24-Feb-10	98.6	0.000063		0.000025	38.8	0.0787	0.00069	1.26	< 0.000005	4.17	0.411	0.0138	0.0012	0.0012
29-Mar-10	94	0.000117	0.816	0.000915	38.3	0.109	0.00084			4.24	0.398	0.0159	0.0099	0.0053
20-Apr-10	65.5	0.000087	0.556	0.000135	27.6	0.058	0.00072	1.48	< 0.000005		0.279	0.00913		0.0019
12-May-10	49.6	0.000228	0.399			0.051	0.00138	1.04	< 0.000005	1.78	0.2	0.00509	0.0042	0.0018
16-Jun-10	68.8			0.000148	25.3	0.0171	0.00083	0.79	< 0.000005	2.45	0.293	0.0087	0.0019	0.0116
14-Jul-10	87	0.000043	0.127	0.0014	27.1	0.0244	0.00068	0.94	< 0.000005	2.72	0.337		0.0059	0.0038
4-Aug-10	80.2	0.000071	0.174	0.000155	32	0.0379	0.00076	0.96	< 0.000005		0.349	0.0105	0.0044	0.0174
7-Sep-10	85.9	0.000051	0.252	0.000031	31.4	0.0459	0.00063	1.06	< 0.000005	3.19	0.356	0.0109	0.0008	
5-Oct-10	89.5	0.000078	0.377	0.00119	35.7	0.0729	0.00066	1.1	< 0.000005	3.71	0.346	0.0111	0.0039	0.0057
1-Nov-10	94.1	0.000067	0.298	0.000283		0.0787	0.00068	1.12	< 0.000005	3.9		0.0122	0.0014	0.0012
1-Dec-10	43.8	0.000171	0.274	0.0135	17.1	0.0586	0.00134	0.69	< 0.000005	1.91	0.185	0.00565	0.0607	0.002
25-Jan-11	97.5	0.000048	0.193	0.000832	39.8	0.056	0.0007	1.63	< 0.000005	4.33	0.432	0.0175	0.0029	0.0024
17-Feb-11	95.2		0.157	0.000321	38.7	0.042	0.00077	1.42	< 0.000005	4.14	0.412	0.0176	0.0019	
16-Jun-11	67	0.000073		0.000165	23.9	0.021	0.0011	0.85	< 0.000005	2.35	0.27	0.00875	0.0021	0.0046
11-Jul-11	72.3	0.000092	0.197	0.000172	23.8	0.0247	0.00106	0.78	< 0.000005	2.43	0.291	0.00723		
10-Aug-11	83.9	0.000075	0.27	0.000241	30.3	0.047	0.00104	1	< 0.000005	3.1	0.347	0.00992	0.0065	0.0055
12-Sep-11	74.7	0.000061	0.184	0.000157	28	0.0335	0.00096	0.95	< 0.000005	2.66		0.00914	0.0025	
18-Oct-11	85.1	0.000114	0.384		33.4	0.0745	0.00085	1.05	< 0.000005	3.15	0.328	0.0118	0.0025	0.0075
24-Nov-11		0.000111	0.35	0.000564	38.6	0.0854	0.00091	1.25		4.01	0.369	0.0129		0.0025
12-Dec-11	94.8	0.000088	0.389	0.000278	37.1	0.0798	0.00093	1.22	< 0.000005	3.79	0.362	0.0122	0.0044	0.0045
25-Jan-12	85	0.00007	0.175	0.000244	34.2	0.0545	0.00069	1.26	< 0.000005	3.88	0.381	0.0145	0.0032	0.0028
21-Feb-12	99.3	0.000067	0.28	0.000096	37.7	0.0529	0.0007	1.34	< 0.000005	4.24	0.409	0.0153	0.0022	0.0011
7-Mar-12	87.7		0.156	0.00069	36.3			1.28	< 0.000005	4.07	0.405	0.0144	0.002	0.0054
30-Apr-12														

Table C.23: Water quality data and summary statistics for mine exposed station V4, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
23-May-12	114	0.022	359	128	0.078	12.8	13.2	7.8	15.7	158	34.4		0.0000806	0.0000528
19-Jun-12	197	0.027	310	236	0.022		6.61	8.01	33		5.5		0.0000252	0.0000291
18-Jul-12	222	0.013	474	249		6.01	5.91	8.17	39.4	280	1.7		< 0.000025	0.0000221
14-Aug-12	259		540	302	< 0.02	5.31	5.65	8.3	46	372	1.9	1.33	0.000046	0.000051
11-Sep-12	251		560	286	< 0.02	5.54	5.72	7.87	39.8	324	< 1	1.18	0.000017	0.00002
17-Oct-12	279	0.031	604	328	0.059	4.91	4.62	8.06	61.2	370	1.1		0.000015	0.000008
n	42	44	39	47	29	42	41	44	46	39	46	18	42	45
minimum	83	<0.005	188.8	13.3	<0.02	2	2.1	7.19	3.4	130	<1	0.69	<0.000005	<0.000005
maximum	340	0.23	908	437	0.19	12.8	13.2	8.5	92	490	120	3.13	0.0000806	0.000069
median	280	0.031	545	336	0.07	4.3	4.5	8.02	56.8	372	1.95	1.60	0.0000215	0.000020
mean [a]	269	0.040	555	319	0.07	4.9	5.0	7.97	57.6	366	7.4	1.64	0.0000239	0.000023
standard deviation (SD) [a]	58	0.048	150	91	0.06	2.2	1.9	0.33	19.7	79	20	0.63	0.0000153	0.000014
max detection limit	-	0.05	-	-	0.02	-	-	-	-	-	4	-	0.000025	0.000005
# < detection limit	-	12	-	-	6	-	-	-	-	-	18	-	2	2
% < detection limit	-	27%	-	-	21%	-	-	-	-	-	39%	-	5%	4%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	95%	25%	97%	91%	0%	0%	0%	7%	96%	95%	9%	11%	0%	2%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	1	1	1	1	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00037	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	2	-	-	0	0	0	0	0	-	4	0	0	-
% > current water quality criterion	-	5%	-	-	0%	0%	0%	0%	0%	-	9%	0%	0%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.23: Water quality data and summary statistics for mine exposed station V4, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
23-May-12	31.4	0.000458	0.833	0.000938	11	0.0663	0.00207	1.06	0.0000116	1.13		0.00197	0.00852	0.00801
19-Jun-12	57.8	0.000105	0.178	0.000204	20	0.0225	0.00118	0.823	< 0.000005	1.94	0.241	0.00468		0.0142
18-Jul-12	2.91		0.0374	< 0.000025	0.81	0.00186	0.00017	1.01	< 0.000025	1850	0.112		0.00051	0.00451
14-Aug-12	72	0.000074	0.238		28.2	0.0421	0.000898	0.888	< 0.000005	2.89	0.331	0.00752	0.00285	
11-Sep-12	72	0.000062		0.000044	25.9	0.0397	0.000777	0.91	< 0.000005	2.72	0.288	0.00667	0.00191	
17-Oct-12				0.000699	30.2	0.0489	0.000677	1.16	< 0.000005		0.337	0.0102	0.00507	0.00197
n	46	41	42	44	47	44	47	46	43	44	45	47	44	41
minimum	2.91	<0.000005	0.013	<0.000005	0.45	<0.00005	0.00017	0.64	<0.000005	0.97	0.0993	<0.000002	0.00051	<0.0001
maximum	107	0.000729	1.58	0.0135	39.8	0.492	0.0088	1.63	0.000025	4.87	0.432	0.0176	0.0607	0.0195
median	83.0	0.0000700	0.24	0.000223	30.2	0.0454	0.00083	1.06	<0.000005	3.17	0.337	0.00992	0.0036	0.0036
mean [a]	74.9	0.000103	0.31	0.000914	28.3	0.0562	0.0011	1.08	0.000003	3.17	0.323	0.00987	0.0058	0.0044
standard deviation (SD) [a]	24.6	0.000124	0.31	0.00254	9.8	0.0716	0.0012	0.23	0.000002	0.94	0.0827	0.00446	0.0097	0.0042
max detection limit	-	0.000005	-	0.001	-	0.00005	0.001	-	0.000025	-	-	0.000002	0.005	0.005
# < detection limit	-	1	-	5	-	1	1	-	41	-	-	1	3	3
% < detection limit	-	2%	-	11%	-	2%	2%	-	95%	-	-	2%	7%	7%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	87%	5%	12%	7%	94%	66%	19%	9%	2%	57%	93%	91%	7%	5%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.9	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	2	2	-	0	0	0	0	-	-	6	1	-
% > current water quality criterion	-	0%	5%	5%	-	0%	0%	0%	0%	-	-	13%	2%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.24: Water quality data and summary statistics for mine exposed station VGMAIN, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
7-Jan-08	144	< 0.01		298					136		< 1	0.15	< 0.0002	< 0.0002
18-Feb-08	180	< 0.01		296				7.6	136		< 1	0.17	< 0.0002	< 0.0002
17-Mar-08	201	< 0.01		347				8	162				< 0.0002	< 0.0002
14-Apr-08	183	0.03		346				8	163		< 1			< 0.0002
14-May-08	93.5	0.03		196				8.4	88.9		< 1	1.5	< 0.0002	< 0.0002
16-Jun-08	47.4	< 0.01		143				8.1	98.9		2	0.71	0.0002	< 0.0002
14-Jul-08	91.9	< 0.01		175					99		3	0.65	< 0.0002	< 0.0002
11-Aug-08	125	0.02						8.1	180		< 1	0.22	< 0.0002	< 0.0002
15-Sep-08	100	0.04		142				8	56.7		< 1	0.49	< 0.0002	< 0.0002
15-Oct-08		< 0.01		200				7.9	88.6		1	0.24	< 0.0002	< 0.0002
3-Nov-08	143	0.02		269				8.2	116		< 1	0.2	< 0.0002	< 0.0002
1-Dec-08	167	0.01		367				8.3	150			0.35	< 0.0002	< 0.0002
12-Jan-09	203	0.02		386				7.6	195		< 1	0.19	< 0.0002	
2-Feb-09	213	< 0.01		380				8.1	200		< 1	0.2	0.0005	0.0003
29-Aug-09	77	< 0.01	700	415		2.5	1.9	8.2	340	560	< 1			
4-Nov-10	150	0.024	293.4	282	0.42			8.3	130	350	< 4		0.000052	0.000042
18-May-11	76	0.009	356	170	0.42	17.4	20.4	8.23	110		190	80	0.000477	0.000077
19-May-11	69	0.03		106	0.2	19.4	18.1	7.96	47	160	44		0.000181	0.000068
25-May-11	39	0.045	121	53.8	0.06	7.7	8.6	7.4	24	70	27	4.57	0.000095	0.00005
29-May-12	79	0.028		114	0.119		8.86		43.5	160	8.9	4.76	0.0000817	
29-Aug-12				167										0.000046
22-Oct-12	161	0.011			0.255		3.04		144	388	< 1	< 0.1		
n	20	21	4	20	6	4	6	17	21	6	19	16	18	18
minimum	39	0.009	121	53.8	0.06	2.5	1.9	7.4	24	70	<1	<0.1	0.000052	0.000042
maximum	213	0.045	700	415	0.42	19.4	20.4	8.4	340	560	190	80	0.0005	0.0003
median	134	0.011	325	235	0.23	12.6	8.7	8.1	130	255	<1	0.30	<0.0002	<0.0002
mean [a]	127	0.017	368	243	0.25	11.8	10.2	8.0	129	281	15	5.90	0.000149	0.000099
standard deviation (SD) [a]	54	0.013	243	109	0.15	8.0	7.6	0.3	69	183	44	19.82	0.000128	0.000054
max detection limit	-	0.01	-	-	-	-	-	-	-	-	4	0.1	0.0002	0.0002
# < detection limit	-	8	-	-	-	-	-	-	-	-	12	1	11	12
% < detection limit	-	38%	-	-	-	-	-	-	-	-	63%	6%	61%	67%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	35%	0%	75%	75%	67%	25%	33%	0%	100%	50%	16%	19%	83%	83%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	1	1	1	1	1	1	1	1	1	0	0	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00032	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	3	3	2	-
% > current water quality criterion	-	0%	-	-	0%	25%	17%	0%	0%	-	16%	19%	11%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.24: Water quality data and summary statistics for mine exposed station VGMAIN, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
7-Jan-08	71.9	< 0.001	0.09	< 0.001	28.7	0.005	0.002	1.1	< 0.00025	3.83	0.31	0.0065	0.018	0.012
18-Feb-08	71.4	< 0.001	< 0.05	< 0.001	28.6	0.007	0.002	0.9	< 0.00025	4	0.31	0.0051	0.019	0.01
17-Mar-08	78	< 0.001	0.07	< 0.001	37	0.004	0.002	1.2	< 0.00025	4.99	0.31	0.0084	0.02	0.007
14-Apr-08	79.7	< 0.001	0.08	< 0.001	35.7	0.004	0.002	1.2	< 0.00025	4.76	0.33	0.0087	0.018	0.008
14-May-08	47.4	< 0.001	0.15	< 0.001	18.8	0.021	0.002	1.4	< 0.00025	2.22	0.17	0.0036	0.023	0.013
16-Jun-08	38.2	< 0.001	< 0.05	< 0.001	11.6	0.14	0.001	0.7	< 0.00025	1.64	0.14	0.0013	0.041	0.024
14-Jul-08	48.2	< 0.001	0.26	< 0.001	13.3	0.014	0.001	0.7	< 0.00025	1.89	0.18	0.0019	0.024	0.01
11-Aug-08	79.9	< 0.001	0.05	< 0.001	21.6	0.006	< 0.001	0.9		2.67		0.003	0.023	0.012
15-Sep-08	35.5	< 0.001	0.09	< 0.001	12.9	0.006	< 0.001	0.6		2.09			0.017	0.009
15-Oct-08	50.6	< 0.001	< 0.05	< 0.001	17.9	0.005		0.8	< 0.00025	2.45	0.2		0.02	
3-Nov-08	64.8	< 0.001	< 0.05	< 0.001	26.1	0.004	0.001	1	< 0.00025	3.18	0.26	0.0056	0.029	
1-Dec-08	85.4	< 0.001	< 0.05	< 0.001	37.3	0.008	< 0.001	1.2	< 0.00025	4.17	0.34	0.0073	< 0.005	< 0.005
12-Jan-09	90	< 0.001	< 0.05		39	0.008	0.002	1.1	< 0.00025	4.06	0.34	0.0097	0.023	0.022
2-Feb-09	87.5	< 0.001	0.1	< 0.001	39.1	0.011	0.003	1.5		4.21	0.34	0.0099	0.03	0.026
29-Aug-09	119	0.000088	0.03			0.0174	0.00114	1.08	< 0.000005	3.01	0.401	0.00263	0.0254	0.0244
4-Nov-10	66.4	0.000083	0.029	0.000077		0.00605	0.00163	0.91	< 0.000005	3.66	0.259	0.00656	0.013	0.012
18-May-11	38.6	0.00473	6.1	0.0464	18	0.318	0.0158	1.9	0.000126	1.9	0.145	0.00317	0.128	
19-May-11	24.9	0.0009	1.75	0.00647	10.7	0.0924		1.5	0.000031	1.2	0.0974	0.00179	0.032	0.0176
25-May-11	13.6	0.000442	0.408	0.00647	4.79	0.0574	0.00156	0.85	0.000008	0.9	0.0563	0.0011	0.0247	0.0213
29-May-12	28.2		0.264	0.00171	10.5	0.0265	0.0016		0.0000084	1.54	0.115	0.00209	0.0198	0.0143
29-Aug-12	42		0.0556	0.00021			0.000685	0.667	< 0.000005	2.22	0.166	0.00239	0.0109	0.0101
22-Oct-12														
n	21	19	21	19	18	20	19	20	7	21	19	19	21	18
minimum	13.6	0.000083	0.029	0.000077	4.79	0.004	0.000685	0.6	<0.000005	0.9	0.0563	0.0011	<0.005	<0.005
maximum	119	0.00473	6.1	0.0464	39.1	0.318	0.0158	1.9	0.000126	4.99	0.401	0.0099	0.128	0.026
median	64.8	<0.001	0.07	<0.001	20.2	0.00800	0.0016	1.04	0.000008	2.67	0.259	0.00360	0.023	0.012
mean [a]	60.1	0.000697	0.46	0.00357	22.9	0.0380	0.0022	1.06	0.000026	2.89	0.235	0.00478	0.027	0.014
standard deviation (SD) [a]	26.3	0.000991	1.35	0.0105	11.3	0.0746	0.0034	0.33	0.000045	1.21	0.101	0.00298	0.025	0.0068
max detection limit	-	0.001	0.05	0.001	-	-	0.001	-	0.000005	-	-	-	0.005	0.005
# < detection limit	-	14	6	13	-	-	3	-	3	-	-	-	1	1
% < detection limit	-	74%	29%	68%	-	-	16%	-	43%	-	-	-	5%	6%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	67%	89%	10%	16%	83%	20%	63%	20%	29%	43%	63%	68%	86%	33%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	0	1	1	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.6	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	1	2	1	-	0	0	0	1	-	-	0	3	-
% > current water quality criterion	-	5%	10%	5%	-	0%	0%	0%	14%	-	-	0%	14%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.25: Water quality data and summary statistics for mine exposed station VW3, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
3-Nov-10	65	< 0.005	90.4	88.5	0.16			7.71	28	100	< 4		0.000031	0.000024
19-May-11	28	0.02		70.7	0.21	20.4	20.6		53	120	39	12.8	0.00112	0.00114
29-May-12	47.4	0.04		73.4	0.156		10.7		33.7		18.4	4.03	0.000387	0.000308
29-Aug-12				69.2									0.000031	0.000026
24-Oct-12	64.9	0.016			0.183		2.66		33.2	140	1.6	0.54		
n	4	4	1	4	4	1	3	1	4	3	4	3	4	4
minimum	28	<0.005	-	69.2	0.156	-	2.66	-	28	100	1.6	0.54	0.000031	0.000024
maximum	65	0.04	-	88.5	0.21	-	20.6	-	53	140	39	12.8	0.00112	0.00114
median	56	0.018	-	72.1	0.17	-	10.7	-	33.5	120	11.2	4.03	0.000209	0.00017
mean [a]	51	0.020	-	75.5	0.18	-	11.3	-	37.0	120	15.3	5.79	0.000392	0.00037
standard deviation (SD) [a]	18	0.016	-	8.9	0.02	-	9.0	-	11.0	20	17.7	6.32	0.000513	0.00053
max detection limit	-	0.005	-	-	-	-	-	-	-	-	4	-	-	-
# < detection limit	-	1	-	-	-	-	-	-	-	-	1	-	-	-
% < detection limit	-	25%	-	-	-	-	-	-	-	-	25%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	0%	0%	0%	25%	100%	33%	0%	100%	0%	25%	67%	50%	50%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	-	-	-	-	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	0	-	0	0	-	1	-	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	218	-	25	4.23	0.00012	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	1	1	2	-
% > current water quality criterion	-	0%	-	-	0%	100%	33%	0%	0%	-	25%	33%	50%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.25: Water quality data and summary statistics for mine exposed station VW3, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
3-Nov-10	26.1	0.000061	0.113	0.000384	5.65	0.0132		0.36	< 0.000005	1.89	0.11	0.00178	0.0149	0.0119
19-May-11	18.3	0.00219	1.31	0.0113	6.1			1.7	0.000036	0.6	0.0755	0.000462	1.24	1.38
29-May-12		0.000521	0.338	0.00218	6.06	0.0394	0.0018	0.74	0.0000139	0.961	0.0911	0.00106	0.455	0.408
29-Aug-12	19.5	0.000031	0.0905	0.000212	4.96	0.00587	0.000407	0.371	< 0.000005		0.0907	0.00108	0.0216	
24-Oct-12														
n	3	4	4	4	4	3	2	4	4	3	4	4	4	3
minimum	18.3	0.000031	0.0905	0.000212	4.96	0.00587	0.000407	0.36	<0.000005	0.6	0.0755	0.000462	0.0149	0.0119
maximum	26.1	0.00219	1.31	0.0113	6.1	0.0394	0.0018	1.7	0.000036	1.89	0.11	0.00178	1.24	1.38
median	19.5	0.000291	0.23	0.00128	5.9	0.0132	-	0.56	0.0000095	0.96	0.0909	0.00107	0.24	0.41
mean [a]	21.3	0.000701	0.46	0.00352	5.7	0.0195	-	0.79	0.000014	1.15	0.0918	0.00110	0.43	0.60
standard deviation (SD) [a]	4.2	0.00102	0.58	0.00526	0.5	0.0176	-	0.63	0.000016	0.67	0.0141	0.000539	0.58	0.70
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	2	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	50%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	0%	50%	25%	50%	0%	33%	50%	25%	25%	0%	0%	0%	100%	67%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	-	1	1	0	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.005	-	0.9	0.074	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	1	1	-	0	0	0	0	-	-	0	2	-
% > current water quality criterion	-	0%	25%	25%	-	0%	0%	0%	0%	-	-	0%	50%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.26: Water quality data and summary statistics for mine exposed station VW1, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
30-Sep-09	130	< 0.005	339	154	0.07			7.93	41	200	12		0.000013	0.00001
21-Oct-09	150	0.089		173	0.11				44	220	7		0.000009	0.000015
24-Nov-09	170	0.011	9.5	205	0.15			8.69	47		6		0.000009	0.000008
21-Jan-10	190	0.009	266.5	253	0.16				59	280	8		0.000015	0.000007
23-Feb-10	210	0.012	276.8	261	0.16			8.06	62	320	7		0.000016	0.00001
30-Mar-10	290	0.051		391	0.19				110	440	52		0.000048	0.000025
3-Nov-10	150	0.086	205.9	189	0.09				52	220	< 4		0.000007	0.000007
18-May-11								8.01						
19-May-11	55	0.064		187	0.05		24.4	8.01	27	130	1500	756		0.000164
29-May-12	79.4	0.015			0.107		10.6		29.2	136	166		0.000245	0.0000719
29-Aug-12													0.000022	0.000018
22-Oct-12	154	0.02			0.124		3.88		45.3	248	6.3	0.46		
n	10	10	5	8	10	0	3	5	10	9	10	2	9	10
minimum	55	<0.005	9.5	154	0.05	-	3.88	7.93	27	130	<4	0.46	0.000007	0.000007
maximum	290	0.089	339	391	0.19	-	24.4	8.69	110	440	1500	756	0.000245	0.000164
median	152	0.018	267	197	0.12	-	10.6	8.01	46.2	220	7.5	-	0.0000150	0.000013
mean [a]	158	0.036	220	227	0.12	-	13.0	8.14	51.7	244	177	-	0.0000427	0.000034
standard deviation (SD) [a]	66	0.033	127	76	0.04	-	10.5	0.31	23.4	96	468	-	0.0000769	0.000050
max detection limit	-	0.005	-	-	-	-	-	-	-	-	4	-	-	-
# < detection limit	-	1	-	-	-	-	-	-	-	-	1	-	-	-
% < detection limit	-	10%	-	-	-	-	-	-	-	-	10%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	50%	30%	20%	88%	0%	-	33%	20%	100%	78%	30%	50%	11%	20%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	-	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	1	1	1	1	-	1	1	1	1	1	-	1	0
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00028	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	-	1	0	0	-	3	1	0	-
% > current water quality criterion	-	0%	-	-	0%	-	33%	0%	0%	-	30%	50%	0%	-
# < current water quality criterion	-	-	-	-	-	-	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.26: Water quality data and summary statistics for mine exposed station VW1, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
30-Sep-09	40	0.000081	0.116	0.000156	13.2	0.0314	0.00056	0.67	< 0.000005	2.73	0.181	0.00202	0.0024	0.0025
21-Oct-09	45	0.00008	0.12	0.000182	14.6	0.0345	0.00055	0.68	< 0.000005	3	0.203	0.00242	0.0025	
24-Nov-09	53.8	0.000083		0.00017	17.3	0.0558	0.00057	0.77	< 0.000005	3.62	0.247	0.00313	0.0027	0.0028
21-Jan-10	66.2	0.000122	0.128	0.000229	21.4	0.0853	0.00065	1	< 0.000005	4.33	0.292	0.00359	0.0035	0.0028
23-Feb-10	68.1	0.00011	0.115	0.000222	22.1	0.082	0.00058	1.05	< 0.000005	4.48		0.0037	0.0033	
30-Mar-10	96.1		0.341	0.00134	36.7	0.116		1.68	< 0.000005	7.16	0.424	0.00557	0.008	0.0036
3-Nov-10	48.9	0.000068	0.106	0.000058		0.0529	0.0005	0.73	< 0.000005	3.38	0.225	0.00261	0.002	0.0018
18-May-11														
19-May-11	41.7	0.0259	44.9	0.0609	20.2	1.07	0.0815	5.1	0.000441	1.7	0.185	0.00259	0.213	0.0169
29-May-12	29.7	0.00141	1.65		9.1	0.0981	0.00437	1.02	0.0000435	1.55	0.137	0.0014	0.167	0.123
29-Aug-12	43.5	0.000128	0.23	0.000271	14.7	0.034	0.00083	0.783	< 0.000005	3.08	0.2	0.00205	0.00884	0.00728
22-Oct-12														
n	10	9	9	9	9	10	9	10	10	10	9	10	10	8
minimum	29.7	0.000068	0.106	0.000058	9.1	0.0314	0.0005	0.67	<0.000005	1.55	0.137	0.0014	0.002	0.0018
maximum	96.1	0.0259	44.9	0.0609	36.7	1.07	0.0815	5.1	0.000441	7.16	0.424	0.00557	0.213	0.123
median	47.0	0.000110	0.13	0.000222	17.3	0.0689	0.00058	0.89	<0.000005	3.23	0.203	0.00260	0.0034	0.0032
mean [a]	53.3	0.003109	5.30	0.00706	18.8	0.166	0.010	1.35	0.000050	3.50	0.233	0.00291	0.041	0.020
standard deviation (SD) [a]	19.1	0.008558	14.9	0.0202	7.9	0.319	0.027	1.35	0.00014	1.60	0.0840	0.00118	0.079	0.042
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	8	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	80%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	50%	22%	22%	11%	89%	70%	22%	20%	20%	50%	89%	60%	20%	13%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.5	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	1	2	1	-	0	0	0	1	-	-	0	2	-
% > current water quality criterion	-	11%	22%	11%	-	0%	0%	0%	10%	-	-	0%	20%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.27: Water quality data and summary statistics for mine exposed station VW2, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
30-Sep-09	300	< 0.005	685	354				8.11	93	410			0.0001	0.000098
21-Oct-09	310	< 0.005		396	0.13				93	430	< 1		0.000105	0.000111
24-Nov-09	310	< 0.005	9.7	394	0.15			8.41	100	460	1		0.00012	0.000118
24-Feb-10	320	0.01	422	436	0.32			8.23	120	530	1		0.000155	0.000162
30-Mar-10	320	< 0.005	424.1	428	0.21			8.22	120	460	8		0.000171	0.000179
3-Nov-10		< 0.005	384.7	391	0.16			8.18	110	420	< 4		0.000115	0.000115
19-May-11	88	0.04		129	< 0.02	25.5	24.2	7.98	28	180	130	24.6	0.000911	0.000089
29-May-12	183	0.04		262	0.241		6.97		73.1	288	2	0.56	0.000071	0.0000478
29-Aug-12				382									0.000089	0.000084
22-Oct-12	298	0.011			0.146		3		95.6	454		0.13		
n	8	9	5	9	8	1	3	6	9	9	7	3	9	9
minimum	88	<0.005	9.7	129	<0.02	-	3	7.98	28	180	<1	0.13	0.000071	0.0000478
maximum	320	0.04	685	436	0.32	-	24.2	8.41	120	530	130	24.6	0.000911	0.000179
median	305	<0.005	422	391	0.16	-	7.0	8.2	95.6	430	2	0.56	0.000115	0.00011
mean [a]	266	0.013	385	352	0.17	-	11.4	8.2	92.5	404	21	8.43	0.000204	0.00011
standard deviation (SD) [a]	85	0.016	242	98	0.09	-	11.3	0.1	28.3	106	48	14.01	0.000267	0.000040
max detection limit	-	0.005	-	-	0.02	-	-	-	-	-	4	-	-	-
# < detection limit	-	5	-	-	1	-	-	-	-	-	2	-	-	-
% < detection limit	-	56%	-	-	13%	-	-	-	-	-	29%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	88%	0%	80%	89%	38%	100%	33%	17%	100%	89%	14%	33%	56%	89%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	0	1	1	1	-	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00037	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	1	1	1	-
% > current water quality criterion	-	0%	-	-	0%	100%	33%	0%	0%	-	14%	33%	11%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.27: Water quality data and summary statistics for mine exposed station VW2, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
30-Sep-09	88.4	0.000017		0.000014	32.5	0.00012	0.00106	0.92	< 0.000005	2.29	0.306	0.00675	0.0036	0.0039
21-Oct-09	99.2	0.000016	0.006	0.000045	36.1	0.00025	0.00106	1.04		2.55		0.00721	0.0042	0.0048
24-Nov-09	98.3	0.000009	0.008	0.000044	36.1	0.00022	0.00118	0.98	< 0.000005	2.53	0.34	0.00802	0.0053	0.0064
24-Feb-10	109	0.000015	0.012	0.000214	39.9	0.00048	0.00159	1.15	< 0.000005	2.68		0.00873	0.0091	0.0084
30-Mar-10	106	0.000015	0.011	0.000072	39.7	0.00045	0.00173	1.1	< 0.000005	2.7	0.341	0.0092	0.0101	0.0111
3-Nov-10	96.3				36.6		0.00129	1.01	< 0.000005	2.55	0.327	0.00774		0.0053
19-May-11	32.1	0.00206	4.31	0.00658	12	0.0825	0.0099	2.1	0.000187	0.9	0.127	0.00151	0.043	0.0063
29-May-12	64.3	0.000047		0.0000957	24.6	0.00122	0.00102	1.05	< 0.000005	1.74	0.247	0.00302	0.00268	0.00998
29-Aug-12	95.7	0.000012	0.0225	0.00005	34.8	0.000431	0.000807	1.03	< 0.000005	2.46	0.341	0.006	0.00292	0.00268
22-Oct-12														
n	9	8	6	8	9	8	9	9	8	9	7	9	8	9
minimum	32.1	0.000009	0.006	0.000014	12	0.00012	0.000807	0.92	<0.000005	0.9	0.127	0.00151	0.00268	0.00268
maximum	109	0.00206	4.31	0.00658	39.9	0.0825	0.0099	2.1	0.000187	2.7	0.341	0.0092	0.043	0.0111
median	96.3	0.0000155	0.012	0.0000610	36.1	0.000441	0.0012	1.04	<0.000005	2.53	0.327	0.00721	0.0048	0.0063
mean [a]	87.7	0.000274	0.73	0.000889	32.5	0.0107	0.0022	1.15	0.000026	2.27	0.290	0.00646	0.010	0.0065
standard deviation (SD) [a]	24.5	0.000722	1.75	0.00230	8.9	0.0290	0.0029	0.36	0.000065	0.59	0.0793	0.00260	0.014	0.0028
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	7	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	88%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	89%	13%	17%	13%	100%	13%	56%	11%	13%	0%	86%	89%	13%	0%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	0	0	0	1	0	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.9	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	1	0	-	0	0	0	1	-	-	0	1	-
% > current water quality criterion	-	0%	17%	0%	-	0%	0%	0%	13%	-	-	0%	13%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.28: Water quality data and summary statistics for mine exposed station V5, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
7-Jan-08	226	0.02		333				8.2	132		7	3	< 0.0002	< 0.0002
14-May-08	97.7	0.05		181				8.4	45.2		137	47	0.0002	< 0.0002
16-Jun-08	101	< 0.01		144				8.3	38.8		34	15	< 0.0002	< 0.0002
14-Jul-08	134	< 0.01		160				8.2	33.8		95	30		< 0.0002
11-Aug-08		0.02		258				8.3	65.1		48	40	< 0.0002	< 0.0002
15-Sep-08	178	0.04		229				8.1	55.1		191	178	< 0.0002	< 0.0002
15-Oct-08	228	0.02		249				8	73.3		12	5.3	< 0.0002	< 0.0002
3-Nov-08	210	0.02		321				8.3	85.6		19	5.6	< 0.0002	
1-Dec-08	227	0.01		369				8.1	102		6	1.4	< 0.0002	< 0.0002
3-Mar-09	300	0.08	29	480		3	3	8.5	210	150	8			
6-Apr-09	300	0.02	377	456		4.1	3.6		190	570	5			0.000063
6-May-09	68	0.07	179	112		24.8	20.8	7.64	27	180	370		0.000484	
10-Jun-09		< 0.005	286	156		4.7	4.6	8.3	44	210	54		0.000055	0.000024
13-Jul-09	180	< 0.01		263		3.5	3.6	8.4	70	310	130		0.000094	0.000021
11-Aug-09	200	< 0.01	460	278		3.6	3.7	8.3	75		62		0.000068	0.000026
10-Sep-09	200	< 0.01		274		5	4.4	7.2	79	320	60		0.000078	0.000024
7-Oct-09	180	< 0.01	398	243		4.6	4.7	7.71	72	270	33		0.000178	0.00004
10-Nov-09	230	0.02	535	331		3.1	2.6	8.23	95	380	9		0.000037	0.000037
15-Dec-09	260	< 0.01	642	370		2.8	3.1	6.82	110	400	15		0.000045	
6-Jan-10	310	< 0.01	722	525		3.3	3.1	7.45	160	450	32		0.00006	0.000059
18-Feb-10	290		1717	464				8.3	160	490	8		0.00005	0.000054
30-Mar-10	310	0.02	777	465		2.2	3	8.86	180	540	6		0.00004	0.000048
20-Apr-10	180	0.11	499	279		6.6	7	8.44	94	430	170		0.000218	0.00004
12-May-10	170	0.01	449	264		7.3			93	320	82			0.000028
17-Jun-10	150	0.07	394	191		4.8	4.1	8.28	61	240	200			
14-Jul-10	130	< 0.05	351	173				8.21	47	200	37		0.00007	0.000048
4-Aug-10	180	< 0.05	446	264			3.7	8.46	75	330	4		0.000038	0.00004
7-Sep-10	180	0.31	520	235	0.03	5.6	5.7	7.58	82	330	6	2.5	0.000034	0.000038
5-Oct-10	190	< 0.05	580	287	0.05	4.4	4	6.89	82	360	3	1.1	0.000031	0.000068
2-Nov-10	220		552	321	0.09	3.1	2.7	8.25	98	350	12	3	0.000071	0.000027
1-Dec-10	230	< 0.05	350	360	0.11	4.4	2.9		120		14	1.8	0.000055	0.000045
25-Jan-11	280	0.012	772	468	0.17	2.8	2.4	7.81	140		14	1.58	0.000066	0.00006
17-Feb-11		< 0.005	830	489	0.18	2.4	2.3	8.03	170	550	< 4	2.09	0.000055	0.000054
22-Mar-11	340	0.025	954	581	0.2	2.4	2.3	8.09	200	650	2		0.000085	0.000074
21-Apr-11	300		783	491	0.13	2.6	2.4	8.01	170	510		1.73	0.000083	0.000061
11-May-11		0.053	334	199	< 0.02	20.7	19.1	8.27	50	230	290	128	0.000436	0.000063
18-May-11	74	0.036	193	213	< 0.02	25.9		8.24	24	180	1600	730	0.00182	0.000084
15-Jun-11	110		300	145	0.03	7.1	9.9	7.64	41	170	110	40.5	0.000113	0.000023
13-Jul-11	160	0.039	382	218	0.03	4.8		6.68	65	270	92	37.4	0.000134	0.000021
10-Aug-11	170	0.029	409	246	0.04	4.5	4.4	8.32	71	280	27	9.24	0.000169	0.000038
12-Sep-11	160	0.057	400	219	0.03	7.1	6.4	7.97	56	260	33	6.76		0.000031
18-Oct-11	200	0.047	590	290	0.09	3.8		7.9	77.4	340	9	1.21	0.00004	0.000027
23-Nov-11	233	0.026	624	374	0.163	3.33	2.95	8.01	107	368	9.8	1.42	0.000051	0.000038
13-Dec-11	234	0.026	616	362	0.131		3.72	8.17	111	386	8.9	1.62	0.000047	

Table C.28: Water quality data and summary statistics for mine exposed station V5, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
7-Jan-08	79.4	< 0.001	0.26	< 0.001	32.6	0.015	0.001	1.2	< 0.00025	3.95	0.32	0.0041	0.02	0.007
14-May-08	43.2	0.002	2.91	0.009	17.7	0.13	0.012	1.9	< 0.00025	2.15	0.16	0.002	0.026	0.005
16-Jun-08	35.3	< 0.001	0.59	0.001	13.5	0.029	0.003	0.8	< 0.00025	2.32	0.14	0.0016	0.015	0.005
14-Jul-08	39.1	0.002	3.19	0.004	15.2	0.081		1.1	< 0.00025	2.62	0.15	0.0016	0.023	< 0.005
11-Aug-08	62.2		2.42	0.002	25	0.065	0.005	1.2		3.2	0.24	0.0031	0.014	
15-Sep-08	54.2	0.005	8.34		22.7	0.17	0.017	1.9	< 0.00025	2.89	0.28	0.0037	0.038	< 0.005
15-Oct-08	63.1	< 0.001	0.14		22.1	0.038	0.002	0.9	< 0.00025	2.75	0.26	0.0033	0.006	< 0.005
3-Nov-08	76.9	< 0.001		< 0.001	31.2	0.04	0.003	1.2	0.0003	3.93	0.31	0.0042	0.011	0.005
1-Dec-08	85.9	< 0.001	0.16	< 0.001	37.4	0.028	0.002	1.3	< 0.00025	4.55	0.35	0.004	0.039	0.039
3-Mar-09	111	0.000142	0.124	0.000253	49.3	0.0183	0.00202	1.5	< 0.000005	5.08	0.425	0.00705	0.0041	0.003
6-Apr-09	98.9	0.000085	0.06	0.000175	45.6	0.0131	0.00164	1.4	< 0.000005	4.75	0.394	0.00688	0.003	0.0033
6-May-09	29.6	0.00318	2.49	0.0124	9.28	0.242	0.00931	1.79	0.000029	1.03	0.115	0.00118	0.0453	0.0086
10-Jun-09	38	0.000355	0.247	0.00128	14.1	0.0357	0.00199	0.68	< 0.000005	2.24		0.0021	0.0059	0.0059
13-Jul-09		0.00102	0.695	0.00298	22.9	0.0746	0.0038	0.94		3.03	0.236	0.00359	0.0085	0.0013
11-Aug-09	65.9	0.000675		0.00166	24.4	0.0661	0.00257	0.95	< 0.000005	3.78	0.261	0.00382	0.0051	0.0017
10-Sep-09	67.1	0.000708	0.686	0.00174	25.9	0.0683	0.00352	1.11	< 0.000005	3.55	0.261	0.0036	0.0072	0.0034
7-Oct-09	59.5	0.000357	0.196	0.00154	22.9	0.0503		0.89	< 0.000005		0.232	0.00343	0.0371	0.004
10-Nov-09	80	0.000157	0.127	0.000357	32			1.09	< 0.000005	4.01	0.304	0.00479	0.0029	0.0025
15-Dec-09	87.9		0.175	0.000389		0.0216		1.26	< 0.000005	4.34	0.346	0.00567	0.0035	0.002
6-Jan-10	108	0.000209	0.248	0.000717	47.7	0.0247	0.00226	1.45	< 0.000005		0.417	0.00713	0.0049	0.0032
18-Feb-10	104	0.00013	0.089	0.000453	44	0.0173	0.0018	1.41	< 0.000005	5	0.381	0.00665	0.0047	0.0052
30-Mar-10	102	0.000091	0.058	0.000239	49.6	0.0116	0.00184	1.47	< 0.000005	5.49	0.401	0.00739	0.0029	0.0029
20-Apr-10	66.7	0.00154	1.27	0.00628	27.3	0.107	0.00628	2.36	0.000011	3.97		0.00378	0.0182	
12-May-10	65.1	0.00115	1.23	0.00287	24.7	0.0926		1.31	0.000011	2.91	0.23	0.00436	0.0104	0.0035
17-Jun-10	49.5	0.00151	1.21	0.00481	19.4	0.0852	0.00505	0.97	0.000011	2.81	0.213	0.00298	0.0158	0.0028
14-Jul-10	44.2	0.000565	0.541	0.00197	14.4	0.0609	0.00208	0.73		2.24	0.172	0.00193	0.015	0.024
4-Aug-10	58.4	0.00014	0.111	0.00081	22.8	0.0228	0.0014	0.87	< 0.000005	3.13	0.239	0.00341	0.0057	0.0027
7-Sep-10	57.2	0.000135	0.166	0.000436	22	0.0283	0.00402	0.88	< 0.000005	3.02	0.237	0.00324	0.0034	0.0076
5-Oct-10	68.2	0.00007	0.087	0.000217	28.4	0.0137	0.00126	1.08	< 0.000005	3.82	0.261	0.00379	0.0018	0.0172
2-Nov-10		0.000384	0.362	0.00109	31.9	0.039	0.00199	1.08	0.000006	4.07	0.29	0.00439	0.0048	
1-Dec-10	85.8	0.00021	0.214	0.000504	35.5	0.03	0.00165	1.23	< 0.000005	4.22	0.321	0.00493	0.004	0.0071
25-Jan-11		0.000217	0.211	0.000341	47.5	0.0282	0.00187	1.57		5.32		0.00675	0.0051	
17-Feb-11	109	0.000144	0.112	0.000311	52.9	0.0191	0.00201	1.68	< 0.000005		0.425	0.00777	0.0045	
22-Mar-11	130	0.000085	0.037	0.000304	62.3	0.0211	0.00237	1.9		5.86	0.495			0.0042
21-Apr-11	122	0.000122	0.076	0.00116	44.4	0.0231		1.55		5.44		0.0071	0.0115	0.0138
11-May-11	47.1	0.00558	9.34	0.0116	19.8	0.369	0.0211	2.7		2.5		0.00238	0.047	0.005
18-May-11		0.0257	42.4	0.0633	22	1.16	0.0873	5	0.00042	2	0.21	0.00263	0.21	0.005
15-Jun-11	35.8	0.00101	0.819	0.00378	13		0.00405		0.000012	2.22	0.151	0.00208	0.0142	0.0031
13-Jul-11	49.7	0.00194	3.64	0.00357	20.1	0.104	0.0083	1.2	0.000034	2.8	0.241	0.00332	0.016	0.0039
10-Aug-11	61.1	0.0017	1.25	0.00462	22.8	0.12	0.00545	1	0.000023	3.13	0.254	0.0034	0.014	0.0075
12-Sep-11	53.3	0.000397	0.365	0.00169	20.7	0.0509	0.00256	0.91	< 0.000005	2.86	0.218	0.00295	0.0093	0.0037
18-Oct-11		0.000165	0.202	0.000509	27.5	0.029	0.00163	1.02		3.54	0.271	0.00456	0.0036	0.0036
23-Nov-11	93.3		0.224	0.000393		0.0281	0.00175	1.2	< 0.000005	4.44	0.313	0.00511	0.0047	
13-Dec-11	84.1	0.000113	0.114	0.000328	35		0.00157	1.23	< 0.000005	4.31	0.317	0.0054	0.0045	0.0064

Table C.28: Water quality data and summary statistics for mine exposed station V5, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
26-Jan-12	262	0.053	686	375	0.216	1.84	3.05	8.03		436	4.5		0.000057	0.000042
21-Feb-12	253	0.023	770	421	0.207	2.54	2.91	8.45	135	450	3.1	1.68	0.00005	
7-Mar-12	281	0.027	771	409	0.22	1.51	2.54	8.23		506	1.3	0.55	0.000053	0.000051
23-Apr-12			573					8.4				16.7		
23-May-12		0.24	426	241	0.071		27.2	7.75		256	1730		0.00182	0.00021
19-Jun-12	111	0.012	310	141	0.048	6.34	6.04	8.24	36.2	168	26.6	11.8	0.0000633	0.0000279
17-Jul-12	131	0.021	392	180	0.043	5.87	6.12	7.75	44.6	238		22	0.0000825	0.0000307
14-Aug-12	181	0.0072	501	240	0.042	5.12	4.56	7.49	60.3	318	12.6		0.000036	0.000028
13-Sep-12	160		1413	229		7.63	8.39	8.18	55.4	286	105	20.6	0.000099	0.000089
15-Oct-12	194	0.016	409	259	0.103		3.96	8.14	85.7	302		3.84	0.000058	0.000028
14-Nov-12	230	0.011	618	341		3.39	3.44	8.18	101				0.000047	0.000031
12-Dec-12	262	0.022	643	368	0.18	2.87	2.87		129	424		35.03		
n	50	50	45	55	26	40	40	52	52	42	50	33	48	47
minimum	68	<0.005	29	112	<0.02	1.51	2.3	6.68	24	150	1.3	0.55	0.000031	0.000021
maximum	340	0.31	1717	581	0.22	25.9	27.2	8.86	210	650	1730	730	0.00182	0.00021
median	200	0.022	501	274	0.09	4.3	3.7	8.18	80.5	325	23	5.6	0.0000705	0.000045
mean [a]	204	0.036	555	301	0.10	5.6	5.4	8.03	92.0	343	119	42.7	0.000168	0.000056
standard deviation (SD) [a]	66	0.054	293	112	0.07	5.5	5.3	0.43	47.5	123	328	129	0.000359	0.000035
max detection limit	-	0.05	-	-	0.02	-	-	-	-	-	4	-	0.0002	0.0002
# < detection limit	-	14	-	-	2	-	-	-	-	-	1	-	7	8
% < detection limit	-	28%	-	-	8%	-	-	-	-	-	2%	-	15%	17%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	80%	14%	91%	91%	15%	8%	8%	15%	100%	88%	50%	67%	35%	28%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	1	1	1	1	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00037	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	2	-	-	0	3	2	0	0	-	25	18	4	-
% > current water quality criterion	-	4%	-	-	0%	8%	5%	0%	0%	-	50%	55%	8%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.28: Water quality data and summary statistics for mine exposed station V5, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
26-Jan-12	86.3		0.139	0.000405	38.8	0.0231		1.35	< 0.000005	4.75	0.347	0.0061	0.0041	0.0029
21-Feb-12	100	0.000097	0.083	0.00019	41.8	0.0183	0.00143	1.5	< 0.000005	5.07	0.373	0.0064	0.0031	0.0031
7-Mar-12	95.2	0.000062	0.065	0.000343		0.0149	0.00135	1.36	< 0.000005	4.76	0.367	0.00573	0.0037	0.0033
23-Apr-12														
23-May-12	63.3	0.0174	16.9	0.0541	20.1	0.859	0.0517	2.99	0.000477	1.79	0.262	0.00339	0.185	0.0344
19-Jun-12	36.4	0.000408	0.499	0.00114	12.3	0.0366	0.00224	0.748	0.0000102	1.96		0.00162	0.0151	0.00589
17-Jul-12	45.6	0.000594	0.553	0.00178	16	0.0493	0.00266	0.726	0.0000136	2.53	0.192		0.0146	0.00761
14-Aug-12	58.3	0.000229	0.241	0.000369	22.9	0.0341	0.00161	0.898		3.16		0.00314	0.00653	0.00735
13-Sep-12	58.2	0.00118	1.14	0.00282	20.3	0.0871	0.0049	0.958	0.000016		0.219	0.00269	0.0159	0.0789
15-Oct-12	62.6	0.000241	0.238	0.00146	25.1	0.0319	0.00185	0.95	0.00003	3.27	0.266	0.0037	0.00955	0.00534
14-Nov-12	82.2	0.000162	0.156	0.00029	32.9	0.0279	0.00194	1.11	< 0.000005	4.11	0.326	0.00497	0.00644	0.00429
12-Dec-12	87.1	0.000698		0.00201	36.5	0.0483	0.00469	1.38	0.000028	4.27	0.357	0.00615	0.0103	0.00399
n	50	51	52	53	52	52	48	54	39	51	48	53	54	49
minimum	29.6	0.000062	0.037	0.000175	9.28	0.0116	0.001	0.68	<0.000005	1.03	0.115	0.00118	0.0018	0.0013
maximum	130	0.0257	42.4	0.0633	62.3	1.16	0.0873	5	0.000477	5.86	0.495	0.00777	0.21	0.0789
median	65.5	0.000408	0.24	0.00109	24.9	0.0362	0.0023	1.20	<0.000005	3.54	0.264	0.00378	0.0089	<0.005
mean [a]	70.9	0.00162	2.06	0.00410	28.6	0.0943	0.0065	1.35	0.000038	3.55	0.282	0.00417	0.019	0.0080
standard deviation (SD) [a]	24.7	0.00430	6.38	0.0113	12.1	0.197	0.014	0.69	0.00011	1.12	0.0847	0.00174	0.037	0.013
max detection limit	-	0.001	-	0.001	-	-	-	-	0.000005	-	-	-	-	0.005
# < detection limit	-	5	-	3	-	-	-	-	23	-	-	-	-	3
% < detection limit	-	10%	-	6%	-	-	-	-	59%	-	-	-	-	6%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	82%	59%	40%	26%	98%	48%	98%	31%	21%	61%	88%	83%	33%	8%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.8	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	5	14	5	-	0	0	0	3	-	-	0	7	-
% > current water quality criterion	-	10%	27%	9%	-	0%	0%	0%	8%	-	-	0%	13%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.29: Water quality data and summary statistics for mine exposed station V8, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
7-Jan-08	182	< 0.01		298				7.8	137		1	0.4	< 0.0002	< 0.0002
18-Feb-08	225	0.02		368				7.7	150		2	0.38	< 0.0002	< 0.0002
17-Mar-08	< 0.5	< 0.01		398				8	168		2	0.46	< 0.0002	< 0.0002
14-Apr-08	224	0.03		390				8	165			0.47	< 0.0002	< 0.0002
14-May-08	96.8	0.02		180				8.3	69.6		54	20	< 0.0002	< 0.0002
26-May-08	53	0.19		88.8	0.05	7.7	8.4		23	120	120		0.000219	
16-Jun-08	60.2	< 0.01		143				8.1	86.7		4	2.1	< 0.0002	
14-Jul-08	106	0.04		169				8	78.7		30	12	< 0.0002	< 0.0002
11-Aug-08	119	< 0.01		278					149		8	6.1	< 0.0002	< 0.0002
15-Sep-08	127	0.04		175				8.1	56.8		49	45	< 0.0002	< 0.0002
15-Oct-08	179	0.02		227				7.9	83.8		4	2	< 0.0002	< 0.0002
3-Nov-08	168	0.02		300				8.3	104		6	1.8	0.0002	< 0.0002
1-Dec-08	194	< 0.01		392				8.3	134					< 0.0002
12-Jan-09	239	0.01		399				7.6	183		1	1.5	< 0.0002	< 0.0002
2-Feb-09	246			414				8	182		1	0.5	< 0.0002	< 0.0002
3-Mar-09	240	< 0.01	694	471		2.6	2.3	8.4	210	520	< 1		0.000074	
6-Apr-09	250	0.02	432	448		3.7	3.4		220		< 1		0.000067	0.000078
6-May-09	71	0.07		117		22.1	20.4	7.62	45		140		0.000282	0.000096
13-May-09											24.6			
16-May-09											1.48			
17-May-09											1.86			
19-May-09											7.6			
20-May-09											12			
10-Jun-09	80	< 0.005		121		2.9	2.7	7.8	48	190	16		0.000038	0.000019
13-Jul-09	120	< 0.01	671	376		2.2	2.4	8.3	190	510	73		0.000122	0.000075
11-Aug-09	150	0.02	500	343		2.9	2.7	8.4	170	500			0.000082	0.000062
10-Sep-09	140			248		2.4	3.4	7.3	110	310	17		0.000063	0.000052
7-Oct-09	140	< 0.01	401	234		3.4		7.79	91	230	8		0.000167	0.000036
10-Nov-09	190	0.02	611	327		2.1	2.1	8.2	110	400	4		0.000042	
15-Dec-09	220	< 0.01	631	376			3.5	7.65	130		5		0.000063	0.000052
6-Jan-10	240	< 0.01	675	464		2	2	7.2	170	470	< 4		0.000065	0.000075
18-Feb-10	240	0.04	720	440		2.1	2.1	8.17	200		2		0.000067	0.000061
30-Mar-10	250	< 0.01	552	431		2.1	2.5	8.72	200	510	2		0.000057	0.000061
20-Apr-10	180	0.09	720	350		3.9	4.5	8.37	160	440	130		0.000209	0.000052
12-May-10	150	0.09	420	238		5	6.9	8.52	110	300	23		0.000061	0.000032
19-May-10	94	< 0.005	182	157	0.15			7.99	62	180	87		0.000141	
17-Jun-10	100	< 0.05	286	156		3.3	2.9	8.31	59	190	48		0.000071	0.000027
14-Jul-10	93	< 0.05	700	378		2	2.1	7.93	230	510	26		0.000118	
3-Aug-10	160	< 0.005	362	239	0.14			8.39	100	300	2		0.000047	
4-Aug-10	140	< 0.05	443	243		2.4	2.3	8.24	100	320	2		0.000053	0.00005
7-Sep-10		0.2	460	211	0.13	3.4	3.4	7.32	97	290	3	0.6	0.000036	0.00003
5-Oct-10		< 0.05	559	266	0.19	3.1	2.8	7.35	100	350	< 1		0.000035	0.000033
2-Nov-10	170	0.015	531	301	0.29	1.2	1.3	8.75	120	360	2	1.1	0.000051	0.000043
1-Dec-10	190	< 0.05	350	350			2.4	7.81	150	410	2	0.7	0.00006	0.000048
25-Jan-11		< 0.005		423	0.5	1.5	1.8	7.97		470	2		0.000061	0.000069
17-Feb-11	230	< 0.005	732	428	0.52	1.9	1.8		180	580	< 4	0.54		0.000063
22-Mar-11	240	0.023	833	447	0.6	1.7	1.7	8.24	200	520	2		0.000078	0.000059
21-Apr-11	240	0.01	752	466	0.45	2	2	8.21	190	530	< 1	< 0.25	0.000063	0.000081
11-May-11	120	0.029	454	217	0.22	16.2	15.6	8.29	120	300	49	18.5	0.000134	0.000073
18-May-11	76	0.04		237	0.23	20.5	21.9	8.2	76		1500	683	0.00181	0.000182
19-May-11	67	0.051		142	0.12	22.6	23.8	7.95	42	180	430	255	0.00064	0.000098
15-Jun-11	80	0.03	239	121	0.05	4.3	4.9	7.94		150	160	14.4	0.000096	0.000025
13-Jul-11	110	0.029	542	302	0.08		3.8	5.98	200	420	22	3.86	0.000126	0.000069
10-Aug-11	120	0.023	357	200	0.09	3.1	3	8.26	76	250	64	3.06	0.00005	0.000049
12-Sep-11	110	0.065	594	322	0.07	4.1	4.2	7.97	200	460	9	2.66	0.000106	0.000089
25-Oct-11	180	0.023	640	326	0.2	2.6	2.6	7.81	121	360	< 1		0.000042	0.000044
23-Nov-11	188	0.024	613	372	0.32	3.08		8.06	122	368	4.1	0.74	0.000051	0.000063

Table C.29: Water quality data and summary statistics for mine exposed station V8, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
7-Jan-08	70.5	< 0.001	0.12	< 0.001	29.6	0.014	0.002	1.2	< 0.00025	3.79	0.3	0.0056	0.016	0.017
18-Feb-08	85.6	< 0.001	< 0.05	< 0.001	37.4	0.019	0.002	1.2	< 0.00025	4.74	0.37		0.015	0.02
17-Mar-08	85.6	< 0.001	0.1	< 0.001	44.5	0.016	0.002	1.4	< 0.00025	5.72	0.35	0.0082	0.011	0.011
14-Apr-08	86.4	< 0.001	0.12	< 0.001	42.2	0.016	0.002	1.5	< 0.00025	5.67	0.4	0.0083	0.011	0.005
14-May-08	42.7	< 0.001	1.33	0.002	17.8	0.06	0.006	1.6	< 0.00025	2.18	0.16	0.0027	0.022	0.009
26-May-08	22.8	0.00135		0.00769	7.75		0.00454	0.98	0.00001	1.21	0.0903	0.00129	0.0412	
16-Jun-08	37.4	< 0.001	0.15	< 0.001	12.1	0.11	0.001	0.7	< 0.00025	1.8	0.14	0.0014	0.035	0.018
14-Jul-08	44	< 0.001	0.86	0.002	14.4	0.039	0.003	0.7	< 0.00025	2.06	0.17	0.0019	0.025	0.007
11-Aug-08		< 0.001	0.3	< 0.001	22.1	0.016	0.001	0.9	< 0.00025		0.27	0.003	0.019	0.011
15-Sep-08	42.8	0.001	2.01	0.002	16.6	0.053	0.005	1	< 0.00025	2.44	0.21	0.0034	0.02	0.005
15-Oct-08	57	< 0.001	< 0.05	< 0.001	20.6	0.016	0.001	0.9	< 0.00025		0.23	0.0037	0.013	0.007
3-Nov-08	71.6	< 0.001	0.54	0.002	29.4	0.032	0.003		0.0004	3.8	0.3	0.0054	0.019	0.006
1-Dec-08	90.5	< 0.001	0.06	< 0.001	40.3	0.014	0.002		< 0.00025	4.65	0.37	0.0063	0.035	0.033
12-Jan-09	93.7	< 0.001	0.12	< 0.001		0.012	0.002	1.2	< 0.00025	4.34	0.36	0.0086	0.015	0.014
2-Feb-09	93.7	< 0.001	0.25	< 0.001	43.6	0.011	0.002	1.2	< 0.00025	4.68	0.41	0.0078	0.018	0.016
3-Mar-09	107	0.000089	0.05	0.000117	49.2	0.00873	0.0021	1.42	< 0.000005	5.22	0.43	0.0104	0.0141	0.013
6-Apr-09	98	0.000088	0.03	0.000074	46.3	0.00734	0.00235	1.36	< 0.000005	4.82	0.394	0.0103	0.0137	0.0164
6-May-09	30.1	0.00194	1.37	0.0167	11.4	0.134	0.0057	1.72	0.00003	1.29	0.114	0.00164	0.0441	0.0175
13-May-09														
16-May-09														
17-May-09														
19-May-09														
20-May-09														
10-Jun-09	29.1	0.000175	0.137	0.001	11.1	0.0133	0.00113	0.59	< 0.000005	1.71	0.115	0.00217	0.0101	
13-Jul-09	96.6	0.00052	0.394	0.0022	25.4	0.0312	0.00268	1.08		2.95	0.348	0.00373	0.0236	0.016
11-Aug-09		0.0002	0.142	0.000645	27.4	0.0196	0.00169	1.07	< 0.000005	3.61		0.00454	0.0134	0.011
10-Sep-09	62.4	0.00023	0.224	0.000609	22.4	0.0198	0.00176	0.98	< 0.000005	3.19	0.236	0.00374	0.0119	0.0147
7-Oct-09	57.1	0.000782	0.232	0.00198	21.3	0.0886	0.00262	0.83		2.93	0.218	0.00398	0.148	0.0102
10-Nov-09	78.6	0.000075	0.048	0.000152	31.8	0.00605	0.00172	1.06	< 0.000005	3.99	0.3	0.0062	0.0105	0.0091
15-Dec-09	89	0.000126	0.103		37.2	0.013	0.00203	1.28	0.000064	4.4	0.348	0.00761	0.014	0.0138
6-Jan-10	97.4	0.000142	0.072	0.000291	43.4	0.0121	0.00264	1.34	< 0.000005	4.96	0.4		0.016	0.0161
18-Feb-10		0.000088	0.043	0.000086	43	0.00849	0.00217	1.3		4.9	0.385	0.00934	0.013	0.013
30-Mar-10	97.2	0.000073	0.03	0.000234	45.2	0.00666	0.00214	1.42	< 0.000005	5.19	0.402	0.0104	0.0127	0.0132
20-Apr-10	79.1	0.00129	1.23	0.00583	34.6	0.0739	0.00598	1.87	0.000012		0.313		0.0255	0.0063
12-May-10	60.8	0.000331	0.37		23.8	0.0265	0.00258	1.15	< 0.000005	2.89	0.23	0.00561	0.0114	0.0064
19-May-10		0.0013	1.6	0.00553	15	0.0934	0.00474	1.02	< 0.000005		0.147	0.0029	0.0284	
17-Jun-10	37.7	0.000449	0.415	0.00163	14.9	0.0237	0.00199	0.75	< 0.000005	2.27	0.154		0.0129	0.0062
14-Jul-10	103	0.000329	0.446		24.8	0.0294	0.00166	1.07	< 0.000005		0.366	0.00212	0.019	0.0326
3-Aug-10	58.2	0.000069	0.054	0.000151	22.8	0.00785	0.00111	0.96	< 0.000005	3.23	0.242	0.0039	0.007	
4-Aug-10	56.4	0.000056	0.051	0.000554	21.9	0.00877	0.00102	0.89	< 0.000005		0.229	0.00386	0.0092	0.0109
7-Sep-10	51.7	0.000055	0.068	0.000193	19.7	0.00813	0.00114	0.85	< 0.000005	2.9		0.00346	0.0072	
5-Oct-10	63.2	0.000046	0.037	0.000077	26.9	0.00539	0.00108	1.02	< 0.000005	3.64	0.244	0.00454	0.0075	0.0092
2-Nov-10	69.5	0.000088	0.06	0.000629	30.9	0.00676	0.00138	1.01	< 0.000005	4.05	0.275	0.0056	0.0099	0.0242
1-Dec-10	81.4	0.000096	0.065	0.000215	35	0.0105	0.00151	1.18	< 0.000005	4.2	0.328	0.00671	0.011	0.0121
25-Jan-11		0.000081	0.045	0.000163	41.6	0.00737	0.00169	1.33	< 0.000005	4.81		0.00896	0.0123	0.0135
17-Feb-11	99.2		0.038	0.000096		0.00565		1.37	< 0.000005	5.05	0.386	0.00967	0.0112	0.0116
22-Mar-11	93.6	0.000063	0.033	0.000497	47.1	0.00689	0.00212	1.51	< 0.000005	5.24	0.429	0.0102	0.0145	0.0138
21-Apr-11	105	0.000058	0.031	0.000127	44.2	0.00679	0.00191		< 0.000005	5.22	0.423	0.00978	0.0102	0.0168
11-May-11	53.4	0.00094	1.61	0.00223	23.8	0.0778	0.0055	1.8	0.000021	2.7	0.209	0.00436	0.017	0.0092
18-May-11	54	0.0221	33	0.0821	25	1.13	0.0729	4		2	0.217	0.00362	0.261	0.0189
19-May-11	32	0.00921	18.2	0.0228	15.1	0.422	0.0332	2.9	0.000215	1.4	0.133	0.0023	0.101	0.0103
15-Jun-11	29.8	0.000729	0.568	0.00305	11.3	0.0455	0.00284	0.66	< 0.000005	1.88	0.125	0.00217	0.0146	0.0072
13-Jul-11	77.8	0.00082	1.27	0.00219	23.1	0.0482	0.0039	1.1	0.000009	2.7	0.344	0.00311	0.022	0.0164
10-Aug-11	49.5	0.000176	0.188	0.000613	18.6	0.0164	0.00134	0.81		2.74	0.204	0.00315		
12-Sep-11	85.5	0.000155	0.156	0.000497	25.9	0.0282	0.00152	1	< 0.000005	2.85	0.323	0.00295	0.0247	0.0255
25-Oct-11	70.1	0.000071	0.065	0.000195	27.1	0.0092		1.11	< 0.000005	3.48		0.00481	0.0098	
23-Nov-11	92	0.000101	0.113	0.00026		0.0117	0.00152	1.2	< 0.000005	4.5	0.292	0.0064	0.0119	0.023

Table C.29: Water quality data and summary statistics for mine exposed station V8, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
8-Dec-11	193	0.051	608	337	0.338		3.18	8.4	144	400	< 4	0.89	0.000052	0.000059
26-Jan-12	219	0.041	663	364	0.433		1.9	8.01		426	2.3	1.07	0.000063	
20-Feb-12	209	0.036	734	409	0.424		1.77	8.23	166	546		0.41	0.000058	0.000052
7-Mar-12	228	0.015	833	379	0.455	1.36	2.53	8.32	166	492	< 1	0.22	0.000063	0.000051
23-Apr-12			669					8.42				3.98		
23-May-12	110	0.025	460	163	0.152	21	16.5	7.85	61.4	232	249		0.000313	0.0000702
29-May-12		0.022		124	0.114		10.2		43.9	182	96.1	32.8	0.000134	0.0000581
3-Jun-12	92.4	0.0127		133	0.0845					167	22.3		0.000249	< 0.000101
19-Jun-12	71.1	< 0.005	220	111	0.069	4.51	4.58	8.1	33.3	146	15.8		0.0000646	0.0000566
17-Jul-12	92.4	0.017	332	154	0.068	4.15		7.5	64	210	28	13.9	0.000083	0.0000397
15-Aug-12	116	0.011		409	0.086	3.3	3.55	8.22	240	534	2.3	0.74	0.000268	0.000294
29-Aug-12				190									0.000045	
12-Sep-12	131	0.0082	444	214	0.083	4.25			83.3		6	3.44	0.000037	
28-Sep-12		< 0.005		221	0.0841	2.81			80.7	297	2.4			0.000028
15-Oct-12	152	< 0.005	382	237		2.44	3.37	8.06	102	284	4.1	1.39	0.000039	0.000034
22-Oct-12	202	0.013			0.154		3.73		127	418	2	0.41		
14-Nov-12		0.017	514	316	0.242	2.43	2.43	8	125	360	< 1	0.84	0.000038	0.000036
12-Dec-12	212	0.019	641	347		2.49	2.48	7.98	159	422		2.51	0.000048	0.00004
n	61	66	43	68	33	43	46	60	64	48	68	39	65	58
minimum	53	<0.005	182	88.8	0.05	1.2	1.3	5.98	23	120	<1	0.22	0.000035	0.000019
maximum	250	0.2	833	471	0.6	22.6	23.8	8.75	240	580	1500	683	0.00181	0.000294
median	152	0.020	552	301	0.15	2.9	2.9	8.04	122	360	4.1	1.5	0.0000780	0.000063
mean [a]	158	0.027	539	288	0.22	5.0	5.0	8.01	126	357	53	29	0.000131	0.000071
standard deviation (SD) [a]	60	0.036	166	110	0.16	5.8	5.5	0.42	55	130	190	115	0.000231	0.000042
max detection limit	-	0.05	-	-	-	-	-	-	-	-	4	0.25	0.0002	0.0002
# < detection limit	-	24	-	-	-	-	-	-	-	-	10	1	12	14
% < detection limit	-	36%	-	-	-	-	-	-	-	-	15%	3%	18%	24%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	51%	9%	91%	82%	42%	9%	11%	13%	100%	88%	32%	41%	43%	47%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.0000120	0.000014
station median > BG median	1	1	1	1	1	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00037	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	4	3	0	0	-	18	10	2	-
% > current water quality criterion	-	0%	-	-	0%	9%	7%	0%	0%	-	26%	26%	3%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	2%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.29: Water quality data and summary statistics for mine exposed station V8, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
8-Dec-11	78.8	0.000086		0.000154	34	0.00935	0.0015	1.15	< 0.000005	4.25	0.321	0.00696	0.0147	0.0175
26-Jan-12	82.6	0.000083	0.061	0.00129		0.00764	0.00171	1.29	< 0.000005	4.73	0.344	0.00825	0.0134	0.0114
20-Feb-12	95.5	0.000059	0.045	0.000144	41.3	0.00603	0.00156		< 0.000005	5.03	0.368	0.00882	0.0105	0.0108
7-Mar-12	84.4	0.000048	0.035	0.000277	40.5	0.00458		1.36	< 0.000005	4.96		0.00775	0.0123	0.0111
23-Apr-12														
23-May-12	43	0.00266	2.81	0.00873	17.1	0.169	0.00967	1.45	0.0000726	1.87	0.171	0.00295	0.0466	0.0132
29-May-12	30.4	0.00086	0.87	0.00301	11.8	0.0648		0.973	0.0000207	1.6	0.132	0.00211	0.0464	0.0247
3-Jun-12	34.3		0.407	0.00466	12.5	0.109		0.929	0.0000079	1.83	0.122	0.00197	0.269	< 0.0497
19-Jun-12	26	0.000218	0.251	0.00177	9.28	0.0194	0.00133	0.636	0.0000071	1.55	0.113	0.00155	0.0162	0.0252
17-Jul-12	39.2			0.00156	13.5	0.0278	0.00198	0.646	0.0000093		0.161	0.00224	0.0187	0.0108
15-Aug-12	113	0.000132	0.0959	0.000311	30.7	0.29	0.00131	1.06		3.09	0.39	0.00283		0.0261
29-Aug-12	47.6	0.000145	0.197	0.000411	17.4	0.02			< 0.000005	2.46	0.192	0.00267	0.00966	0.00666
12-Sep-12	54.4	0.000135	0.19	0.000398	19	0.021	0.00164		< 0.000005	2.61		0.00304	0.0111	0.00813
28-Sep-12	51.5	0.00011	0.143	0.000377	19.3	0.014	0.00116	0.755	< 0.00001	2.58	0.197	0.00321	0.0097	0.0077
15-Oct-12	55.5	0.000094	0.0836	0.000503	23.6	0.0123	0.00118	0.846	< 0.000005		0.24	0.00421	0.00951	0.00989
22-Oct-12														
14-Nov-12	66.9	0.000066	0.0554	0.00014	31.3	0.00802	0.00123	0.999	< 0.000005	3.87		0.00632	0.00803	0.00653
12-Dec-12	79.6	0.000105	0.0873	0.000959	36	0.00965	0.00157	1.26	< 0.000005	4.29	0.332	0.00815	0.0101	0.00902
n	63	65	65	65	64	67	62	62	49	60	61	64	66	61
minimum	22.8	0.000046	0.03	0.000074	7.75	0.00458	0.001	0.59	<0.000005	1.21	0.0903	0.00129	0.007	0.005
maximum	113	0.0221	33	0.0821	49.2	1.13	0.0729	4	0.0004	5.72	0.43	0.0104	0.269	0.0497
median	69.5	0.000200	0.12	<0.001	24.9	0.0160	0.0020	1.09	<0.000005	3.55	0.275	0.00410	0.014	0.012
mean [a]	67.5	0.000874	1.14	0.00306	26.9	0.0552	0.0040	1.19	0.000020	3.48	0.271	0.00508	0.028	0.014
standard deviation (SD) [a]	24.5	0.00293	4.62	0.0106	11.5	0.149	0.0098	0.51	0.000064	1.29	0.101	0.00275	0.047	0.0066
max detection limit	-	0.001	0.05	0.001	-	-	-	-	0.00001	-	-	-	-	0.0497
# < detection limit	-	13	2	10	-	-	-	-	36	-	-	-	-	1
% < detection limit	-	20%	3%	15%	-	-	-	-	73%	-	-	-	-	2%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	76%	46%	22%	20%	97%	25%	92%	19%	14%	57%	75%	81%	48%	23%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.9	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	3	10	5	-	0	0	0	2	-	-	0	10	-
% > current water quality criterion	-	5%	15%	8%	-	0%	0%	0%	4%	-	-	0%	15%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.30: Water quality data and summary statistics for mine exposed station R8, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
8-Jan-08		< 0.01		120					9.55		< 1		< 0.0002	< 0.0002
19-Feb-08		0.03		159				8	9.1		< 1		< 0.0002	< 0.0002
18-Mar-08		0.01		138					9.84		< 1		< 0.0002	< 0.0002
14-Apr-08		0.02		132				7.8	10.3		< 1		< 0.0002	< 0.0002
15-May-08		0.03		38				8.7	2.41		4		< 0.0002	< 0.0002
17-Jun-08		< 0.01		45				8	5.17		3		< 0.0002	< 0.0002
15-Jul-08		0.01		41					4.02		69		< 0.0002	< 0.0002
12-Aug-08		0.01		70					6.13		< 1		< 0.0002	< 0.0002
15-Sep-08		0.03		67				7.3	6.15		2		< 0.0002	< 0.0002
15-Oct-08		0.02		74					7.05		< 1		< 0.0002	< 0.0002
4-Nov-08		< 0.01		90				7.7	8.08		1		< 0.0002	< 0.0002
2-Dec-08		0.05		123				7.9	8.62		1		< 0.0002	< 0.0002
13-Jan-09		0.05		129					10.2		< 1		< 0.0002	< 0.0002
3-Feb-09		0.03		126				7.8	10.4		< 1			< 0.0002
4-Mar-09	130	0.1	214	133		1.8	1.5	8.3	14	140	< 1		0.000009	0.000009
7-Apr-09	130	< 0.01	148.1	132		2.8	2.1	7.69	13	190	< 1		0.000024	0.000007
5-May-09	24		55	27.9		21.3	19.4	7.4	< 0.5	54	33		0.000116	0.000071
10-Jun-09	40	< 0.005	78	41.4		4.1	4.2	7.4	4.7		9			
14-Jul-09	28	< 0.01	69	25.7			3	7.6	4.1	48			0.000033	0.000021
6-Aug-09	96		188	98.8		2.7	2.4		7.6	200	2		0.000016	0.000078
2-Sep-09	71		90	68.7		3.3	2.9	8.1	6.3	86	< 1		0.000008	< 0.000005
4-Oct-09	74		117	74.3		2	2	8.1	6.7	110	< 4		0.000012	< 0.000005
4-Nov-09	93	0.02	187	97.3		2.6	1.8	7.55	6.5		< 1		0.00001	< 0.000005
2-Dec-09	110		192	113		1.5	1.3	7.06	9.3	130	< 1		0.000007	< 0.000005
11-Jan-10	130			130		1.6	1.3	6.91	10	170	< 1		< 0.000005	< 0.000005
23-Feb-10	130	< 0.01	220	141		1	1.2	7.94	9.6		< 1		< 0.000005	< 0.000005
10-Mar-10		0.02	244	138		1.1	1.2	7.84	11	140	< 1		< 0.000005	< 0.000005
11-Apr-10	140	< 0.01	230	144		0.7	0.8	7.73	9.2	140	< 1		< 0.000005	< 0.000005
3-May-10			87	54.3		14.6	12.1		< 0.5	82			0.000041	0.000034
5-Jun-10	44	< 0.05	89	48.7			3.3	7.92	5.1	64	2		0.000016	0.000014
8-Jul-10	63	< 0.05	121	57.8		2.9	3.2	8.09	5.8	70	2		0.000011	
3-Aug-10			177	84.1		2.3	2.3	7.26	6	90	2			< 0.000005
1-Sep-10	83		172	84.1	< 0.02	4.5	2.3	7.66	7	92	< 1	0.7	0.000007	0.000024
19-Oct-10	92	0.035	193	101	0.06	2	1.5		7.8	100	< 1	1.1	0.000006	0.000017
10-Nov-10		< 0.005	195	120	0.09	1.6	1.8	7.76	8.9	130	2		0.000008	0.000006
1-Dec-10	120	< 0.05	100	117	0.1	< 0.5	< 0.5	7.28	9.8	120		0.86	0.000007	0.000007
20-Jan-11	130	< 0.05	270	145	0.15	1.1		7.74	11	150	< 1	0.77	0.000008	0.000008
15-Feb-11	130	0.02	295	134	0.16	1.1	1.3	8	9.6	130		0.57	0.000015	0.000011
16-Mar-11	140	0.039	280	144		0.9	0.9		9.5	170	< 1	0.51	< 0.000005	0.000021
12-Apr-11	140	0.006	279	151	0.18	1.2	1.1	8.04	9.5	170	< 1	0.49	< 0.000005	0.000012
9-May-11	94		218	92.3	0.09	10.4	9.4	7.87	5.4	120	2	1.85		0.000017
22-Jun-11	37	0.018	85	41.6	< 0.02	5.7		7.69	6.4	64	6	1.22	0.000026	0.000121
21-Jul-11		0.026	113	57.7	< 0.02	4.9	5.1	7.9	5.4	88	< 1	0.6	0.000013	0.000017
24-Aug-11	62	0.026	123	62.2	< 0.02	3.1	3.5	7.56	6.3	82		0.46	0.000009	< 0.000005
22-Sep-11	71	0.07	180	75.5	< 0.02	2.7	2.6	7.64		96	< 1		0.000011	0.00001
19-Oct-11	86	0.018	160	95.1	0.06	2.4	2	7.76	8.2	92	< 1	0.57	0.000009	0.000014

Table C.30: Water quality data and summary statistics for mine exposed station R8, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8-Jan-08	36	< 0.001	0.12	< 0.001	7.2	0.01	< 0.001	0.9	< 0.00025	2.7	0.14	0.0018	< 0.005	< 0.005
19-Feb-08	47.4	< 0.001	< 0.05	< 0.001	9.8	0.011	< 0.001	0.9	< 0.00025	3.71	0.2	0.0019	< 0.005	< 0.005
18-Mar-08	39.7	< 0.001	0.06	< 0.001	9.3	0.006	< 0.001	1.1	< 0.00025	3.76	0.16	0.0025	< 0.005	< 0.005
14-Apr-08	38.8	< 0.001	0.12	< 0.001	8.43	0.006	< 0.001	1	< 0.00025	3.55	0.18	0.0025	< 0.005	< 0.005
15-May-08	11.8	< 0.001	0.47	0.001	2.2	0.036	0.001	1.5	< 0.00025	1.07	0.049	< 0.0005	0.009	0.008
17-Jun-08	12.9	< 0.001	0.11	< 0.001	3.16	0.01	< 0.001	0.5	< 0.00025	1.29	0.049	0.0005	0.008	0.006
15-Jul-08	11.9	0.001	1.73	0.021	2.64	0.049	0.004	0.6	< 0.00025	1.28	0.047	0.0006	0.03	0.007
12-Aug-08	20.9		0.19	< 0.001	4.23	0.017		0.5		1.76	0.079		< 0.005	
15-Sep-08	20.1	< 0.001	0.17	< 0.001	4.1	0.019	< 0.001	0.5	< 0.00025	1.67	0.094	0.001	< 0.005	< 0.005
15-Oct-08	22.9		0.05	< 0.001	4.18	0.019		0.5	< 0.00025	1.67	0.09		< 0.005	< 0.005
4-Nov-08	26.6	< 0.001	< 0.05	< 0.001	5.73	0.016	< 0.001		< 0.00025	2.21	0.11	0.0013	0.006	< 0.005
2-Dec-08	37.4	< 0.001	0.11	< 0.001	7.09	0.026		1	< 0.00025	2.9	0.13		0.015	0.012
13-Jan-09	38.7	< 0.001	0.1	< 0.001	7.75	0.017		0.9	< 0.00025	2.87	0.16	0.0024	0.007	< 0.005
3-Feb-09	38.2	< 0.001	0.19	< 0.001	7.41	0.018	< 0.001		< 0.00025	2.83	0.18	0.0021	< 0.005	
4-Mar-09	40.3	0.000017	0.08	0.000065	7.8	0.0109	0.00021	0.94	< 0.000005	2.9	0.174	0.00257	0.0007	0.0007
7-Apr-09	39.8	0.000021	0.077	0.000435	7.85	0.00976	0.00022	0.99	< 0.000005	4.35	0.174	0.00267	0.0025	0.0027
5-May-09	8.47	0.000372	0.645	0.00393	1.64	0.0606	0.00145	1.75	0.00001	0.73	0.0371	0.000305	0.0175	0.0118
10-Jun-09	11.9	0.000049	0.131	0.00114	2.47	0.011	0.0004	0.42	< 0.000005	1.02	0.0456	0.000524	0.0019	0.0013
14-Jul-09	7.29	0.000036	0.032	0.00235		0.00083	0.001	0.37	< 0.000005	1.87	0.0376	0.000371	0.0058	0.0048
6-Aug-09	29.8	0.000042	0.16	0.0003	5.93	0.0216	0.00032	0.63	< 0.000005	2.11	0.12	0.0013	0.0014	0.0072
2-Sep-09	20.4		0.19	0.000444		0.0207	0.00037	0.46	< 0.000005	1.79	0.0891	0.000818	0.0014	0.0012
4-Oct-09	21.3	0.000037	0.16	0.000679	4.22	0.022	0.00037	0.48	< 0.000005	1.94	0.0922	0.00101	0.0033	0.001
4-Nov-09		0.000031	0.134	0.000666	5.32	0.0215	0.0003	0.68	< 0.000005	2.2	0.12	0.00142	0.0019	0.0018
2-Dec-09	33.8	0.000026	0.106	0.000081	5.72	0.0202	0.00024	0.71	< 0.000005	2.15	0.14	0.00172	0.0005	0.0007
11-Jan-10	38.6	0.000019	0.09	0.000089	7.6	0.0148	0.00019	0.89	< 0.000005	2.95	0.157	0.00223	0.0007	0.0007
23-Feb-10	42.6	0.000016	0.077	0.000023	8.34	0.00995	0.00018	0.99	< 0.000005	3.25	0.177	0.00265	0.0004	0.0003
10-Mar-10	40.6	0.000013	0.074	0.000017	7.97	0.00916	0.00018	0.94		3.18	0.171	0.0027	0.0005	0.0004
11-Apr-10	43.5	0.000021	0.07	0.000026	8.25	0.0083	0.00026	1.05	< 0.000005	3.36	0.182	0.00283	0.0004	0.0006
3-May-10	16.1	0.000107	0.398	0.00168	3	0.0363	0.0017	1.27	< 0.000005		0.0694	0.000706	0.0086	0.0068
5-Jun-10		0.000061	0.167	0.000832	3.11	0.0137	0.00043	0.48	< 0.000005	1.58	0.0567	0.00057	0.0026	0.0041
8-Jul-10	16.6	0.00004	0.137	0.000407	3.72	0.0153	0.00037	0.4	< 0.000005	1.6	0.0725	0.000653	0.0015	0.0025
3-Aug-10	25	0.000035	0.168	0.000272	5.29	0.0156	0.00034	0.54	< 0.000005	2	0.103	0.00103	0.0026	0.0026
1-Sep-10	25.3	0.000029	0.188	0.000525	5.1	0.0165	0.00027	0.52		2.04	0.106	0.00107	0.0029	0.022
19-Oct-10	29.3	0.000029	0.176	0.000273	6.06	0.0195	0.00025	0.66	< 0.000005	2.4	0.121	0.00139	0.0015	0.0078
10-Nov-10	36.1	0.000044	0.147	0.000251	7.16	0.0171	0.00032		< 0.000005		0.145	0.00175	0.0016	0.0017
1-Dec-10	35.1	0.000027	0.128	0.000066	7	0.0154	0.00022	0.8	< 0.000005	2.65	0.146	0.00176	0.0035	0.0033
20-Jan-11	36	0.000021	0.088	0.000175	7.23	0.0104	0.0002	0.92	< 0.000005	2.67	0.177	0.00243	0.0025	0.0022
15-Feb-11	36.2	0.000027	0.086	0.000247	7.72	0.00792	0.00028	0.96	< 0.000005	2.99	0.174	0.00246	0.0021	0.0023
16-Mar-11	42.8	0.00002	0.08	0.000293	8.95	0.0096	0.00022	1.1	< 0.000005	3.54	0.19	0.00284	0.0037	0.0042
12-Apr-11	40.2	0.000017	0.076	0.00013	8.08	0.0067	0.00019	1	< 0.000005	3.12	0.171		0.0006	0.0027
9-May-11	25.4	0.000038	0.434				0.00057	1.53	0.000006	1.99	0.116	0.00125	0.0024	
22-Jun-11	12.5	0.000135	0.208	0.00322		0.0156	0.00167	0.36	0.000006	1.22	0.0522	0.00042	0.0039	0.0122
21-Jul-11	17.3	0.000051	0.135	0.000487	3.51	0.0143		0.32	< 0.000005	1.46	0.0648	0.000542	0.002	0.0043
24-Aug-11	18.6	0.000042	0.137	0.00114	3.68	0.0163	0.00048	0.39	< 0.000005	1.56	0.0757	0.000631	0.0015	0.0041
22-Sep-11	22.5	0.000044	0.155	0.000239	4.57	0.02	0.0004	0.56	< 0.000005	1.81		0.000901	0.0016	0.0019
19-Oct-11	27.8	0.000041	0.157	0.000079	5.45				< 0.000005	2.23	0.112	0.00141	0.0026	

Table C.30: Water quality data and summary statistics for mine exposed station R8, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
15-Nov-11	101	0.024	200	100	0.101	3.86	2.35	7.63	9.45	116	< 1	0.76	0.000011	< 0.000005
6-Dec-11	105	0.036	212	108	0.112	1.69	1.35	7.66	9.08	118	< 1	1.07	0.000009	0.000006
11-Jan-12	110	0.029	220	108	0.129	1.22	1.31	8.13	8.86	118	< 1	1.04	< 0.000005	0.000006
14-Feb-12	122	0.027		130	0.166	1.28		7.18	9.11	136	< 1	0.88	< 0.000005	0.000017
6-Mar-12	124	0.022	237	145	0.177	1.29	1.21	7.88	8.44		< 1	0.82	0.000012	0.00001
19-Apr-12			264					7.93						
17-May-12	82.3	0.033	172	82.7	0.049	8.58	7.68			114	2.4		0.00003	0.000034
13-Jun-12	29.1	0.017	30	32.7	< 0.02		5.49	7.46		54	49.9		0.0000442	0.0000206
11-Jul-12	46.4	0.029	70	50	0.039	4.9	6.09	7.77	2.85	68	8.3	2.14	0.0000272	0.0000168
8-Aug-12	77.1	0.012	130	84.4	< 0.02	2.14	2.9	7.89	6.92	90	< 1	0.56	0.000012	0.00001
5-Sep-12	73.2	0.0053	154	76.1	< 0.02	3.44	2.82	8.02	6.82	100	< 1	0.45	0.000008	0.000013
9-Oct-12	72.6	0.0084	153	76.9	< 0.02	2.64	2.99	7.51	7.37		1.3	0.7	0.000009	0.00001
6-Nov-12	102	0.013	277	106	0.111	1.62	1.07	7.74	10.2		< 1	0.77	0.00001	0.000006
5-Dec-12		0.017	235	121	0.161	1.26	1.28	7.65	9.95	128	< 1	0.78	0.000007	0.000006
n	39	49	44	59	26	42	42	49	56	39	54	23	42	43
minimum	24	<0.005	30	25.7	<0.02	<0.5	<0.5	6.91	<0.5	48	<1	0.45	<0.000005	<0.000005
maximum	140	0.1	295	159	0.18	21.3	19.4	8.7	14	200	69	2.14	0.000116	0.000121
median	93	0.020	179	97	0.08	2.2	2.2	7.76	8.1	114	<1	0.77	0.0000090	0.000010
mean [a]	91	0.022	171	95	0.08	3.4	3.2	7.74	7.7	112	4	0.86	0.000015	0.000016
standard deviation (SD) [a]	35	0.018	70	37	0.06	3.9	3.5	0.32	2.7	38	12	0.42	0.000019	0.000023
max detection limit	-	0.05	-	-	0.02	0.5	0.5	-	0.5	-	4	-	0.000005	0.000005
# < detection limit	-	13	-	-	9	1	1	-	2	-	35	-	8	11
% < detection limit	-	27%	-	-	35%	2%	2%	-	4%	-	65%	-	19%	26%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	4%	2%	0%	0%	2%	2%	2%	0%	5%	6%	0%	2%	7%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	2%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	0	0	1	1	1	0	1	0	0
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00015	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	3	0	0	-
% > current water quality criterion	-	0%	-	-	0%	2%	2%	0%	0%	-	6%	0%	0%	-
# < current water quality criterion	-	-	-	-	-	1	1	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	2%	2%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.30: Water quality data and summary statistics for mine exposed station R8, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
15-Nov-11	29.9			0.000113			0.00024	0.78	< 0.000005	2.34	0.136	0.00156	0.0011	0.0009
6-Dec-11	32.8	0.000035	0.172	0.000054	6.43	0.0216	0.00026	0.8	< 0.000005	2.49	0.137	0.00173	0.001	0.0015
11-Jan-12	32.2	0.000027	0.142		6.74	0.0147	0.00026	0.79	< 0.000005	2.62	0.141	0.00177	0.0008	0.0051
14-Feb-12	37.1	0.000016	0.111	0.000029	7.24	0.0132	0.00022	0.96	< 0.000005	2.93	0.157	0.00209	0.0008	0.0081
6-Mar-12	39.2	0.000021	0.107	0.000167	8	0.0114	0.00031	1.02	< 0.000005	3.23	0.166	0.00218	0.0017	0.0024
19-Apr-12														
17-May-12	25.4	0.0000544	0.403	0.0011	4.69	0.0194	0.000719	1.23	0.0000059	1.96	0.0984	0.0012	0.00448	0.00323
13-Jun-12	9.61	0.000207	0.331	0.00325	2.12	0.0209	0.000933	0.489		0.998	0.0399	0.000377		0.00543
11-Jul-12	12.8	0.00013	0.235	0.00143	2.8	0.0167	0.000857	0.306	0.0000069	1.41		0.000458	0.00531	0.00704
8-Aug-12	24.6	0.000051	0.178	0.000239	4.82	0.0237	0.00042	0.494		1.83	0.101	0.000976		0.00092
5-Sep-12	23.1	0.000035	0.164	0.000112	4.5	0.0236	0.000349	0.555	< 0.000005	1.97	0.0917	0.000924	0.00172	0.00632
9-Oct-12		0.000042	0.165	0.000861	4.54	0.0229	0.000278		< 0.000005	1.89	0.0967	0.000989	0.00204	0.00607
6-Nov-12	31.4	0.000054	0.162	0.000169		0.0307	0.000422		< 0.000005	2.51		0.0017	0.00156	0.00057
5-Dec-12	36	0.000034	0.134	0.000049	7.51	0.026	0.000242	0.865	< 0.000005	2.76	0.151	0.00208	0.00191	0.00153
n	56	44	58	57	53	56	53	53	41	57	56	55	57	55
minimum	7.29	0.000013	0.032	0.000017	1.64	0.00083	0.00018	0.306	<0.000005	0.73	0.0371	0.000305	0.0004	0.0003
maximum	47.4	0.001	1.73	0.021	9.8	0.0606	0.004	1.75	0.00001	4.35	0.2	0.00284	0.03	0.022
median	29.6	0.0000355	0.14	0.000487	5.7	0.0164	0.00037	0.79	<0.000005	2.20	0.120	0.00139	0.0025	0.0041
mean [a]	28.2	0.000073	0.19	0.000985	5.8	0.0178	0.00053	0.78	0.000003	2.30	0.119	0.00145	0.0036	0.0040
standard deviation (SD) [a]	10.8	0.000156	0.24	0.00282	2.1	0.0101	0.00060	0.33	0.000002	0.80	0.0471	0.000784	0.0048	0.0039
max detection limit	-	-	0.05	0.001	-	-	0.001	-	0.000005	-	-	0.0005	0.005	0.005
# < detection limit	-	-	2	12	-	-	8	-	36	-	-	1	8	8
% < detection limit	-	-	3%	21%	-	-	15%	-	88%	-	-	2%	14%	15%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	2%	5%	5%	9%	0%	4%	8%	6%	0%	18%	13%	11%	5%	2%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.006	-	1.0	0.094	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	1	1	-	0	0	0	0	-	-	0	0	-
% > current water quality criterion	-	0%	2%	2%	-	0%	0%	0%	0%	-	-	0%	0%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.31: Water quality data and summary statistics for mine exposed station R9, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
8-Jan-08		< 0.01		128				8	18.4		< 1		< 0.0002	< 0.0002
19-Feb-08		0.02						8.1	18.6		< 1		< 0.0002	< 0.0002
18-Mar-08				152				7.4	19.9		< 1		< 0.0002	< 0.0002
14-Apr-08		0.03		150				7.7	20.1		< 1		< 0.0002	< 0.0002
15-May-08		0.02		41				8.4	3.6		3		< 0.0002	< 0.0002
17-Jun-08		0.01		60				7.9	6.61		2		< 0.0002	< 0.0002
15-Jul-08		0.01		43				7.5	4.9		68		< 0.0002	< 0.0002
12-Aug-08		0.01		77				7.5	8.73		< 1		< 0.0002	< 0.0002
15-Sep-08		0.03						7.4	7.85		4		< 0.0002	< 0.0002
15-Oct-08				85				7.5	11.5		< 1		< 0.0002	< 0.0002
4-Nov-08		< 0.01						7.7	12.5		< 1		< 0.0002	< 0.0002
2-Dec-08				137				7.8	14.1		< 1		< 0.0002	< 0.0002
13-Jan-09		0.03		135				7.5	18.7		< 1		< 0.0002	< 0.0002
3-Feb-09		0.03		138				7.8	19.1		< 1		< 0.0002	< 0.0002
4-Mar-09	130	0.02	241	143		1.9	2	8.2	20	180			0.00001	0.00001
7-Apr-09	140	0.07	159.4	143		3.4	3	7.73	22	220	< 1		0.000009	0.00001
5-May-09	25	0.03	60	31		22.4	21.2	7.14	1.7	58	440			0.000063
10-Jun-09	41	< 0.005		43.6		3.9	3.9	7.4	6.4	78	9		0.000016	0.000008
14-Jul-09	79		157	84.7		2.1	2	7.7	11	94	2		0.000047	0.000019
6-Aug-09		< 0.01		107		2.6	2.4	7.5	13	130	< 1		0.000011	0.000027
2-Sep-09		< 0.01		79		3.2		7.77	9.8	92	< 1		0.000011	0.000013
4-Oct-09	78	< 0.01	117	85.2		2.1	2.1	8.1	10		< 4		0.000011	< 0.000005
4-Nov-09	98	0.02	190	109		2.4	2.1	7.69	12	150	< 1			0.000019
2-Dec-09	110	0.02	222	124		1.3	1.2	7.42	17	140	< 1		0.00001	
11-Jan-10	130	0.02	272	147		1.2	1.1	7.11	21	190	< 1		0.000015	< 0.000005
23-Feb-10	140	< 0.01	250	150		1.3	1.5	7.73	18	160	< 1			< 0.000005
10-Mar-10	140	< 0.01	262	151		1.4	1.3	7.88	19	150	< 1		< 0.000005	< 0.000005
11-Apr-10	140	< 0.01	230	155		1	1.1	7.81	17		< 1		0.00001	0.000008
3-May-10	54	0.1	95	57.8		14.3	10.8	7.78	< 0.5	94	3		0.000027	0.000032
5-Jun-10		< 0.05	101	53.8		3	3.2	8.05	6	58	2		0.000021	0.00002
8-Jul-10	47	< 0.05	127	64.3		3.2	3.4	8.01	7.9	78	3		0.000008	0.000011
3-Aug-10	91	< 0.05	194	91.2			2	7.47	9.3	100	< 1		0.000011	0.00001
1-Sep-10		0.13	187	92.1	0.04	1.9	1.7	7.81	11		< 1	0.7	0.00001	0.000017
19-Oct-10	96	0.017	211	113	0.13	1.7	1.4	7.6	14	110	< 1	1	0.000015	0.000015
10-Nov-10	110	< 0.005	254	131	0.19	2.1	2.8	7.87	18	130	< 1	0.64		0.000024
1-Dec-10		< 0.05	120	130		< 0.5	< 0.5	7.46	19	140	< 4	1	0.000009	0.000007
20-Jan-11		< 0.05	290	149	0.25	1.1	0.9	7.81	20	150	< 1	0.75	0.000008	0.000019
15-Feb-11	130	0.014	293	142	0.23	1	1	7.99	17	150	< 1	0.56	0.000006	< 0.000005
16-Mar-11	150	0.019	290	150	0.26	1	1	8.02	16	180	< 1	0.39	0.000014	0.000006
12-Apr-11	140	0.007	282	149	0.23	1.7	0.8	8.08	15	160	< 1	0.39	< 0.000005	0.00002
9-May-11	93	0.027	209	99.9	0.09	10.8		7.78	12	130	3	1.73	0.00002	
22-Jun-11		0.031	93	45.6	< 0.02	5.1	5.2	7.67	5	62	7	1.28	0.000022	0.000099
21-Jul-11	57	0.042	131	63.1	< 0.02	4.5	6	7.8	6.5	82	< 1	0.58	0.000016	0.00002
23-Aug-11	65	0.026		70	< 0.02	3.1	4.1	7.93	9.1	88	< 1	0.53	< 0.000005	0.000019
22-Sep-11	75	0.031	230	84.5	0.03	2.4	3.3	7.51	12		< 1	0.65	0.000018	0.000011
19-Oct-11	93	0.023	180	104		1.9	2.1	7.66	14		< 1	0.5	0.000014	0.000008

Table C.31: Water quality data and summary statistics for mine exposed station R9, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8-Jan-08	37.9	< 0.001	0.1	< 0.001	8.02	0.012	< 0.001	1	< 0.00025	2.75	0.15	0.0019	< 0.005	< 0.005
19-Feb-08	41.9	< 0.001	< 0.05	< 0.001	9.16	0.015	< 0.001	1	< 0.00025	3.38	0.18	0.0017	< 0.005	< 0.005
18-Mar-08	42.9	< 0.001	0.06	< 0.001	11	0.01	< 0.001	1.2	< 0.00025	3.97	0.18	0.0027	< 0.005	< 0.005
14-Apr-08	43.4	< 0.001	0.1	< 0.001	10.1	0.011	< 0.001	1.1	< 0.00025	3.84	0.19	0.0027	< 0.005	< 0.005
15-May-08	12.3	< 0.001	0.45	0.001	2.45	0.035	< 0.001	1.4	< 0.00025	1.08	0.053	< 0.0005	0.008	0.005
17-Jun-08	16.8	< 0.001	0.14	< 0.001	4.24	0.013	< 0.001	0.6	< 0.00025	1.61	0.063	0.0006	0.009	0.006
15-Jul-08	12.5	< 0.001	1.55	0.017	2.79	0.048	0.003	0.6	< 0.00025	1.29	0.053	0.0006	0.026	0.009
12-Aug-08	22.8	< 0.001	0.17	< 0.001	4.86	0.019	< 0.001	0.5	< 0.00025	1.85	0.09	0.0007	0.008	< 0.005
15-Sep-08		< 0.001	0.32	0.005	4.02	0.023	< 0.001	0.5	< 0.00025	1.64	0.096	0.001	< 0.005	< 0.005
15-Oct-08	25.6	< 0.001	0.07	< 0.001	5.03	0.04	< 0.001	0.6	< 0.00025	1.88		0.0011	0.008	0.008
4-Nov-08		< 0.001	< 0.05	< 0.001	6.23	0.016	0.012	0.8	< 0.00025	2.23	0.13	0.0014	0.012	< 0.005
2-Dec-08	40.7	< 0.001	0.1	< 0.001	8.41	0.026	< 0.001	1.1	< 0.00025	3.02		0.002	0.013	0.015
13-Jan-09	39.6	< 0.001	0.1	< 0.001	8.73	0.019	< 0.001	1	< 0.00025	2.8		0.0025	< 0.005	< 0.005
3-Feb-09		< 0.001	0.17	< 0.001	8.7	0.017	< 0.001	0.9	< 0.00025		0.19	0.0024	< 0.005	< 0.005
4-Mar-09	41.8	0.00002	0.079	0.000077	8.68		0.00023	1	< 0.000005	2.91	0.185	0.0028	0.0009	0.0008
7-Apr-09	42.5	0.000018	0.068	0.000162	9.01	0.0108	0.00023	1.05	< 0.000005	3.18	0.185		0.0012	0.001
5-May-09	9.31	0.000323	0.684	0.00487	1.88	0.0682	0.0027	1.8	0.000014	0.75	0.0414	0.000332	0.0209	0.0146
10-Jun-09		0.000044	0.109	0.000544	2.73	0.00955	0.00041	0.45	< 0.000005	1.06	0.0509	0.000543	0.0017	0.0021
14-Jul-09	24.1	0.000055	0.116	0.000522	5.43	0.0137	0.00034	0.57	< 0.000005	1.8	0.094	0.001		0.0052
6-Aug-09		0.000044	0.116	0.000155	6.53	0.0153	0.00028	0.7		2.16	0.132	0.00145	0.0015	
2-Sep-09	22.2	0.000055	0.187	0.000358	4.46	0.022	0.00032	0.51	< 0.000005	1.83		0.000962		0.0018
4-Oct-09	23.8		0.149	0.000422		0.0198	0.00031		< 0.000005	2.03	0.107	0.00116	0.0014	0.0027
4-Nov-09	33.6	0.000044	0.132	0.0021	6.08	0.0221		0.78	< 0.000005	2.24	0.134	0.00161	0.0045	0.007
2-Dec-09	37.3	0.000031	0.108	0.000234	6.69	0.0211		0.82	< 0.000005	2.23	0.156	0.00192	0.0013	0.0015
11-Jan-10	43.5	0.000026	0.088	0.00025	9.25	0.017	0.00022	1.01		3.12	0.172	0.00249	0.0013	0.0016
23-Feb-10	44.5	0.000027	0.063	0.000119	9.57	0.0128	0.00022		< 0.000005	3.39	0.186	0.00282	0.0012	0.0011
10-Mar-10	42.7	0.000027	0.071	0.000193	8.88	0.0107	0.00023	1.02	< 0.000005	3.19	0.18	0.0029	0.0041	0.0036
11-Apr-10	46.8	0.000019	0.064	0.00013	9.35	0.00936	0.00023	1.14	< 0.000005	3.42	0.193	0.00309	0.0011	0.0007
3-May-10	15.2	0.000081	0.29	0.000912	3.01	0.0209		1.13		1.27		0.000619	0.004	0.004
5-Jun-10	15.1		0.183	0.00109		0.0167	0.0005	0.52	< 0.000005	1.6	0.0616	0.000617	0.0032	0.0056
8-Jul-10	19	0.000047	0.153	0.000505	4.08	0.0145	0.0004	0.44	< 0.000005		0.0812	0.000715		0.002
3-Aug-10	26.2	0.000041	0.152	0.00162	5.81	0.0138	0.00045	0.63	< 0.000005	2.11		0.00117	0.0067	0.0035
1-Sep-10	26.5		0.18	0.000131		0.0168	0.00028		< 0.000005	2.16	0.118	0.00116	0.0008	0.0108
19-Oct-10	31.7	0.000031	0.172	0.000163	7	0.0196			< 0.000005	2.42	0.133	0.00156	0.002	0.0044
10-Nov-10	38.7		0.11	0.0006	8.35	0.0171	0.00034	0.91	< 0.000005	2.84	0.161	0.00199	0.0058	0.0526
1-Dec-10	38.5	0.000043	0.156	0.000149	8.07	0.0227	0.00026	0.87	< 0.000005		0.16	0.00204	0.0019	0.0037
20-Jan-11	40	0.000026	0.089	0.000055	8.4	0.0126	0.00023	0.98	< 0.000005	2.75	0.186		0.0008	0.0012
15-Feb-11	42.2	0.000017	0.08	0.000081	8.89	0.00956	0.0002	1.03	< 0.000005	3.13	0.184	0.00268	0.0008	
16-Mar-11	44.4	0.000025	0.066	0.000612	9.56	0.0108	0.00022	1.15	< 0.000005			0.00306	0.0019	0.0007
12-Apr-11	40.7	0.000023	0.065	0.000103	8.68	0.00779	0.00022	1.04	< 0.000005	3.18	0.177	0.00282	0.0006	0.0085
9-May-11		0.000061	0.418	0.000609	5.57	0.0229	0.00066	1.6		2	0.121	0.00127	0.0049	0.0072
22-Jun-11	13.5	0.000092	0.191	0.00118	2.87	0.0181	0.00095	0.39		1.23	0.0593		0.0034	0.0106
21-Jul-11	18.2	0.00005		0.000932	3.74	0.0127	0.00049	0.36	< 0.000005	1.43	0.0711	0.000582	0.0018	0.0083
23-Aug-11	20.9	0.000053	0.148	0.000499	4.32	0.0176	0.00062	0.45	< 0.000005	1.73	0.0848	0.000707		
22-Sep-11	24.6	0.000041	0.147	0.000232	5	0.0206	0.00045	0.61	< 0.000005	1.85	0.101	0.000979	0.005	0.0014
19-Oct-11	30.1	0.000049	0.147	0.000284	6.26	0.0252	0.00045	0.71	< 0.000005	2.31	0.128	0.00157	0.0065	0.0035

Table C.31: Water quality data and summary statistics for mine exposed station R9, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
16-Nov-11	103	0.11	187	115	0.179	1.85	1.66	7.89	14.5	144	< 1	0.66	0.000015	0.000013
6-Dec-11	108	0.039	236	118	0.184	1.26	1.58	7.61	16	128	< 1	0.84	0.000012	0.000007
9-Jan-12	115	0.033		141	0.184	1.26	1.19	7.49	18.8	136	< 1	0.89	< 0.000005	0.00014
14-Feb-12	124	0.028	283	144	0.268	1.11	0.91		18.8	176	< 1	0.97	0.000012	0.000009
6-Mar-12	126	0.011	260	147	0.29	0.63	1.48	7.89	18.8	156	< 1	0.71	0.000011	0.000009
19-Apr-12			288					7.95				1.05		
17-May-12	83.5	0.043	191	90.4	0.1	8.3		7.8	13.3	118	5.9		0.0000348	
12-Jun-12	29.9	0.036	58	33.3	< 0.02	5.36		7.71	4.34	62			0.0000466	0.0000209
11-Jul-12	47.9	0.022	97	53	< 0.02	5.82		7.29	7.03	68	14.7	2.48	0.0000301	0.0000165
8-Aug-12	79.6	0.013	150	88.8	0.04	3.24	2.63		9.86	100		0.53	0.000009	0.000012
5-Sep-12	77.5	< 0.005		84.2	0.03	2.92	2.82	7.71	9.82	88	< 1		0.000006	0.000007
9-Oct-12	76		160	84.6	0.04	2.99	3.07	7.57	10.5	102	2.1	0.82	< 0.000005	0.000012
6-Nov-12	105	0.015	248	116	0.155	1.62	1.7	7.82	16.2	132	2.3	0.64	0.000011	0.000012
5-Dec-12	126	0.022	256	149	0.252	1.86		7.73	19.7	154	< 1	0.66	0.000009	0.000008
n	38	54	40	56	25	44	39	58	59	40	56	25	41	42
minimum	25	<0.005	58	31	<0.02	<0.5	<0.5	7.11	<0.5	58	<1	0.39	<0.000005	<0.000005
maximum	150	0.13	293	155	0.29	22.4	21.2	8.4	22	220	440	2.48	0.0000470	0.00014
median	97	0.021	202	108	0.13	2.1	2	7.73	13.3	130	<1	0.70	0.0000110	0.000012
mean [a]	96	0.026	197	105	0.13	3.4	2.9	7.73	13.1	123	11	0.84	0.0000141	0.000019
standard deviation (SD) [a]	34	0.025	70	38	0.10	4.0	3.5	0.25	5.5	40	59	0.45	0.0000103	0.000025
max detection limit	-	0.05	-	-	0.02	0.5	0.5	-	0.5	-	4	-	0.000005	0.000005
# < detection limit	-	16	-	-	5	1	1	-	1	-	40	-	5	5
% < detection limit	-	30%	-	-	20%	2%	3%	-	2%	-	71%	-	12%	12%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	7%	3%	0%	28%	2%	3%	0%	2%	5%	4%	4%	0%	5%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	2%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	0	0	1	1	1	0	1	0	0
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00017	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	2	0	0	-
% > current water quality criterion	-	0%	-	-	0%	2%	3%	0%	0%	-	4%	0%	0%	-
# < current water quality criterion	-	-	-	-	-	1	1	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	2%	3%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.31: Water quality data and summary statistics for mine exposed station R9, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
16-Nov-11	34.5	0.000042	0.122	0.000984	6.98	0.0179	0.00054	0.8	< 0.000005	2.43	0.146	0.00188	0.0038	0.0057
6-Dec-11	35.4	0.000025	0.167	0.000092	7.17	0.0216	0.00027	0.84		2.49	0.145	0.00182	0.0009	0.0009
9-Jan-12	43	0.00003	0.157	0.000132	8.27	0.0175	0.00026			2.95	0.173			0.0176
14-Feb-12	43.3	0.000019	0.109	0.000081	8.7	0.0142	0.00036	1.06	< 0.000005	3.08	0.168	0.00227	0.002	0.0013
6-Mar-12	43.4			0.000226	9.32	0.0133	0.00028	1.13	< 0.000005		0.177	0.00245	0.0018	0.0009
19-Apr-12														
17-May-12	27.1	0.0000664	0.375	0.00137	5.52	0.0193	0.00091	1.29		1.96	0.114	0.0013	0.00862	0.00946
12-Jun-12	10	0.000357	0.596	0.00339	2.01			0.543	0.0000158	0.908	0.0413	0.000344	0.00663	0.00324
11-Jul-12	15.6	0.000138	0.268	0.00288	3.32	0.0183	0.000887	0.386	0.0000122	1.41	0.0637	0.000525	0.0111	0.00517
8-Aug-12	26.7	0.000044	0.178	0.000228	5.35			0.558	< 0.000005	1.92	0.109	0.00104	0.0012	0.00198
5-Sep-12	25.4	0.000043	0.166	0.00012	5.06	0.0234	0.000331	0.617		1.97		0.000987	0.00063	0.00183
9-Oct-12	25.5	0.000042	0.169	0.000162	5.07	0.0231	0.000309	0.638		1.91	0.106	0.00105		0.00488
6-Nov-12	34	0.000053	0.135	0.000239	7.6	0.0288	0.000419	0.835	< 0.000005	2.55	0.137	0.0018	0.00158	0.00458
5-Dec-12	44.9	0.000037	0.144	0.00008	8.92	0.0272	0.000375	0.985	< 0.000005	2.93	0.182	0.00255	0.00089	0.0006
n	53	40	57	59	56	56	53	54	35	54	51	55	53	56
minimum	9.31	0.000017	<0.05	0.000055	1.88	0.00779	0.0002	0.36	<0.000005	0.75	0.0413	0.000332	0.0006	0.0006
maximum	46.8	0.000357	1.55	0.0170	11	0.0682	0.012	1.8	0.0000158	3.97	0.193	0.00309	0.026	0.0526
median	33.6	0.0000425	0.14	0.000522	6.61	0.0176	0.00042	0.84	<0.000005	2.20	0.133	0.00145	0.0038	0.0049
mean [a]	31.0	0.000058	0.19	0.000989	6.52	0.0193	0.00072	0.85	0.000003	2.28	0.129	0.00157	0.0044	0.0053
standard deviation (SD) [a]	11.3	0.000069	0.22	0.00235	2.42	0.0100	0.0017	0.31	0.000003	0.77	0.0483	0.000832	0.0050	0.0075
max detection limit	-	-	0.05	0.001	-	-	0.001	-	0.000005	-	-	0.0005	0.005	0.005
# < detection limit	-	-	2	11	-	-	12	-	32	-	-	1	7	9
% < detection limit	-	-	4%	19%	-	-	23%	-	91%	-	-	2%	13%	16%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	2%	5%	5%	10%	2%	5%	6%	6%	0%	19%	27%	18%	4%	4%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.1	0.10	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	1	1	-	0	0	0	0	-	-	0	0	-
% > current water quality criterion	-	0%	2%	2%	-	0%	0%	0%	0%	-	-	0%	0%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.32: Water quality data and summary statistics for mine exposed station R10, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
8-Jan-08		0.02		120				8	18.5		< 1		< 0.0002	< 0.0002
19-Feb-08		0.01		140				8	18.8		< 1		< 0.0002	< 0.0002
18-Mar-08		0.02		154				7.4	20.6		3		< 0.0002	< 0.0002
14-Apr-08		0.03		150				7.6	20.5		< 1		< 0.0002	< 0.0002
15-May-08		0.02		43					3.88		4		< 0.0002	< 0.0002
17-Jun-08		< 0.01		59				7.9	6.64		2		< 0.0002	< 0.0002
15-Jul-08		0.01		43				7.5	5.08		73		< 0.0002	< 0.0002
12-Aug-08		< 0.01		76				7.5	8.64		< 1		< 0.0002	< 0.0002
15-Sep-08		0.04		64				7.4	7.87		2		< 0.0002	< 0.0002
15-Oct-08		< 0.01		78				7.5	10.1		< 1		< 0.0002	< 0.0002
4-Nov-08		< 0.01		104					12.5		< 1		< 0.0002	< 0.0002
2-Dec-08		0.02						7.7	14.3		2		< 0.0002	< 0.0002
4-Mar-09	130	0.03	232	142		1.9	1.6	8.1	21	200			0.000018	0.000018
7-Apr-09	140	< 0.01	162.4	137		3	2.9	7.71	22	190	< 1		0.000018	0.000011
10-Jun-09	39	< 0.005	83	44.8		4.1	4.3	7.7	6.4	64	8		0.000022	0.000009
14-Jul-09		< 0.01		83.5		1.8	1.7	7.6	10	110	2		0.000013	0.000017
6-Aug-09	98	< 0.01	209	105		2.3	2	7.5	13	130	< 1		0.000014	0.000023
2-Sep-09	76	< 0.01	110	78.7			3	7.9	9.8	86	< 1		0.000014	0.000018
5-Oct-09	78	< 0.01	130	84.7		2.7	2.8	8.1	10	110	< 4		0.000017	0.000024
4-Nov-09	98	< 0.01	190	108		1.9	1.4	7.48	12	130	< 1		0.000014	
2-Dec-09	110	0.02	223	124		1.3	1.4	7.47	18	130	< 1		0.000006	
11-Jan-10	130	0.03	241	146		1.3	1.5	7.06	20	180	< 1		0.00001	0.000008
23-Feb-10	140	< 0.01	235	151		1.7	1.9	7.87	19	190	< 1		0.00001	< 0.000005
10-Mar-10	140	< 0.01	259	154		1.3	1.1	7.79	19	190	< 1			0.000011
11-Apr-10	140	< 0.01	240	151		1.8	2.4	7.43	19	170	< 1		0.000025	0.000027
3-May-10	51	0.012	95	59.2		14.7	14.5	7.7	< 0.5	80	3		0.00004	0.000037
5-Jun-10		< 0.05	103	53.1		3.3	3.1	7.93	6.2	68	2		0.000018	0.000052
8-Jul-10	61	< 0.05	125	62.4		3.4	3.3	7.94	8.4	76	3		0.000013	0.000021
3-Aug-10	93	< 0.05	188	85.1		2.2	2.3	7.46	9.1	100	< 1		0.00001	0.000009
1-Sep-10		0.15	187	93.1	0.04	2.4	2.2	7.79	11	110		0.6	0.000009	0.000022
19-Oct-10	96	0.029	207	110	0.13	2.5	1.5	7.65	15	130	< 1	1.1	0.000015	0.000028
10-Nov-10	110	0.009	234	129	0.19	1.7	2.7	7.86	19	140	< 1	0.63	0.000017	0.000032
1-Dec-10	120	< 0.05	350	132	0.2		1.1	7.58	19	140	< 4	0.84	0.000013	0.000017
20-Jan-11		< 0.005	280	157	0.25	0.9	0.9	7.78	20	160	< 1	0.8	0.00001	0.00001
15-Feb-11	130	0.028	306	130	0.23	1	1.1	7.92		150	< 1	0.53	0.000012	0.000015
16-Mar-11	140	0.015	300	151	0.26	1.3	1.1	8.05	16	180	< 1	0.47	0.00001	0.000009
12-Apr-11		0.014	292	165	0.23	1.6	1.3	7.69	15	160	< 1	0.44	0.000017	0.000023
9-May-11	93	0.022	206	94	0.08	10.6	10.4	7.67		120	3	2.01	0.000123	0.000124
22-Jun-11	43	0.034	92	46.8	< 0.02		5.4	7.73	6.1	68	6	1.12	0.000026	0.00009
21-Jul-11	57	0.076	132	61.3	< 0.02	4.8	4.8	7.11	7.1	90	2	1.04		0.00002
23-Aug-11	64	0.024	188	68.9	< 0.02	3.7	3.6	8.15	8		< 1	0.51	0.000009	0.000045
22-Sep-11	77	0.064	208	82.2	< 0.02	2.6	2.5		9.4	110	< 1	0.53	0.000012	
19-Oct-11	93		180	104	0.1	1.9		7.5	14.8	110	< 1	0.52	0.000013	0.000014
16-Nov-11	103	0.049		113	0.185	3.14	5.15	7.82	16.7	144	1.1	0.59	0.000015	0.000024
6-Dec-11	109	0.033	239	117	0.185	1.53			16.9	126	< 1	0.84	0.000013	0.00001
9-Jan-12	117	0.04	305	128	0.185		1.3	8.13	18.9		< 1	0.88	0.000013	0.000018

Table C.32: Water quality data and summary statistics for mine exposed station R10, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8-Jan-08	35.5	< 0.001	0.09	< 0.001	7.56	0.012	< 0.001	0.9	< 0.00025	2.64	0.14	0.0018	0.006	0.082
19-Feb-08	41	< 0.001	< 0.05	< 0.001	8.98	0.014	< 0.001	0.9	< 0.00025	3.34	0.18	0.0017	< 0.005	< 0.005
18-Mar-08	43.4	< 0.001	0.32	0.001	11	0.027	< 0.001	1.3	< 0.00025	4.07	0.19	0.0027	0.016	0.012
14-Apr-08	43	< 0.001	0.14	0.0005	10.2	0.012	< 0.001	1.1	< 0.00025	3.85	0.19	0.0027	0.015	0.015
15-May-08	12.9	< 0.001	0.46	0.001	2.63	0.035	0.001	1.5	< 0.00025	1.15	0.056	0.0005	0.014	0.01
17-Jun-08	16.8	< 0.001	0.14	< 0.001	4.2	0.014	< 0.001	0.6	< 0.00025		0.062	0.0006	0.008	0.007
15-Jul-08	12.5	0.001	1.68	0.02	2.88	0.051	0.004	0.6	< 0.00025	1.3	0.053	0.0006	0.031	0.009
12-Aug-08	22.8	< 0.001	0.16	< 0.001	4.72		< 0.001	0.5	< 0.00025	1.84	0.089	0.0008	0.007	0.005
15-Sep-08	19	< 0.001	0.21	0.001	3.92	0.018	< 0.001	0.5	< 0.00025	1.62	0.094	0.001	0.006	< 0.005
15-Oct-08	23.8	< 0.001	< 0.05	< 0.001	4.41		< 0.001	0.6	< 0.00025	1.66	0.096	0.001	0.006	< 0.005
4-Nov-08	31	< 0.001	0.07	< 0.001	6.56	0.017	< 0.001	0.8	0.0004		0.12	0.0014		0.005
2-Dec-08	37.1	< 0.001	0.09	< 0.001	7.36	0.026	< 0.001	1	< 0.00025	2.77	0.14	0.0018	0.017	0.007
4-Mar-09	43.4	0.000045	0.078	0.000067	9.53		0.00033	1.03	< 0.000005	3.23	0.188	0.00283	0.0086	0.0077
7-Apr-09	40.5	0.000031	0.067	0.00006		0.0127	0.00026	1	< 0.000005	3.12	0.177	0.00272	0.0068	0.0065
10-Jun-09		0.000077	0.12	0.000932	2.76	0.0113	0.00047	0.47	< 0.000005	1.07	0.0531	0.000571	0.0049	0.0043
14-Jul-09		0.000073	0.164	0.00159	5.37	0.0198	0.0005	0.54		1.78		0.00102	0.009	
6-Aug-09		0.000043	0.119	0.000207	6.54	0.0146	0.00034	0.7		2.15	0.13	0.00145	0.0052	0.0056
2-Sep-09	21.9	0.000052	0.167	0.000271	4.43	0.0182	0.00038	0.51	< 0.000005	1.8		0.00093	0.0044	0.007
5-Oct-09	23.7	0.000051	0.143	0.000713	4.95		0.00048	0.57	< 0.000005	2.03	0.105	0.00114	0.0095	0.0112
4-Nov-09	33.3	0.000038	0.119	0.000339	6.07		0.0003	0.77	< 0.000005	2.22	0.133	0.00157	0.0057	0.006
2-Dec-09	38.3		0.085	0.000089		0.0198		0.85	< 0.000005	2.27	0.154	0.00192	0.0028	0.0037
11-Jan-10	43.1	0.000044	0.1	0.000227	9.24	0.0195		1	< 0.000005	3.15	0.174	0.00251	0.0069	0.0062
23-Feb-10	44.6	0.000042	0.078	0.000071	9.55		0.00027	1.05	< 0.000005	3.39	0.187	0.00285	0.0074	0.0069
10-Mar-10		0.000039	0.075	0.000837	8.96	0.0132	0.0003	1.05	< 0.000005	3.3	0.19	0.00302	0.0122	0.0126
11-Apr-10	39.3	0.000318	0.099	0.00047	7.85	0.0369	0.00053	1	< 0.000005	2.99	0.187	0.00297	0.0198	0.0218
3-May-10	17.9		0.36	0.00147	3.35	0.0324	0.00149	1.36	< 0.000005	1.43	0.0773	0.000699	0.0114	0.0101
5-Jun-10	15	0.000058	0.145	0.00101	3.55		0.00056	0.52	< 0.000005	1.59	0.061	0.000592	0.0066	0.0087
8-Jul-10	18.1	0.000048	0.147	0.000302	4.19	0.0146	0.00038		< 0.000005	1.65	0.0806	0.000726	0.004	0.0095
3-Aug-10	26.6	0.000042	0.152	0.000388	5.83	0.0139	0.00098	0.61		2.09		0.00115	0.0068	0.0043
1-Sep-10	26.3	0.000043	0.18	0.000116		0.0169	0.00031	0.58	< 0.000005	2.05	0.118	0.00119	0.0034	0.0173
19-Oct-10	31.8		0.176	0.000385	7.11	0.0213	0.00038	0.75	< 0.000005	2.48	0.133		0.006	0.0086
10-Nov-10	38	0.000035	0.109	0.0002	8.36	0.0166	0.00038	0.87	< 0.000005	2.79	0.16	0.00197	0.0161	0.0268
1-Dec-10	37		0.136	0.000174	8.22	0.0208		0.88	< 0.000005	2.76	0.157	0.00191	0.0052	0.0051
20-Jan-11	40.1		0.094	0.000092	8.22	0.0151	0.00026	0.97	< 0.000005	2.7	0.189		0.0049	
15-Feb-11	37.4		0.08	0.000147	8.95	0.0125	0.0003	1.05	< 0.000005	3.17	0.184	0.00266	0.0071	0.0071
16-Mar-11	42.8	0.000047	0.067	0.000207		0.015		1.2	< 0.000005	3.71	0.204	0.00303	0.0099	0.0092
12-Apr-11	41.1	0.000071		0.000207	9.17	0.0157	0.00038	1.08	< 0.000005	3.31	0.183	0.00258	0.0097	0.0123
9-May-11	28.8	0.000303	0.494	0.00243	5.9	0.0403	0.00101	1.82	0.000007	2.12	0.127	0.00135	0.0798	0.0784
22-Jun-11	13.8	0.000088	0.179	0.00131	2.97	0.0144	0.0008	0.4	< 0.000005	1.24	0.0609	0.000466	0.0039	0.0095
21-Jul-11	18.2	0.000085	0.154		3.83		0.00053	0.37	< 0.000005	1.49	0.0735	0.000588	0.0064	0.0087
23-Aug-11	20.5	0.000053	0.133	0.000392	4.28	0.0172	0.00048	0.44	< 0.000005	1.72	0.086	0.000717	0.006	
22-Sep-11	24	0.000055	0.151	0.000233	5.17			0.63	< 0.000005	1.89	0.1		0.0047	0.0041
19-Oct-11		0.000047	0.148	0.000077	6.15	0.0245	0.00035	0.69	< 0.000005	2.29		0.00156	0.0069	0.0065
16-Nov-11	33.4	0.000052	0.116	0.000378	7.29	0.0185	0.00085	0.8	< 0.000005	2.56	0.142	0.00178	0.0082	0.0101
6-Dec-11	35.1		0.162	0.0001	7.21	0.0223	0.00033	0.84	< 0.000005	2.51	0.146		0.0057	0.0048
9-Jan-12	38.7	0.000032	0.137	0.000052	7.73	0.0167	0.0003	0.89		2.74	0.158	0.00196	0.0063	0.0081

Table C.32: Water quality data and summary statistics for mine exposed station R10, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
14-Feb-12	125	0.024	270	145	0.291	1.36	0.97	7.22	19.5	142	< 1	0.83	0.000018	0.000019
6-Mar-12	127	0.025	262	154	0.291	1.83	1.43	7.65	19	172	< 1	0.82	0.000019	0.000021
19-Apr-12			300					7.65				1.12		
17-May-12	84.7		189	90.9	0.085	7.37	8.27	7.56	11.5	128	1.6		0.0000515	0.0000466
12-Jun-12	29.9	0.046	60	32.9	< 0.02	6.61	6.55	7.66	6.8	38	13.8		0.0000435	0.000036
11-Jul-12	48.3	0.026	99	52.8	< 0.02		5.43	7.22	5.42	66	12.3	2.71	0.0000218	0.0000331
8-Aug-12	79.2	0.016	150	88.5	0.027	2.67	2.76	7.89	9.76	100	< 1	0.78	0.000016	0.000013
5-Sep-12	77.2	0.0087	157	87.9	0.03	3.03	2.93	7.62	11	102	< 1		0.000012	0.000011
9-Oct-12	76.8	0.0055	172	82.7	0.041	3.42	2.82	8.01	10.6	104	1.2		0.000012	0.000013
6-Nov-12	106	0.013	229	118	0.151	2.44	1.57		16.6	144		0.59	0.000025	0.000023
5-Dec-12	129	0.022	253	148	0.248	1.98	2.07	7.51	19.7	156	< 1	0.7	0.000011	0.000012
n	39	54	43	55	27	39	42	52	54	42	53	24	42	41
minimum	29.9	<0.005	60	32.9	<0.02	0.9	0.9	7.06	<0.5	38	<1	0.44	0.000006	<0.000005
maximum	140	0.15	350	165	0.291	14.7	14.5	8.15	22	200	73	2.71	0.000123	0.000124
median	98	0.020	207	104	0.13	2.3	2.35	7.68	12.8	129	<1	0.79	0.0000140	0.000019
mean [a]	96	0.022	202	103	0.13	3.1	3.1	7.69	13.2	126	3	0.88	0.0000195	0.000025
standard deviation (SD) [a]	32	0.024	71	37	0.10	2.7	2.7	0.26	5.6	40	10	0.51	0.0000188	0.000022
max detection limit	-	0.05	-	-	0.02	-	-	-	0.5	-	4	-	-	0.000005
# < detection limit	-	19	-	-	6	-	-	-	1	-	34	-	-	1
% < detection limit	-	35%	-	-	22%	-	-	-	2%	-	64%	-	-	2%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	6%	14%	2%	30%	0%	0%	0%	2%	10%	2%	4%	2%	5%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	0	1	0	1	1	0	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00016	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	0	0	0	0	-	1	0	0	-
% > current water quality criterion	-	0%	-	-	0%	0%	0%	0%	0%	-	2%	0%	0%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.32: Water quality data and summary statistics for mine exposed station R10, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
14-Feb-12	42.6	0.000033	0.108	0.000093	8.57	0.0159	0.00034	1.06	< 0.000005	3.01	0.17	0.00228		0.0105
6-Mar-12	43.3	0.000051	0.098	0.000406	9.21	0.0156	0.00035	1.11	< 0.000005	3.31	0.182	0.0025		0.0099
19-Apr-12														
17-May-12	27.4	0.0000976	0.371	0.00248	5.49	0.0207	0.000922	1.3	0.0000053		0.114	0.00129		0.0143
12-Jun-12	9.93	0.000206		0.00223	2.07	0.0191	0.00104	0.627	0.0000134	1.07	0.0413	0.000304	0.0106	0.00966
11-Jul-12	15.3		0.304	0.000912	3.36		0.000987	0.365	< 0.000005	1.38	0.0644	0.00052	0.00495	0.0148
8-Aug-12	26.5	0.000061	0.177	0.000325	5.43	0.0239	0.000436	0.562	< 0.000005	1.94	0.109	0.00104	0.00449	
5-Sep-12	26.9	0.000048	0.173	0.000281	5.02	0.0245	0.000426	0.616	< 0.000005	1.99	0.102			0.00602
9-Oct-12	24.8	0.000039	0.156	0.000188	5.02	0.0232	0.000482	0.634	< 0.000005	1.9	0.104			0.00631
6-Nov-12	34.8	0.000092	0.135	0.000454	7.62	0.0323	0.000441	0.806	< 0.000005	2.57	0.143	0.00184	0.0122	0.0142
5-Dec-12	40.5	0.000052	0.128	0.000127	9.08	0.0295	0.000409	1.02	< 0.000005	3.06	0.18	0.00254	0.00613	0.00542
n	51	48	54	55	52	46	51	55	41	53	52	50	50	52
minimum	9.93	0.000031	<0.05	0.000052	2.07	0.0113	0.00026	0.365	<0.000005	1.07	0.0413	0.000304	0.0028	0.0037
maximum	44.6	0.001	1.68	0.02	11	0.051	0.004	1.82	0.0004	4.07	0.204	0.00303	0.0798	0.082
median	31.8	0.0000565	0.14	0.000388	6.11	0.0181	0.00048	0.81	<0.000005	2.27	0.133	0.00151	0.0068	0.0084
mean [a]	30.3	0.000189	0.18	0.000910	6.31	0.0206	0.00059	0.83	0.000013	2.36	0.130	0.00159	0.010	0.012
standard deviation (SD) [a]	10.4	0.000224	0.23	0.00268	2.33	0.00836	0.00055	0.30	0.000062	0.77	0.047	0.000839	0.011	0.015
max detection limit	-	0.001	0.05	0.001	-	-	0.001	-	0.000005	-	-	-	0.005	0.005
# < detection limit	-	11	2	7	-	-	10	-	37	-	-	-	1	3
% < detection limit	-	23%	4%	13%	-	-	20%	-	90%	-	-	-	2%	6%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	0%	29%	4%	7%	2%	4%	4%	4%	2%	23%	27%	24%	14%	8%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.1	0.098	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	1	1	-	0	0	0	1	-	-	0	2	-
% > current water quality criterion	-	0%	2%	2%	-	0%	0%	0%	2%	-	-	0%	4%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.33: Water quality data and summary statistics for mine exposed station NF1, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
2-Jun-08		< 0.01		34				8	4.9		1		< 0.0002	< 0.0002
30-Sep-08								7.4	8.83		9		< 0.0002	< 0.0002
5-May-09	24	0.02	89	30		18	17.1	7.28	0.3	60	9		0.000313	0.000272
10-Jun-09	41			43		4.2	3.9	7.5	9	60	26		0.000028	0.000022
14-Jul-09	82	< 0.01	185	88.8		2.2	2	7.4	12		10		0.000056	0.00007
6-Aug-09		0.04	393	175		4.2	5	7.1	34	240	12		0.000167	0.000121
2-Sep-09		< 0.01	130	86.7		3.2	3.1	7.5	15	92	2		0.000023	0.00003
4-Oct-09	84	< 0.01	160	92.3		2.5	2.6	7.8	12	110	< 4		0.000044	0.000033
4-Nov-09	100	0.02	189	114		< 0.5	1.9	7.62	12	150	2			0.000019
2-Dec-09	120	0.03		128			1.9	7.35	19	130	2		0.000028	0.000026
23-Feb-10	140	0.02	240	160			1.8	7.77	19	240	12		0.000041	0.000033
10-Mar-10	140	< 0.01	269	155		1	1.1	7.84	20	180	< 1		0.00002	0.000009
11-Apr-10		0.04	260	168		3.2	3.2	7.37	20	170			0.000065	0.000032
3-May-10	49	< 0.005	90	53.3		13.5	13.3	7.43	0.8	74	2		0.000043	0.000038
5-Jun-10	46	< 0.05		53.6		3.1	3.2	7.84	6.1	70	2			0.00005
8-Jul-10	64	< 0.05	129	68.8		3.4	3.4	7.71	8	80			0.000021	0.000018
3-Aug-10	140	< 0.05	421	176		4.1	5.4		48	230	7		0.000203	0.000367
n	12	15	12	16	0	13	15	16	17	14	15	0	13	17
minimum	24	<0.005	89	30	-	<0.5	1.1	7.1	0.3	60	<1	-	0.00002	0.000009
maximum	140	0.05	421	176	-	18	17.1	8	48	240	26	-	0.000313	0.000367
median	83	0.020	187	91	-	3.2	3.2	7.5	12	120	<4	-	0.0000430	0.000033
mean [a]	86	0.018	213	102	-	4.8	4.6	7.6	15	135	7	-	0.0000809	0.000079
standard deviation (SD) [a]	42	0.013	109	53	-	5.1	4.5	0.2	12	68	7	-	0.0000902	0.000098
max detection limit	-	0.05	-	-	-	0.5	-	-	-	-	4	-	-	0.0002
# < detection limit	-	9	-	-	-	1	-	-	-	-	2	-	-	2
% < detection limit	-	60%	-	-	-	8%	-	-	-	-	13%	-	-	12%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	0%	17%	25%	-	0%	7%	0%	12%	21%	7%	-	23%	35%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	-	1	1	0	1	1	1	-	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00015	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	-	0	0	0	0	-	1	-	3	-
% > current water quality criterion	-	0%	-	-	-	0%	0%	0%	0%	-	7%	-	23%	-
# < current water quality criterion	-	-	-	-	-	1	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	8%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.33: Water quality data and summary statistics for mine exposed station NF1, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
2-Jun-08	10	< 0.001	0.2	0.002	2.15	0.009	< 0.001	0.6	< 0.00025	1.16	0.041	< 0.0005	0.007	0.005
30-Sep-08		< 0.001	0.3	< 0.001	5.22	0.052	< 0.001	0.7	< 0.00025	2.06	0.091	0.0006	0.009	0.007
5-May-09	8.61	0.000504	0.63	0.0125	1.98	0.0496	0.00154	1.7	0.000018	0.61	0.038	0.000266	0.132	0.123
10-Jun-09		0.000208	0.223	0.00207	2.66	0.0675	0.00057	0.48			0.0508	0.000511	0.009	0.0072
14-Jul-09	26.1	0.000411	0.383	0.00224	5.72	0.109	0.00084	0.63	< 0.000005	1.93	0.104		0.019	0.0222
6-Aug-09	52.2	0.00419	6.25	0.0086	11	2.03	0.00846			3.72	0.235		0.149	0.135
2-Sep-09		0.000331	0.296	0.00167	5.07	0.0786	0.00104	0.59		1.98		0.000945	0.0231	0.0224
4-Oct-09	25.6	0.000424	0.391	0.00432		0.0901	0.00136	0.61	< 0.000005	2.16	0.115	0.00115	0.0367	0.0305
4-Nov-09	35.1	0.000118	0.207	0.003		0.0584	0.00047	0.82	< 0.000005	2.37	0.142	0.00165	0.0097	0.0099
2-Dec-09	38	0.000384	0.333	0.001	6.98	0.114	0.00085	0.87	< 0.000005	2.31	0.161	0.00186	0.0196	0.0202
23-Feb-10	47.4	0.000367	0.44	0.00149	10.1	0.0769	0.00075	1.21	< 0.000005	3.63	0.197	0.00293	0.0212	0.0171
10-Mar-10	46.3	0.000263	0.084	0.000128	9.47	0.0343	0.00047	1.11	< 0.000005		0.194	0.00299	0.0172	0.0178
11-Apr-10	42.9	0.000556	0.161	0.00175	8.76	0.111	0.00069	1.24	< 0.000005	3.34	0.201	0.00303	0.0282	0.0237
3-May-10	16.2		0.348	0.00173	3.1	0.0381		1.31	< 0.000005	1.27	0.0729	0.000641	0.0113	0.0142
5-Jun-10	15.5	0.000093	0.172		3.63		0.00102	0.55	< 0.000005	1.63	0.0605	0.000565	0.006	0.006
8-Jul-10	18.6	0.00008	0.151	0.000878	4.34	0.024	0.00048	0.48	< 0.000005		0.0807	0.000691	0.0068	0.0069
3-Aug-10	50.5	0.00317	3.29	0.00587	12.2	1.04	0.00842	1.34		3.52	0.222	0.00159	0.262	
n	14	16	17	16	15	16	16	16	11	14	16	15	17	16
minimum	8.61	0.00008	0.084	0.000128	1.98	0.009	0.00047	0.48	<0.000005	0.61	0.038	0.000266	0.006	0.005
maximum	52.2	0.00419	6.25	0.0125	12.2	2.03	0.00846	1.7	0.000018	3.72	0.235	0.00303	0.262	0.135
median	30.6	0.000398	0.30	0.00188	5.22	0.0722	0.00093	0.76	<0.000005	2.11	0.110	0.000945	0.019	0.017
mean [a]	30.9	0.000756	0.82	0.00311	6.16	0.249	0.0017	0.89	0.000004	2.26	0.125	0.00131	0.045	0.029
standard deviation (SD) [a]	15.6	0.00117	1.58	0.00331	3.39	0.534	0.0026	0.38	0.000005	0.97	0.068	0.000993	0.070	0.040
max detection limit	-	0.001	-	0.001	-	-	0.001	-	0.000005	-	-	0.0005	-	-
# < detection limit	-	2	-	1	-	-	2	-	10	-	-	1	-	-
% < detection limit	-	13%	-	6%	-	-	13%	-	91%	-	-	7%	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	29%	75%	18%	44%	13%	81%	25%	6%	0%	29%	31%	20%	59%	50%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.006	-	1.0	0.089	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	2	2	2	-	2	0	0	0	-	-	0	4	-
% > current water quality criterion	-	13%	12%	13%	-	13%	0%	0%	0%	-	-	0%	24%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.34: Water quality data and summary statistics for mine exposed station NF2, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
24-Jan-08	120	< 0.005	332	146	0.28	1	0.8	7.45	20.3	160	< 1		0.000018	0.000012
21-Feb-08	140	< 0.005	336		0.3	0.8		6.9	23.9	180	< 1		0.000016	0.000016
11-Mar-08	140	< 0.005	306	150	0.31	1.2	1.2	7.3	21.6	190	< 1		0.000019	0.000017
29-Apr-08	120	< 0.005	299	136	0.22	1.2	1.3	7.43	20	170	2		0.000168	0.000164
22-May-08	25	< 0.005		30.8	< 0.02	12.4	12.6	7.39	< 0.5	58	11		0.000066	
2-Jun-08		0.01		33				8	4.7		3		< 0.0002	< 0.0002
25-Jun-08	35	< 0.005	92.8	40.6	< 0.02	5	5.4	7.12	3.8	78	5		0.000025	0.000012
29-Jul-08	69	< 0.005	180.6	74.5	0.1	3.6	3.3	7.62	8.7	84	1		0.000019	0.00002
17-Sep-08	63	< 0.005	159.4	69.3	< 0.02	3	4.3	6.85	8.8	110	< 1		0.000016	0.000023
30-Sep-08		0.04		78				7.6	9.65				< 0.0002	< 0.0002
7-Oct-08	77	< 0.005	194.4		0.06	2.3	2.6	7.1	13	110	4		0.000025	0.00003
11-Dec-08	16	< 0.005	422	14.6	0.03	1.5	1.5		1.5	22	1		0.000027	0.00003
22-Jan-09	120			129	0.2				18	150	12			0.000039
24-Feb-09	130	< 0.005		141	0.25				21	160	< 1		0.000022	0.000027
5-Mar-09	130		260	146		1.9	1.9		20	170	< 1		0.000024	0.000022
6-Apr-09	140	< 0.01	162.2	145		1	0.9	6.81	22		< 1		0.000019	0.000022
6-May-09	25	0.07	56	30.4		18.3	19.2	7.6	< 0.5	64	8		0.000105	
10-Jun-09	41	< 0.005	82	44		4.3	3.9	7.3	6.9	56	7		0.000027	0.000024
13-Jul-09	78		165	90.3		2.3	2.1	7.6	12	100	< 1		0.000032	0.00002
6-Aug-09	100	< 0.01	211	109		2.2		7.3	15	210			0.000017	0.000021
2-Sep-09	78	< 0.01		82.2		3.2	2.6	7.59	11				0.000013	0.00001
5-Oct-09	82	< 0.01		88.8		2	2.7	7.9	12	120	< 4		0.000032	0.000032
4-Nov-09	100	< 0.01	230	114		2.4	1.9	7.49	15	140	2		0.000028	0.000021
2-Dec-09	120	0.05	222	128		2.2	2.1		18	150	< 1		0.000014	0.000012
12-Jan-10	130	< 0.01	266	147		1.5	0.9		22	190	< 1		0.000008	0.000013
23-Feb-10	140	< 0.01	230	158		2	1.9	7.71	19	160	< 1		0.000017	0.000012
10-Mar-10	140		267	149		1.1	1.2	7.62	20	180	< 1		0.000009	0.000008
14-Apr-10	150	< 0.01	270	153		1.8	1.4	7.48	21		< 1		0.000018	0.000017
3-May-10	52	< 0.005	97	57.1			13.9	7.29	< 0.5	88	3		0.000091	0.000041
4-Jun-10	42	< 0.05	81	48		3	3.2	7.86		56	4		0.000024	0.000046
8-Jul-10	65	< 0.05	154	65.1			3.6	8.18	9	78	3		0.000018	0.00001
3-Aug-10	93	< 0.05	193	88.9		2.3	2.1	7.5	10	110			0.000026	0.000009
1-Sep-10	89	0.16	222	95.9	0.05	2.6		8.1	12	120	< 1	0.7	0.00001	0.000012
18-Oct-10	96	< 0.005	200	111	0.14	1.5	1.8	7.46	15	130	< 1	1.1	0.000013	0.000014
9-Nov-10	110	0.019	252	122	0.19	< 0.5	1.5		21	170	< 4	0.83	0.000042	0.000021
1-Dec-10		0.14	120	131	0.21	1.4	1.3	7.41	20	150	< 4	0.82	0.000018	0.000015
19-Jan-11	130	< 0.05	220	156	0.3	1.2	1.1	7.91		180	< 1		0.000016	0.000008
2-Feb-11	140	< 0.05	302	144	0.24	1	1.4	7.78	19	150	< 1	0.83	0.000014	0.000019
16-Mar-11	160	0.016	300	188	0.56	1.5	1.3	7.68	38	220	< 1	0.82	0.000078	0.000138
13-Apr-11		0.014	316	161	0.22	2.5	1.5	7.73	17	170	< 1	0.69	0.000033	0.000036
12-May-11	89	0.036	227	90.5	0.28	9.9	9.8	8.1	16	140	< 1	1.67	0.000127	
20-Jun-11	48	0.015	103	49.8		3.2	3.2	6.19	6.9	72	6		0.000033	0.000017
21-Jul-11	56	0.072	118	63.1	< 0.02	4.5	4.5		7.8	88	< 1	0.7	0.000025	0.000018
25-Aug-11	66		136	70.7	< 0.02	2.9	4.2	7.48		100	< 1	0.49	0.000017	0.000016
21-Sep-11	80	0.058	184	90	< 0.02	2.7	2.2		12	120	< 1	0.85	0.000018	0.000024
20-Oct-11	100	0.028	210	113	0.13	2.1	2	7.14	19.1	120		2.63	0.000071	0.00002
14-Nov-11	107	0.027	203	112	0.194		2.87	7.54	20.4	148	1.6	0.81	0.000046	0.000023

Table C.34: Water quality data and summary statistics for mine exposed station NF2, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
24-Jan-08	43.3	0.000101	0.114	0.000268	9.1	0.0286	0.0009	0.99	< 0.000005	3.2	0.183	0.00245	0.0104	0.0089
21-Feb-08	44	0.00012	0.118	0.000282	9.49	0.0356	0.00046	1.08	< 0.000005	3.45	0.192	0.00283	0.0099	0.0106
11-Mar-08	44.6	0.000106	0.127	0.000282	9.47	0.0389	0.00038	1.07	< 0.000005	3.48	0.191	0.00282	0.0144	0.0147
29-Apr-08	40.2	0.000355	0.287	0.0011	8.65	0.0487	0.00101	1.23	< 0.000005	3.24	0.185	0.00267	0.122	0.124
22-May-08	9.33	0.00027	0.513	0.00591	1.83	0.0353	0.00164	1.17	0.000014	< 0.05	0.041	0.000372	0.0135	0.0139
2-Jun-08	9.87	< 0.001	0.25	0.002		0.017	< 0.001	0.6	< 0.00025	1.15	0.041	< 0.0005	0.006	< 0.005
25-Jun-08	12.1	0.000108	0.214	0.00118	2.52	0.0119	0.00078	0.46	0.000007	1.14	0.0523	0.00041	0.0055	0.0056
29-Jul-08	22	0.000061	0.131	0.000699	4.74	0.0138	0.00054	0.49	< 0.000005	2.53	0.0894	0.000863	0.007	0.0075
17-Sep-08	20.8	0.000045	0.103	0.000477	4.19	0.00972	0.00045	0.52	< 0.000005	1.71	0.0839	0.000801	0.0061	0.0071
30-Sep-08	22.6	< 0.001	0.13	< 0.001	5.36	0.013	< 0.001	0.6	< 0.00025	2.12	0.096	0.0009	0.006	0.009
7-Oct-08	24.2	0.000163	0.207	0.00112	5.03	0.0588	0.0006	0.3	0.000005	1.97	0.102	< 0.000002	< 0.0001	0.0114
11-Dec-08	36.8		0.152	0.000692		0.0415	0.00055	0.87	< 0.000005	2.62	0.153	0.0021	0.0152	
22-Jan-09	38.7	0.000069	0.178		7.74	0.0279	0.00038	0.92	< 0.000005	3.53	0.168	0.00244	0.009	0.0126
24-Feb-09	42.8	0.000132	0.163	0.000556	8.38	0.0349	0.00046	0.99	< 0.000005	2.83	0.191	0.00265	0.0157	0.0157
5-Mar-09	42.7	0.000122	0.075	0.000195	9.1	0.0247	0.00047		< 0.000005	3.03	0.184			0.0151
6-Apr-09	43	0.000105	0.07	0.000229	9.13	0.018	0.00043	1.07		3.2	0.189	0.00292		0.0124
6-May-09	8.79	0.000343	0.45	0.00876	1.96		0.00151	1.66	0.000009	1.04	0.0435		0.0326	0.0243
10-Jun-09	12.6	0.000075		0.002	2.69	0.00857	0.00057	0.56	< 0.000005	1.2	0.0521	0.000515	0.0087	0.0088
13-Jul-09	25.2	0.000057	0.148	0.000823	5.77	0.0149	0.00051	0.57	< 0.000005		0.104	0.00105	0.0088	0.0086
6-Aug-09	32.3	0.000139	0.26	0.00124	6.63	0.0619	0.00064	0.75	< 0.000005	2.33	0.137	0.00152	0.0093	0.009
2-Sep-09	22.2	0.000103	0.198	0.00068	4.55	0.0221	0.00052	0.52	< 0.000005	1.84	0.102	0.000928	0.0089	0.0094
5-Oct-09	24.7	0.000177	0.171	0.00133	5.26	0.0384	0.00071		< 0.000005	2.23	0.112	0.00112	0.0189	0.0246
4-Nov-09	34.9	0.000209	0.253	0.00189	6.55	0.0818	0.00072		< 0.000005	2.38	0.139	0.00159	0.0197	
2-Dec-09	38.4	0.000105	0.141	0.000863	6.95	0.0414	0.00041	0.85	< 0.000005		0.159	0.00193	0.008	0.0082
12-Jan-10		0.000073	0.082	0.000266	9.28	0.0161	0.00041	1.01	< 0.000005	3.2	0.177	0.00252	0.0095	0.0095
23-Feb-10	46.9	0.000094	0.064	0.000147	9.95	0.0152	0.00039	1.1		3.52	0.198		0.0122	0.0118
10-Mar-10	43.8	0.000118	0.08		9.08		0.00038	1.05	< 0.000005	3.27	0.185	0.00293	0.0128	0.0131
14-Apr-10		0.000142	0.069	0.000321	8.43	0.0194	0.0005	1.04			0.196	0.00299		0.0172
3-May-10	17.3	0.000199	0.378	0.0038	3.35	0.032	0.00147	1.37	< 0.000005	3.07	0.0758	0.000625	0.0412	0.0136
4-Jun-10	13.7	0.000088	0.181	0.00169	3.26	0.0175	0.00095	0.54		1.54	0.0558	0.000497	0.0065	
8-Jul-10		0.000073	0.152	0.00129	4.4	0.0176	0.00046	0.48	< 0.000005	1.71		0.000729	0.0058	0.0045
3-Aug-10	26.1	0.000158	0.275	0.00479	5.8	0.0437	0.00057	0.65		2.1	0.116		0.0097	0.007
1-Sep-10	28		0.181	0.000292	5.86	0.026		0.62	< 0.000005	2.15	0.121		0.0077	0.0092
18-Oct-10	32.6	0.000116	0.209	0.000739	7.1	0.0434	0.00044	0.75	< 0.000005	2.5		0.00152	0.0099	
9-Nov-10	36.3	0.000252	0.228	0.00118	7.64	0.0762	0.0009	0.82	< 0.000005	2.57	0.157	0.00194	0.051	0.0247
1-Dec-10	38.1	0.000139	0.143	0.000379	8.31	0.0374	0.00047	0.91		2.83	0.163		0.0135	0.0159
19-Jan-11	40.6	0.0001	0.097	0.000206	8.88	0.0269		1.02		2.93	0.194	0.00265	0.0106	
2-Feb-11	42	0.000264	0.255	0.00047	9.42	0.0442	0.0007	1.09	< 0.000005	3.25	0.183	0.00263	0.0788	
16-Mar-11	54.6	0.000206	0.113	0.00129	12.7		0.00148	1.55	< 0.000005	5.59	0.239	0.00367	0.0218	0.0453
13-Apr-11	44	0.000094	0.109	0.000653	9.91	0.0429	0.00075	1.23	< 0.000005	3.72	0.206	0.00295	0.0332	0.0216
12-May-11	26.8		0.355	0.00213	5.75	0.0118	0.00138		< 0.000005	2.44	0.121		0.069	0.0687
20-Jun-11	13.8	0.000119	0.16	0.0021	3.36	0.0218	0.00058	0.42			0.0573	0.000523		0.0048
21-Jul-11	18.8	0.000086		0.00141	3.94	0.0146	0.0006	0.4	< 0.000005	1.54	0.0723	0.000561	0.009	0.014
25-Aug-11	21	0.000061	0.114	0.00113	4.45	0.0109	0.00052	0.47	< 0.000005	1.77		0.000708		
21-Sep-11	26.1		0.153	0.000342	5.13		0.00048	0.61	< 0.000005	1.89	0.109		0.007	0.033
20-Oct-11		0.000515	0.844	0.0216	6.81	0.158	0.00139	0.86	0.000029	2.52	0.142	0.0018	0.0356	0.0137
14-Nov-11	30.1	0.000175	0.181	0.00257	7.04	0.0545	0.0008	0.88	0.000006	2.47	0.148	0.00169	0.0248	0.0155

Table C.34: Water quality data and summary statistics for mine exposed station NF2, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
5-Dec-11	109	0.039	250	121	0.192	2.89	1.65		17.2		< 1	0.89	0.000037	0.000014
4-Jan-12		0.015	302	133	0.204	1.9	1.68	7.58	18.5	158	< 1	0.83	0.000031	0.000017
13-Feb-12		0.025	310	147	0.28	1.91	1.25	7.93	20.2	182	< 1	0.88	0.000019	0.000028
6-Mar-12	127	0.013	254	147	0.292	1.99	1.45	7.4	21.6	172	< 1	0.8		0.00002
18-Apr-12			310					7.42				1.07		
16-May-12	90.7	0.031	216	98.1	0.098	6.69	7.07	7.85	13.4	134	2		0.0000523	0.0000498
12-Jun-12	28.6	0.11	63	31.7		6.09	5.71	7.39	3.75	40	3.4		0.0000291	0.0000253
12-Jul-12	47.8	0.026	96	53.4	< 0.02	5.65	5.87	7	6.69		4.5	1.98	0.0000292	0.0000162
8-Aug-12	80.2		160	92.2	0.041	2.73	2.81	7.64	11.5	110	< 1	0.58	0.000014	0.000011
5-Sep-12			233	86.1	0.04	2.9	2.97	7.35	15.9	100	< 1	0.45	0.000012	
11-Oct-12		0.01		91.8	0.079	1.95	2.26	7.49	15.6	130	1.2	0.57		0.000031
13-Nov-12	104	0.014	226	114	0.248	1.99	1.28	7.96	16.7	154	2.8	1.08	0.000027	0.000026
12-Dec-12	123	0.017	251	131		1.42	1.48	7.68	18.5	148	< 1	0.88	0.000016	0.000013
n	51	52	52	57	36	52	52	50	56	52	54	24	54	53
minimum	16	<0.005	56	14.6	<0.02	<0.5	0.8	6.19	<0.5	22	<1	0.45	0.000008	0.000008
maximum	160	0.16	422	188	0.56	18.3	19.2	8.18	38	220	12	2.63	0.000168	0.000164
median	96	0.014	221	109	0.19	2.2	2.1	7.50	15.8	137	<1	0.83	0.0000240	0.000020
mean [a]	93	0.024	213	102	0.16	3.1	3.3	7.50	14.5	130	2	0.96	0.0000328	0.000026
standard deviation (SD) [a]	38	0.033	81	42	0.13	3.1	3.5	0.37	7.2	46	3	0.49	0.0000305	0.000027
max detection limit	-	0.05	-	-	0.02	0.5	-	-	0.5	-	4	-	-	-
# < detection limit	-	27	-	-	7	1	-	-	3	-	33	-	-	-
% < detection limit	-	52%	-	-	19%	2%	-	-	5%	-	61%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	2%	12%	21%	4%	44%	0%	2%	0%	11%	10%	0%	4%	4%	4%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	2%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	0	0	0	1	1	0	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00017	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	0	0	0	0	-	0	0	0	-
% > current water quality criterion	-	0%	-	-	0%	0%	0%	0%	0%	-	0%	0%	0%	-
# < current water quality criterion	-	-	-	-	-	1	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	2%	0%	2%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.34: Water quality data and summary statistics for mine exposed station NF2, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
5-Dec-11	36	0.000097	0.167	0.00113	7.51	0.0307	0.00056	1.02	< 0.000005	2.84	0.147	0.00195	0.0151	0.0091
4-Jan-12	39.8		0.056	0.000308	8.25	0.0384		1.47	0.000021	3.05	0.161		0.0216	0.0098
13-Feb-12	43.6		0.132	0.000291	8.72		0.00037	1.08	< 0.000005	3.08	0.176		0.0134	0.0262
6-Mar-12	41.4	0.000149	0.117		9.6		0.00048	1.14	< 0.000005	3.39	0.186	0.0025	0.0168	0.0196
18-Apr-12														
16-May-12	29.4	0.000324	0.585	0.00159	5.98	0.0857	0.00103	1.34	0.0000065	2.1	0.122	0.00135	0.0234	0.0247
12-Jun-12	9.38	0.00012	0.188	0.00203	1.92	0.00917	0.00089	0.5	0.0000073	0.958	0.0407	0.000276	0.00821	
12-Jul-12	14.9	0.0001	0.194	0.0017	3.36	0.0119	0.000804	0.382	0.0000073		0.063	0.000494	0.0105	0.00793
8-Aug-12	26.1	0.000079	0.176	0.000642		0.0211	0.000859	0.569		1.96	0.11	0.00107	0.00626	0.00537
5-Sep-12	25.9	0.000063	0.161	0.000262	5.14	0.0202	0.000433	0.638	< 0.000005	2.09		0.001	0.006	0.00586
11-Oct-12	26.4	0.000212		0.000597	5.7	0.0742	0.000682	0.654	< 0.000005	2.08	0.113	0.00126	0.0165	0.0252
13-Nov-12	33.4	0.00016	0.221	0.00116	7.37	0.0529	0.000674	0.832	< 0.000005	2.55	0.149	0.00178	0.0162	0.0176
12-Dec-12	38.6	0.000071	0.121	0.000282	8.45	0.0299	0.00052	1.02	< 0.000005		0.172	0.00262	0.00952	0.0106
n	55	51	56	56	56	53	56	55	48	53	55	49	54	51
minimum	8.79	0.000045	0.056	0.000147	1.83	0.00857	0.00037	0.3	<0.000005	<0.05	0.0407	<0.000002	<0.0001	0.0045
maximum	54.6	0.000515	0.844	0.0216	12.7	0.158	0.00164	1.66	0.000029	5.59	0.239	0.00367	0.122	0.124
median	30.1	0.000118	0.16	0.000932	6.72	0.0286	0.00058	0.86	<0.000005	2.50	0.142	0.00152	0.011	0.012
mean [a]	30.2	0.000145	0.20	0.00164	6.55	0.0346	0.00069	0.85	0.000004	2.47	0.134	0.00160	0.018	0.017
standard deviation (SD) [a]	11.8	0.000091	0.14	0.00310	2.50	0.0260	0.00033	0.32	0.000005	0.91	0.053	0.000965	0.021	0.019
max detection limit	-	-	-	0.001	-	-	0.001	-	0.000005	0.05	-	0.0005	0.0001	0.005
# < detection limit	-	-	-	1	-	-	2	-	38	1	-	2	1	1
% < detection limit	-	-	-	2%	-	-	4%	-	79%	2%	-	4%	2%	2%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	4%	14%	5%	16%	2%	36%	11%	5%	4%	25%	31%	27%	37%	25%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.1	0.102	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	2	-	0	0	0	0	-	-	0	8	-
% > current water quality criterion	-	0%	0%	4%	-	0%	0%	0%	0%	-	-	0%	15%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.35: Water quality data and summary statistics for mine exposed station X2, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
7-Jan-08		0.01		119				7.5	30.9		< 1	0.58	< 0.0002	< 0.0002
8-Jan-08									30.9					
18-Feb-08		< 0.01		168				7.2	36.4			0.84	< 0.0002	
17-Mar-08		< 0.01		151				7.4	38.2		< 1	0.86	< 0.0002	< 0.0002
14-Apr-08		0.03		162				7.5	36.3		< 1	1.6	< 0.0002	< 0.0002
14-May-08		0.03		41				8.4	6.12		2	2.5	< 0.0002	< 0.0002
12-Jun-08		< 0.02			0.0064				7.92				0.00003	0.000028
16-Jun-08		< 0.01		68					8.35		4	2.4	< 0.0002	< 0.0002
14-Jul-08		0.12		54				7.8	7.3		< 1	1.9	< 0.0002	< 0.0002
22-Jul-08	55	< 0.01		63.9					9.7		2		0.000026	0.000022
11-Aug-08				78				7.9	11.7		< 1	0.61	< 0.0002	< 0.0002
19-Aug-08	76	< 0.01		80.2	0.02				9.7	110	5		0.000018	0.000016
25-Aug-08	44	< 0.005							8.1		30		0.000074	0.000023
15-Sep-08		0.02						8	10.1		< 1	0.65	< 0.0002	< 0.0002
15-Oct-08		0.05		85				7.6	14.6		< 1	0.55	< 0.0002	< 0.0002
3-Nov-08		0.01		116				7.7	22.2			0.75	0.0003	0.0002
1-Dec-08		0.03		139				8.2	23.7			1.5	< 0.0002	
12-Jan-09		0.03		172				7.6	44		< 1	0.92	< 0.0002	< 0.0002
2-Feb-09		< 0.01		158				7.9	35.3		< 1	0.74	< 0.0002	
3-Mar-09	130	< 0.01	267	167		1.5	1.4	8.1	38	200	< 1		0.000034	
6-Apr-09	140	< 0.01	147.5	163		1.2	1		39	210	< 1		0.00003	0.000022
6-May-09	26	0.1	72	34.2		19.7	18.4	7.4	< 0.25	70	7		0.000229	0.000187
8-Jun-09	29	< 0.01	54			6.4	5.3	8	4	62	6		0.00003	0.000009
13-Jul-09	79	0.02		93.7		2.3	2.2	8	13	110	2		0.000039	0.000043
6-Aug-09		< 0.01		114		2.6	2.4	7.4	18	140	< 1		0.000016	0.000028
17-Aug-09														
2-Sep-09		< 0.01	120	84.4		2.7	2.6	7.9	12	98	5		0.000021	0.00001
5-Oct-09	81	< 0.01	130	89.7		2.6	2.8	7.9	13	130	< 4		0.00002	0.000024
4-Nov-09	100	< 0.01	220	115		2.6	1.8	7.53	20	120	< 1		0.00003	0.000023
1-Dec-09	120	0.02	249	134		2	1.8	7.86	25	140	< 1		0.00001	0.000019
11-Jan-10	130	< 0.01	266	158		1.5	1.3	6.94	29	190	< 1		0.000021	0.000018
22-Feb-10	140	< 0.01	288	164		0.9	1.4	7.31	28	240	< 1		0.000017	0.00002
10-Mar-10	140		132	156		1.1	1.2	7.27	31	190	< 1		0.000015	0.000022
14-Apr-10	140	< 0.01	290	159		2.1	1.6	7.03	28	150	< 1		0.000026	0.000024
3-May-10	52	0.015	188	59.1		14.5	13.3	7.46	4.5	68	4		0.00005	0.00005
4-Jun-10	38	< 0.05	94	48.1		2.8	3.2	7.81	6.6	54	4		0.000022	
8-Jul-10			131	65.4		3.1	3.4	7.82	15	80	2		0.000018	0.000037
3-Aug-10	95	< 0.05	197	96.9		2.7	3	7.68	15	110			0.000015	0.000017
2-Sep-10		0.17	189	106	0.04	2.2	2	7.37	13	120	< 1	0.8	0.000014	0.00007
18-Oct-10	99	0.039	220	115	0.15	1.2	2	7.6	19	130	< 1	1.1	0.000018	0.000019
9-Nov-10	110	0.026	258	127	0.19	2	1.7	7.98	25	160	< 4	0.84	0.000023	0.000014
1-Dec-10	120	< 0.05	130	138	0.21	1.6	2.2	7.2	29	140	< 4	1.1	0.000037	
19-Jan-11	140	< 0.005	160	172	0.28	1.4	1.2	8.2	28	190	< 1	0.84	0.000031	0.000022
1-Feb-11	140	< 0.05	140	172	0.25	1.7	1.4	8.01	26	160	< 1	0.83	0.000026	0.000022
16-Mar-11	140	0.021	330	172	0.36	1.6		7.52	31	190	< 1	0.85	0.000044	0.000034
13-Apr-11	140	0.018	305	167	0.21	1.5	1	7.63	26	180	< 1	0.76	0.000025	0.000021
11-May-11	97	0.01	224	106	0.21	8.6	8.4	7.82	17	140		2.12	0.000143	0.00013
20-Jun-11		0.02	118	53.4	< 0.02	3.2	3.2	8.29	8.7	72	7	1.09	0.000064	0.000027
13-Jul-11	69	0.031	143	73.9	< 0.02		3.3	6.8		90	< 1	0.43	0.000014	0.00002
25-Aug-11	67	0.034	139	71.7	< 0.02	3.2	3.7	7.54	9.3	110	< 1	0.41	0.000018	< 0.000005
21-Sep-11	80	0.033	183	89.5	< 0.02	2.6	2.7	7.31	14	110		0.48	0.000019	0.000021
20-Oct-11	99	0.021	210	121	0.14		2.5	7.43	25.8	130	3	1.74	0.000034	0.000021

Table C.35: Water quality data and summary statistics for mine exposed station X2, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
7-Jan-08	33.3	< 0.001	0.14	< 0.0005	8.71	0.08	< 0.001	0.9	< 0.00025	2.68	0.13	0.0016	0.056	0.051
8-Jan-08													0.056	
18-Feb-08	47.4	< 0.001	0.26	< 0.001	12.1	0.17	0.002	1.3	< 0.00025	3.74	0.21	0.0018	0.099	0.079
17-Mar-08	39.6		0.19	< 0.001	12.7	0.16	0.002	1.1	< 0.00025	4.41	0.18	0.0034	0.094	0.064
14-Apr-08	44.9	< 0.001	0.26	< 0.001	12.1	0.15	0.001	1.2		3.9	0.21	0.0028	0.097	0.074
14-May-08	12.1	< 0.001	0.47	0.003	2.63	0.06	0.002	1.6	< 0.00025	1.01	0.053	< 0.0005	0.076	0.058
12-Jun-08	14.2	< 0.0003	0.257	0.00184	3.25	0.0262	0.001	< 2	< 0.00002	< 2		0.00057	0.026	0.0229
16-Jun-08	19.3	< 0.001	0.25	0.002	4.7	0.033	< 0.001	0.6	< 0.00025	1.72	0.073	0.0007	0.037	0.015
14-Jul-08	15.6	< 0.001	0.16	0.001	3.54	0.017	< 0.001	0.5	< 0.00025	1.38	0.063	< 0.0005	0.024	0.018
22-Jul-08	18.8	0.00007	0.101	0.000883	4.14			0.43	< 0.000005	1.5	0.0705	0.00065	0.0225	0.0221
11-Aug-08	21.6	< 0.001	0.18	< 0.001	5.79	0.035	< 0.001	0.6	< 0.00025	1.98	0.089	0.0009	0.03	0.022
19-Aug-08	23.3	0.000085	0.153	0.000767	5.37			0.53	< 0.000005	2.03	0.1	0.000881	0.036	0.0345
25-Aug-08	15.7	0.00049	0.834	0.00743	3.41	0.103	0.00181	0.68	0.00001	1.9	0.0674	0.000556	0.0431	0.0254
15-Sep-08	19.9	< 0.001	0.13	< 0.001	4.33	0.027	0.002	0.5	< 0.00025	1.71	0.099	0.001	0.024	0.016
15-Oct-08	25.4	< 0.001	0.07	< 0.001	5.31	0.052	< 0.001	0.6	< 0.00025	1.82	0.1	0.0011	0.039	0.032
3-Nov-08	32.7	< 0.001	0.07	0.001		0.12	0.002	0.9	< 0.00025	2.54	0.13	0.0014	0.1	0.079
1-Dec-08	38.7	< 0.001	0.29	0.001	10.2		0.001	0.9	< 0.00025	3.37	0.14	0.0016	0.092	0.08
12-Jan-09	47.4	< 0.001	0.2	< 0.001	12.9	0.22	0.002	1.1	< 0.00025	3.34	0.2	0.0028	0.2	0.17
2-Feb-09	44.8	< 0.001	0.25	< 0.001	11.2		0.001	1	< 0.00025	3.25	0.21	0.0025	0.14	0.13
3-Mar-09	47	0.000259	0.158	0.000293	11.7		0.00143	1.09	< 0.000005	3.27	0.2	0.00283	0.121	0.119
6-Apr-09	46.2		0.151	0.000281			0.00129	1.12	< 0.000005	3.48	0.198	0.00299	0.0994	0.0985
6-May-09	9.53		0.49	0.00747		0.0664	0.0025	1.67	0.000012	1.01	0.0452	0.000322	0.168	0.154
8-Jun-09	9.83	0.000087	0.171	0.0015	2.01	0.0147	0.00066	0.52	< 0.000005	0.95	0.0412	0.000351	0.0092	0.0085
13-Jul-09	27.1		0.158	0.00122	6.34	0.0414	0.00083		< 0.000005	2	0.106		0.033	0.0245
6-Aug-09	33.1	0.000131	0.204	0.00119	7.26	0.0662	0.00072	0.78	< 0.000005	2.37		0.00153	0.027	0.0264
17-Aug-09													0.0272	
2-Sep-09		0.000074	0.198	0.00104	4.79	0.0377	0.00058	0.54		1.89	0.104	0.000964	0.0169	0.0153
5-Oct-09	24.2	0.000102	0.16	0.000727	5.4		0.00057	0.57	< 0.000005	2.09	0.111	0.00116	0.0189	0.0178
4-Nov-09	34.2		0.158	0.00132			0.00069	0.8	< 0.000005	2.31	0.136	0.00158	0.0284	0.03
1-Dec-09	40.1	0.000173	0.157	0.0006	8.28	0.0716	0.00073	0.88	< 0.000005	2.74	0.163	0.00198	0.0239	0.0212
11-Jan-10	45.3	0.000167	0.124	0.000318	10.3	0.0721		1.05	< 0.000005	3.35	0.182	0.00255	0.0237	0.0239
22-Feb-10	49.3	0.00019	0.11	0.000145	11.4	0.0769	0.00068	1.17	< 0.000005	3.67	0.202	0.0029	0.0247	0.0228
10-Mar-10	46.7	0.000206	0.138		10.5	0.0827	0.00074	1.1	< 0.000005	3.48	0.193	0.00292	0.0255	0.025
14-Apr-10	45.4	0.000256	0.156	0.00169	9.87	0.085	0.00133	1.14	< 0.000005		0.202	0.00296	0.0311	0.031
3-May-10	16.6	0.0002	0.393	0.00245	3.54	0.0459	0.00135	1.26	< 0.000005	1.41	0.0753	0.000653	0.016	0.0158
4-Jun-10	13.7	0.000161	0.253	0.00263	3.3		0.00061	0.53	< 0.000005	1.49	0.0567	0.000498	0.0082	0.0117
8-Jul-10	18.8	0.000097	0.175	0.00131	4.47	0.0253	0.00055	0.5		1.72	0.0841		0.0078	0.0231
3-Aug-10	28.1	0.000092	0.192	0.000856	6.47	0.0391	0.00078	0.71	< 0.000005	2.23	0.121	0.00119	0.0097	
2-Sep-10		0.000118	0.194	0.000388		0.0401	0.00048	0.65	< 0.000005		0.12	0.00112	0.0144	0.392
18-Oct-10	33.2	0.000181	0.215	0.000524	7.69	0.0746	0.00064		< 0.000005	2.59	0.141		0.0142	0.0144
9-Nov-10	36.8	0.000219	0.149	0.000833	8.38	0.0864	0.0008	0.87		2.72	0.161	0.00191	0.022	0.0226
1-Dec-10		0.000197	0.212	0.000605	9.05	0.0744	0.00079	0.94	< 0.000005	2.91	0.169	0.00192	0.0194	0.019
19-Jan-11	43.2		0.115	0.000191	9.48		0.00074	1.04	< 0.000005	2.95	0.2		0.0179	
1-Feb-11	51.7	0.0002	0.173	0.000528	10.4	0.0743	0.00061	1.15	< 0.000005	3.4	0.198	0.00262	0.0197	0.0204
16-Mar-11	48.7	0.000334	0.268		12.2	0.131	0.0009	1.27	< 0.000005	4.02	0.224	0.00321	0.0407	0.0285
13-Apr-11	45	0.000166	0.169	0.000223	11	0.087	0.0007	1.27	< 0.000005	3.77	0.214	0.00298		0.0384
11-May-11	30.1	0.000258	0.578	0.00205		0.0645	0.00127	1.66	< 0.000005	2.58	0.134	0.00158	0.083	0.0819
20-Jun-11	14.9	0.00023	0.215	0.0034	3.51	0.0355	0.0008	0.44	< 0.000005	1.36	0.0595		0.0451	0.0078
13-Jul-11	21.8	0.000065	0.125	0.000841	4.71	0.0171	0.00051	0.46	< 0.000005		0.0891	0.000716	0.0069	0.0065
25-Aug-11	21.3		0.117	0.000346		0.0165	0.00044	0.45	< 0.000005	1.65	0.0905	0.000718	0.0063	0.0084
21-Sep-11	26.4	0.000077	0.163	0.000461	5.44	0.0312	0.00051	0.65	< 0.000005	1.96	0.11	0.00109	0.0081	0.0304
20-Oct-11	35.1	0.000381	0.455	0.00395	7.34	0.16	0.00097		0.000006	2.59	0.141			0.0153

Table C.35: Water quality data and summary statistics for mine exposed station X2, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
14-Nov-11	109	0.015	198	115	0.197	2.75	2.38	7.51	22.7	150	< 1	0.6	0.000033	0.000039
6-Dec-11	109	0.04	258	122		1.95	1.84	7.48	19.9	136	< 1	0.99	0.000026	0.000015
18-Jan-12	121	0.055	328	155	0.241	1.75	1.05	7.55	24.8	146		0.84	0.000026	< 0.000005
7-Feb-12	128	0.023	290	151	0.257	1.07	1.08	7.76	26.6	158	1.6	1.12	0.00002	0.000069
5-Mar-12	133	0.0097		151	0.279	1.21	0.83	7.69	25.4	170	< 1	1.13		0.000024
18-Apr-12			319					7.58				0.92		
9-May-12	91.5	0.0053		110	0.148				16.5	141	< 3	2.24	0.000071	
16-May-12	93.4	0.038		103		6.22	7.21	7.81	15.6	140	2.2			0.0000467
30-May-12	32.7	< 0.005		34.2	0.0093	10.2			3.68		3.1		0.000031	< 0.00004
5-Jun-12	27.4	< 0.005		26.3	0.0112				3.91	59	5	5.32	0.00004	0.000028
12-Jun-12	28.2		52	34.2	< 0.02	5.71	5.97	7.2		40	4.7		0.0000291	0.0000256
11-Jul-12	48.2	0.02	104	53.3	0.025	5.47	5.98	7.7	7.11	76		1.92	0.0000503	0.0000211
26-Jul-12	75.6	< 0.005		83.8						99	< 3	0.96	0.000017	< 0.000017
7-Aug-12	81.3	0.018	211	94.3	0.03	2.31	2.9	7.91	12.4	96	1.7	0.64	0.00002	0.000022
9-Aug-12	87.9	< 0.005		86.9	0.0322				12.3	96.5	6.6	3.29	0.00003	< 0.000017
5-Sep-12	78.6	< 0.005	232	88.7	0.03	2.49	2.51	7.62	12		1.4	0.48	0.000013	0.000018
13-Sep-12	76.1	< 0.005		89.2					11.8		< 3	1.02	0.000018	0.000018
20-Sep-12	75.7	< 0.005		86.2					11	101	< 1		0.000015	0.000013
10-Oct-12	88.1	0.011	237	96.5	0.066		2.64	7.7	17.2	110	3.2	1.13	0.000035	0.000026
8-Nov-12	105	0.019	265	122	0.185	1.85	1.51	7.51	18.7	160	4.7	1.49		0.000031
12-Dec-12	122		263	137	0.268	2.21	1.29	7.48	25.3	164	2	0.97	0.000024	0.000017
n	50	65	42	66	31	43	44	58	68	50	61	45	54	53
minimum	26	<0.005	52	26.3	0.0064	0.9	0.83	6.8	<0.25	40	<1	0.41	0.00001	<0.000005
maximum	140	0.17	330	172	0.36	19.7	18.4	8.4	44	240	30	5.32	0.0003	0.0002
median	94	0.015	204	108	0.14	2.3	2.3	7.61	17.1	130	1	0.92	0.0000260	0.000022
mean [a]	93	0.021	199	109	0.13	3.4	3.2	7.64	19.0	129	2	1.22	0.0000389	0.000032
standard deviation (SD) [a]	36	0.028	77	42	0.11	3.7	3.3	0.33	10.4	45	4	0.88	0.0000497	0.000038
max detection limit	-	0.05	-	-	0.02	-	-	-	0.25	-	4	-	-	0.00004
# < detection limit	-	30	-	-	5	-	-	-	1	-	36	-	-	5
% < detection limit	-	46%	-	-	16%	-	-	-	1%	-	59%	-	-	9%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	6%	10%	15%	32%	2%	2%	0%	41%	14%	2%	11%	6%	9%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	0	0	0	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00017	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	0	0	0	-	1	1	2	-
% > current water quality criterion	-	0%	-	-	0%	2%	0%	0%	0%	-	2%	2%	4%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.35: Water quality data and summary statistics for mine exposed station X2, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
14-Nov-11	33.5	0.000154	0.108	0.00161	7.58	0.0664	0.00077	0.92	< 0.000005	2.52	0.155	0.00173	0.0232	0.026
6-Dec-11	35.9	0.00014	0.201	0.000602	7.94	0.0531	0.00053	0.86	< 0.000005			0.00198	0.0128	
18-Jan-12	42.6	0.000167	0.194	0.000563	9.56	0.0742	0.00057	1.03	< 0.000005	3.17	0.179	0.00238	0.0159	0.0045
7-Feb-12	42.8	0.00019	0.182	0.000309	9.79	0.0699	0.00062	1.06	< 0.000005	3.33	0.178	0.00252	0.0198	0.042
5-Mar-12	43.9			0.000251	10.2	0.0778	0.00068	1.14	< 0.000005	3.41	0.187	0.00251	0.0214	0.024
18-Apr-12														
9-May-12	32.4		0.515	0.00257	6.81		0.0012	< 2	< 0.00002	2.1			0.044	0.0419
16-May-12	30.8	0.00033		0.00111	6.37	0.0971	0.000986	1.34	< 0.000005	2.15	0.124	0.00134	0.0241	
30-May-12	10.8	0.00015	0.408	0.00324	2.14	0.0217	0.00105	0.801		0.934	0.0486	0.000361	0.0094	< 0.0264
5-Jun-12	8.27	< 0.0003	0.52	0.00544	1.68	0.0241	0.0014	< 2	0.000027	< 2		0.00032	0.0102	0.0059
12-Jun-12	9.73	0.000123	0.206	0.00318		0.0113	0.000955	0.498	0.0000162	0.893	0.0405	0.000273	0.00883	
11-Jul-12	15.7	0.000155	0.244	0.00651	3.42	0.0174	0.00108	0.417	0.0000308	1.48	0.0636	0.000464	0.0263	0.00957
26-Jul-12	24.7	< 0.0003	0.187	0.00078	5.22		< 0.001	< 2	< 0.00002	< 2		0.00086	0.0076	0.0061
7-Aug-12		0.00009	0.214	0.00115	5.65	0.0313		0.624		1.94	0.11	0.00102		0.0199
9-Aug-12		< 0.0003	0.446	0.00249	5.62	0.057	< 0.001	< 2		2		0.00098	0.0111	0.0068
5-Sep-12	26.4	0.000081	0.169	0.000412	5.52	0.0316	0.000535	0.655	< 0.000005	2.12	0.106	0.000989	0.00777	0.00795
13-Sep-12	26	< 0.0003	0.253	0.00083		0.037	< 0.001	< 2	< 0.00002	2.1		0.00098	0.0125	0.0087
20-Sep-12	24.2	< 0.0001	0.164	0.000361	5.14	0.0231	0.00051	0.562	< 0.00001	1.85	0.0994		0.0092	0.0076
10-Oct-12	27.7	0.000345	0.349	0.00137	6.02		0.000809	0.705	< 0.000005	2.17	0.119	0.00131		0.0164
8-Nov-12	35.9			0.00327	7.74		0.000838	0.905	0.000006	2.6	0.152	0.00182	0.0233	0.026
12-Dec-12	39.4	0.000163	0.206	0.000659	9.42	0.066	0.000708	1.1	< 0.000005	3.17		0.00254		0.0152
n	65	47	67	68	61	56	66	67	50	66	61	62	67	65
minimum	8.27	0.000065	0.07	0.000145	1.68	0.0113	0.00044	0.417	<0.000005	0.893	0.0405	0.000273	0.0063	0.0045
maximum	51.7	0.00049	0.834	0.00747	12.9	0.22	0.0025	2	0.0000308	4.41	0.224	0.0034	0.2	0.392
median	30.8	0.000167	0.19	<0.001	6.47	0.0623	0.00087	0.90	<0.000005	2.16	0.124	0.00133	0.024	0.023
mean [a]	30.3	0.000173	0.23	0.00146	7.10	0.0648	0.00093	0.89	0.000005	2.35	0.130	0.00152	0.039	0.040
standard deviation (SD) [a]	12.4	0.000090	0.14	0.00162	3.09	0.0442	0.00049	0.31	0.000006	0.90	0.054	0.000916	0.040	0.057
max detection limit	-	0.0003	-	0.001	-	-	0.001	2	0.00002	2	-	0.0005	-	0.0264
# < detection limit	-	6	-	9	-	-	8	6	43	3	-	2	-	1
% < detection limit	-	13%	-	13%	-	-	12%	9%	86%	5%	-	3%	-	2%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	12%	28%	9%	22%	15%	64%	23%	13%	4%	27%	30%	24%	73%	68%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.1	0.101	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	2	-	0	0	0	0	-	-	0	23	-
% > current water quality criterion	-	0%	0%	3%	-	0%	0%	0%	0%	-	-	0%	34%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.36: Water quality data and summary statistics for mine exposed station R1, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
23-Jan-08	170	0.096	456	248	0.27		2.5	7.51		270			0.000035	0.000029
21-Feb-08	130	0.058		141	0.16	1.4	1.2		33.6	170	3		0.00001	0.000008
3-Mar-08	127	0.04		146				7.1	30.7		< 1	3	< 0.0002	
11-Mar-08	130	0.071	244		0.13		2	6.37		200			0.000021	0.000018
29-Apr-08	83	0.018		105	0.1	3.6		6.69	28	140	2		0.000029	
22-May-08	43	< 0.005	108.9	53.6	< 0.02	11	11.3	7.5	1.4	86	28		0.00003	0.000019
24-Jun-08	24	0.009	72.8	32.3	< 0.02	4.2		6.94	6	64	150		0.000063	0.000335
22-Jul-08	56	< 0.01		63.8					9.4		1		0.000021	0.000021
29-Jul-08	70	< 0.005	197.8	82.5	0.04	3.9	3.4	8.15	14	96	3		0.000009	0.000008
19-Aug-08	91.7	< 0.01		84				7.8	14.3		2		< 0.0002	< 0.0002
25-Aug-08	44	< 0.005		51.2					8.1		18		0.00005	0.000024
17-Sep-08	74	< 0.005	194.9	83.7	0.03	7.1			16	130	3		0.000008	0.000008
8-Oct-08	88	< 0.005	231	100	0.05	1.7	2.8		20	140	5		0.00002	0.000023
10-Dec-08	110	0.036	516	132	0.12	2.2	2.1		24	200	1		0.000028	0.000015
22-Jan-09	160	0.043		187	0.14				43	210			0.00003	0.000046
24-Feb-09	130	0.065							31	170	2		0.00004	0.000033
20-May-09	68	< 0.005	414	72.4	0.04					90	11		0.000012	0.000006
23-Jun-09	54	< 0.005	321	53.3	< 0.02			7.99	8	86	18		0.000037	
30-Jul-09	89	0.006	202	105	< 0.02			8.28	15				< 0.000005	0.000019
25-Aug-09	58	0.015	144		< 0.02			8.25		74	2		0.000008	0.000011
30-Sep-09	84	< 0.005	206	93.3	0.05			7.75	17	120	< 1		0.000007	0.00001
21-Oct-09		0.015		106	0.1				20	140	1		0.000006	
24-Nov-09	110	0.048	15.6		0.12			8.94	24	150	< 1		0.000005	< 0.000005
21-Jan-10	120	0.047	161.8	145	0.14				29	170	4			
24-Feb-10	120	0.115	187.2	152	0.15				30	180	110		0.000081	0.000018
30-Mar-10	140			155	0.18			7.86	33	190	3		0.000018	0.000008
3-Nov-10	94	0.041	121.1	103	0.07			7.86	21		< 4		< 0.000005	< 0.000005
18-May-11	33	0.041		44.3	< 0.02	19.9	21.4	7.33	< 0.5	66	210	5.03	0.000171	0.000029
28-May-12	32.6	0.067		34.4	0.0138		11.8		< 0.5	70	3.9	2.8		0.0000095
30-Aug-12				84									0.000012	0.000015
24-Oct-12	103	0.023			0.0955		2.72		20.6	144	< 1	0.46		
n	29	29	17	26	25	9	10	16	26	24	26	4	26	25
minimum	24	<0.005	15.6	32.3	0.0138	1.4	1.2	6.37	<0.5	64	<1	0.46	<0.000005	<0.000005
maximum	170	0.115	516	248	0.27	19.9	21.4	8.94	43	270	210	5.03	0.000171	0.000335
median	89	0.018	198	97	0.07	3.9	2.8	7.78	20	140	3	2.90	0.0000205	0.000018
mean [a]	91	0.030	223	102	0.08	6.1	6.1	7.65	19	140	22	2.82	0.0000291	0.000033
standard deviation (SD) [a]	39	0.031	134	51	0.07	6.0	6.6	0.65	11	54	52	1.87	0.0000348	0.000066
max detection limit	-	0.01	-	-	0.02	-	-	-	0.5	-	4	-	0.000005	0.0002
# < detection limit	-	10	-	-	6	-	-	-	2	-	5	-	2	3
% < detection limit	-	34%	-	-	24%	-	-	-	8%	-	19%	-	8%	12%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	7%	21%	24%	8%	4%	11%	10%	6%	38%	21%	15%	75%	4%	8%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	6%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00015	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	4	1	1	-
% > current water quality criterion	-	0%	-	-	0%	11%	10%	0%	0%	-	15%	25%	4%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	6%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.36: Water quality data and summary statistics for mine exposed station R1, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
23-Jan-08	80.3	0.000185	0.901	0.000535	11.5	0.217	0.00079	2.16		4.87	0.368	0.00391	0.0041	0.0057
21-Feb-08	45	0.000091	0.428	0.000058	7.07		0.00044	1.45	< 0.000005	3.16	0.231	0.00275	0.0008	0.0013
3-Mar-08		< 0.001	0.43	< 0.001	8.66	0.095	< 0.001	1.7	< 0.00025	3.79	0.27	0.0021	< 0.005	< 0.005
11-Mar-08		0.000119	0.528	0.000328	7.3	0.125	0.00059	1.48		3.29		0.0025	0.0169	0.0163
29-Apr-08	33.8	0.000228	0.83		5.09	0.138	0.00083	2.12	< 0.000005	2.31	0.177	0.00176	0.0088	0.0083
22-May-08	15.7		0.791	0.00124	3.53	0.0509	0.00162	1.27	< 0.000005	1	0.074		0.0052	0.0023
24-Jun-08	9.72	0.000873		0.00441	1.95	0.0944	0.00208	0.58	0.00001	1.02	0.0537	0.00103	0.0102	0.0104
22-Jul-08	18.8	0.000063	0.091		4.07	0.0159	0.00076	0.4	< 0.000005	1.44	0.0747	0.000684	0.0195	0.019
29-Jul-08	25.1	0.000098	0.285	0.000322	4.83	0.0313	0.00049	0.69	< 0.000005		0.126		0.0025	0.0025
19-Aug-08	25.8	< 0.001	0.17	< 0.001	4.83		< 0.001	0.8	< 0.00025	1.83	0.13	0.0011	< 0.005	
25-Aug-08	15.2	0.000305	0.578	0.00469	3.25	0.0602	0.00149	0.69	0.000009	2	0.0649		0.0369	
17-Sep-08	25.2	0.000065		0.000215	5.08	0.0261	0.00041	0.72	< 0.000005	1.89	0.128	0.00131	0.0016	0.0013
8-Oct-08	30.1		0.257	0.000333	6.08	0.0394	0.00041	0.19	0.000005	1.94	0.151		< 0.0001	0.0025
10-Dec-08	41.4	0.000086		0.000159	6.94	0.0808	0.00039	1.1	< 0.000005	2.52	0.204	0.00226	0.0019	0.004
22-Jan-09	59.3	0.000119	0.285	0.000721	9.33	0.123	0.00054	2.05	< 0.000005	4.42	0.308	0.00373	0.0064	0.0194
24-Feb-09		0.000027	0.268	0.000252	7.18	0.0281	0.00035	1.36	< 0.000005		0.249	0.0028	0.0053	0.005
20-May-09	21.4	0.000136	0.457	0.000663	4.62	0.0368	0.00079		< 0.000005		0.103	0.00132		0.0018
23-Jun-09	16.2		0.477	0.00101		0.0347	0.00063	0.54	< 0.000005	1.66	0.0839	0.000882	0.0038	0.0027
30-Jul-09	33.1	0.000044	0.31	0.000068	5.39	0.0368	0.0003	0.93	< 0.000005	2.3	0.161	0.00159	0.0005	0.001
25-Aug-09		0.000047	0.216	0.000147	3.91	0.0232	0.00035	0.57	< 0.000005		0.106	0.000924	0.0008	0.001
30-Sep-09	28	0.000048	0.206	0.000084	5.69	0.0341	0.00028		< 0.000005	2.04	0.138		0.0007	0.0024
21-Oct-09	32.2	0.000063	0.286	0.000072	6.3		0.0003	0.86	< 0.000005	2.24	0.156	0.00171	0.0005	0.0007
24-Nov-09	36.4	0.000054	0.323	0.000098	6.36	0.0658	0.0004	0.97	< 0.000005	2.45	0.184	0.00205	0.0013	
21-Jan-10	45.4		1.37	0.00085		0.108	0.00056	1.32	< 0.000005	2.98	0.227	0.00267	0.0118	0.0067
24-Feb-10	47.8	0.000668	5.17	0.00302	7.87	0.396	0.00226	1.46	0.000008	3.12	0.237		0.0179	0.005
30-Mar-10	49.1	0.000108	0.5	0.000443	7.88		0.00048	1.48	< 0.000005	3.14	0.255	0.00321	0.0061	0.0019
3-Nov-10		0.000051		0.000036	5.95	0.0612	0.00033	0.89	< 0.000005	2.37	0.181	0.00174	0.0007	0.001
18-May-11	12.5	0.00244	8.39	0.00886	3.2	0.555	0.006	2	0.000042	0.7	0.0701	0.00138	0.029	0.0053
28-May-12	10.7		0.331	0.00198			0.000889	0.899	0.0000136	0.845	0.0485	0.000337	0.00756	0.00944
30-Aug-12	25.1	0.000057	0.156	0.000305	5.18		0.00048	0.611	< 0.000005	2.01	0.104	0.000933	0.00595	0.0057
24-Oct-12														
n	25	25	26	28	27	24	30	28	26	26	29	24	29	27
minimum	9.72	0.000027	0.091	0.000036	1.95	0.0159	0.00028	0.19	<0.000005	0.7	0.0485	0.000337	<0.0001	0.0007
maximum	80.3	0.00244	8.39	0.00886	11.5	0.555	0.006	2.16	0.000042	4.87	0.368	0.00391	0.0369	0.0194
median	28.0	0.0000980	0.38	0.000388	5.69	0.0607	0.00055	0.95	<0.000005	2.27	0.151	0.00173	0.0050	0.0040
mean [a]	31.3	0.000279	0.92	0.00114	5.89	0.103	0.00087	1.12	0.000005	2.36	0.161	0.00186	0.0073	0.0054
standard deviation (SD) [a]	16.7	0.000500	1.80	0.00195	2.09	0.126	0.0011	0.55	0.000008	1.04	0.082	0.000958	0.0090	0.0053
max detection limit	-	0.001	-	0.001	-	-	0.001	-	0.000005	-	-	-	0.005	0.005
# < detection limit	-	2	-	2	-	-	2	-	20	-	-	-	3	1
% < detection limit	-	8%	-	7%	-	-	7%	-	77%	-	-	-	10%	4%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	16%	24%	38%	14%	4%	63%	17%	32%	4%	27%	41%	25%	17%	7%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	7	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.006	-	1.0	0.093	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	3	1	-	0	0	0	0	-	-	0	1	-
% > current water quality criterion	-	0%	12%	4%	-	0%	0%	0%	0%	-	-	0%	3%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.37: Water quality data and summary statistics for mine exposed station X3, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
7-Jan-08		0.03		138				7.6	29.9		< 1	0.67	< 0.0002	< 0.0002
18-Feb-08		0.02		169				7.3	35.6		< 1	0.55	< 0.0001	< 0.0002
17-Mar-08		0.02		146				7.3	36.4		< 1	0.72	< 0.0002	< 0.0002
14-Apr-08		0.04		160				7.4	34.7		< 1	1.4	< 0.0002	< 0.0002
14-May-08		0.02		42				8.3	7.45		10	3.5	< 0.0002	< 0.0002
16-Jun-08		< 0.01		52				8	8.06		3	1.9	< 0.0001	< 0.0002
14-Jul-08		0.03		62				8	8.95		3	2.1	< 0.0002	< 0.0002
11-Aug-08		0.02		85				8.1	13.4		< 1	0.52	< 0.0002	< 0.0002
15-Sep-08		0.03		76				8	13.2		1	0.13	< 0.0002	< 0.0002
15-Oct-08		0.04		92					16.3		< 1	0.57	< 0.0002	< 0.0002
3-Nov-08		0.02		116				7.9	21.4		< 1	0.7	0.0003	0.0003
1-Dec-08		0.04		146				8.1	23.5		< 1		< 0.0001	< 0.0002
12-Jan-09		0.04		165				7.7	40		< 1	0.82	< 0.0002	< 0.0002
2-Feb-09		0.02		158				7.9	34.3		< 1	0.74	< 0.0002	< 0.0002
3-Mar-09		0.03	335	164		1.4	1.4	7.9	37	180	< 1		0.00003	0.000033
6-Apr-09	140	0.02	104.8	161		2	1.8		37	210	< 1		0.000021	0.000024
6-May-09	31	0.05	65	37.3		14.9	16.4	7.3	12	76	13		0.000083	0.000055
8-Jun-09	34	0.03	68	37.2		4.9	5		7	72	6		0.000008	0.000011
13-Jul-09	76	0.03	174	89.2		2.4	2.2	7.9	13	110	< 1		0.000024	
6-Aug-09	97	< 0.01	200	111		2.2	2.5	8.1	18	120	< 1		0.000009	0.00002
3-Sep-09	74	< 0.01	130	80.7		2.8	2.5	8.21	12	88	< 1		0.00002	
5-Oct-09	86	< 0.01	130	95		2.8		7.9	16	170	< 4		0.000013	< 0.000005
4-Nov-09			190	120		2.2	2	7.56	19	120			0.000016	0.000016
1-Dec-09	110	0.05	248	129		1.9	1.8		23	150			< 0.000005	0.000011
11-Jan-10		0.03	266	157		1.4	1.2	6.92	28	190	< 1		0.000021	0.000014
22-Feb-10		< 0.01	302	164		1.4	1.2	7.53	28	180	< 1		0.000012	0.000011
9-Mar-10	140		260	162		1.3	0.9	7.39	30	200	< 1		0.000013	0.000045
14-Apr-10	150	0.05	290	163		1.7	1.8	7.02	30	170	< 1		0.000019	0.000023
3-May-10	52	0.075	114	62.9		11.6	11.9	7.74	5.4	72	8		0.00003	0.000038
4-Jun-10	40	0.77	86	44.8		2.3	2.6	7.83	6.3	54	5		0.000018	0.000015
8-Jul-10	54	< 0.05	111	55.7		3.1	2.9	7.91	11	70	< 1		0.00001	0.000019
3-Aug-10	87	< 0.05	183	85		2	2.5	7.86	14		< 1		0.000008	0.00001
2-Sep-10		0.19	205	94.3	0.03	2.7	2.3	7.34	13	110	< 1	0.7	0.00001	0.000016
21-Oct-10	98	0.067	225	114	0.08	1.9	1.7	7.57	20	130		0.8	0.000015	0.000028
9-Nov-10	110	0.019	256	131	0.16	1.8	2	7.92	24	170	< 4	0.62	0.000022	0.000016
1-Dec-10	110	< 0.05	230	129	0.17	2	2	7.62	27	130	< 4	0.9	0.000014	
18-Jan-11	130		301	155	0.25	1.5	1.4	7.52	27	180	< 1	0.86	0.000013	0.000016
2-Feb-11	130	< 0.05	311	146	0.22	1	0.9	7.99	26	150	< 1	1.02	0.000015	0.00001
14-Mar-11		0.019		172	0.29	1.2	1	7.51	29	180	< 1		0.000012	0.000021
13-Apr-11	140	0.02	306	171	0.22	1.3	1.8			180	< 1	0.89	0.000019	0.000024
5-May-11	130	0.023	250	140	0.15	2.6	2.5	7.58	26	180	< 1	1.32		0.000105
20-Jun-11	46	0.027	104	47.1		2.8	3.1	7.55	7.8	68	9	1.08	0.000026	0.000016
13-Jul-11	69	0.025	157	77.8	< 0.02	2.6	3.5	6.86	13	90	< 1	0.5	0.00002	0.000008
25-Aug-11		0.038	147	74.8	< 0.02	2.8	4.1	7.76	12	92	2	0.44	0.000006	
21-Sep-11	86		207	96.8	0.03	2.8		7.42	14	120	< 1	0.4	0.000018	0.000014
27-Oct-11		0.016	230	115	0.14	2.9	1.9	7.6	19.3	120	< 1	0.92	0.00002	0.000068

Table C.37: Water quality data and summary statistics for mine exposed station X3, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
7-Jan-08	39.3	< 0.001	0.15	< 0.001	9.65	0.077	< 0.001	1.1	< 0.00025	3.06	0.17	0.0018	0.047	0.069
18-Feb-08	48		0.15	< 0.001	11.9	0.13	0.002	1.4	< 0.00025	3.67	0.21	0.0018	0.088	0.064
17-Mar-08	38.5	< 0.001	0.12	< 0.001	12.1	0.11	0.001	1.1	< 0.00025	4.27	0.18	0.0033	0.071	0.051
14-Apr-08	45	< 0.001	0.21	< 0.001	11.5	0.11	0.001	1.2	< 0.00025	3.78	0.21	0.0027	0.076	0.058
14-May-08	12.5	< 0.001	0.86	0.003	2.54	0.086	0.001	1.6	< 0.00025	1.23	0.058	< 0.0005	0.043	0.028
16-Jun-08	15.3	< 0.001	0.2	< 0.001	3.26	0.02	< 0.001	0.6	< 0.00025	1.39	0.068	0.0006	0.012	0.006
14-Jul-08	18.1	< 0.001	0.2	< 0.001	4.04	0.018	< 0.001	0.6	< 0.00025	1.47	0.081	0.0007	0.017	0.006
11-Aug-08	24	< 0.001	0.21	< 0.001	6.02	0.032	< 0.001		< 0.00025	2	0.11	0.0011	0.016	0.011
15-Sep-08	22.4		0.18	< 0.001	4.79	0.026			< 0.00025	1.72	0.13	0.0013	0.01	0.007
15-Oct-08	28.1	< 0.001	0.08	< 0.001	5.3	0.043	< 0.001	0.7	< 0.00025		0.13	0.0012	0.023	0.013
3-Nov-08	33.8	< 0.001	0.07	< 0.001	7.64	0.083	< 0.001	1	< 0.00025	2.77	0.15	0.0014	0.054	0.038
1-Dec-08	41.8	< 0.001	0.33	< 0.001		0.11	0.001	1.1	< 0.00025	3.38	0.18	0.0017	0.065	0.053
12-Jan-09	46.9	< 0.001	0.18	< 0.001	11.7	0.16	0.002	1.2	< 0.00025	3.25	0.21	0.0027	0.14	0.13
2-Feb-09	45.3	< 0.001	0.26	< 0.001	10.8	0.13	0.001	1.1	< 0.00025		0.21	0.0025	0.12	0.1
3-Mar-09	46.6	0.000185	0.127	0.000223	11	0.123	0.00125	1.14	< 0.000005		0.204	0.0028	0.098	0.0966
6-Apr-09		0.000177	0.131	0.000243	11.2	0.105	0.00113	1.18		3.34	0.206	0.00298	0.078	0.0761
6-May-09	10.8	0.000313	0.823	0.00338	2.46	0.0775	0.00145	1.57		0.78	0.052			
8-Jun-09	10.6	0.000081	0.157	0.00083	2.13	0.0148	0.00046	0.51	< 0.000005	0.94	0.0514		0.007	0.0037
13-Jul-09	24.1	0.00014	0.15	0.000426	5.25	0.0395	0.00047	0.67	0.000013	1.8	0.107	0.00104	0.0352	0.0436
6-Aug-09	32.7	0.000072	0.184	0.0006	6.62	0.0411	0.00053	0.84	< 0.000005	2.27	0.15	0.00162	0.0128	0.0119
3-Sep-09	23	0.000057	0.167	0.000369	4.59	0.0245	0.00038	0.58	< 0.000005	1.83	0.11	0.00099	0.0083	0.0078
5-Oct-09		0.00007	0.164	0.000346	5.57	0.0319	0.00042	0.64	< 0.000005	2.03		0.0013	0.0093	0.009
4-Nov-09	36.5	0.000103	0.158	0.000431	6.93	0.0626	0.00051	0.9	< 0.000005		0.154	0.0017	0.017	0.0175
1-Dec-09		0.0001	0.16	0.000245	7.78	0.0525	0.00053	0.92			0.173	0.00205	0.0148	0.0147
11-Jan-10	45	0.000115	0.09	0.000264	10.2	0.051	0.00065	1.13	< 0.000005	3.22	0.185	0.00254	0.0219	0.0212
22-Feb-10	47.6	0.000118	0.072	0.00011	10.9	0.0504	0.00062	1.19		3.47	0.199	0.00278	0.02	0.02
9-Mar-10	47.5		0.075	0.000121	10.7		0.00067	1.19	< 0.000005	3.44	0.204	0.00299	0.021	0.159
14-Apr-10	45	0.000144	0.076	0.000454	9.73	0.053	0.00202			3.18	0.203	0.00298	0.025	0.0255
3-May-10	18.4	0.000136	0.427	0.00137	3.76	0.056	0.00146	1.24		1.39		0.000828	0.0111	0.0142
4-Jun-10	13		0.183	0.000747	2.95	0.02	0.00048		< 0.000005	1.47	0.0607	0.000534	0.0112	0.0045
8-Jul-10	16.4	0.000053	0.133	0.000694	3.6	0.0164	0.00041		< 0.000005	1.64	0.082	0.000683	0.004	0.0125
3-Aug-10		0.000047	0.227	0.000674	5.56	0.028	0.00045	0.7	< 0.000005	2.09	0.122	0.00119	0.0056	0.0068
2-Sep-10	26.7	0.000055	0.171	0.00041		0.024	0.00045	0.68	< 0.000005	2.11	0.124	0.00111	0.0087	0.0428
21-Oct-10	33.5	0.000093	0.223	0.000862	6.81	0.0533	0.00054	0.85	< 0.000005	2.34	0.158	0.00172	0.0095	0.03
9-Nov-10		0.000066	0.127	0.000706	7.58	0.0436	0.00056	0.93		2.52	0.166		0.014	0.014
1-Dec-10	37.9	0.000099	0.14	0.000268	7.84	0.0462	0.00047		< 0.000005	2.69	0.175	0.00193	0.0154	0.0116
18-Jan-11	40.5	0.000106	0.124	0.000207	9.7	0.0508	0.00062	1.12	0.000007	3.19	0.195	0.00265	0.0133	0.014
2-Feb-11		0.000093	0.116	0.000123	9.4	0.047		1.14	< 0.000005	3.06	0.192	0.00248	0.0124	0.0134
14-Mar-11	47.4	0.00012	0.11	0.00021	11.6	0.0709	0.00076		< 0.000005	3.74	0.216			0.0201
13-Apr-11	45.2	0.000104	0.15	0.000176	10.7	0.0612	0.00062	1.4		3.83		0.00293	0.0159	0.0171
5-May-11	42		0.302	0.00037	8.54	0.0677		1.38	< 0.000005	3.07	0.188	0.00261	0.0774	0.0773
20-Jun-11	14		0.324	0.00206	2.98	0.0282	0.00064	0.5	< 0.000005	1.36	0.0669		0.0065	0.0029
13-Jul-11	23.4	0.00005	0.143	0.0004	4.68	0.0203	0.00045	0.59	< 0.000005	1.64	0.111	0.00101	0.0036	0.0034
25-Aug-11	22.4	0.000066	0.2	0.000654	4.57	0.0252	0.00043	0.57	< 0.000005	1.7	0.108	0.000929	0.0045	0.0034
21-Sep-11	28.8	0.000057	0.177	0.000245	5.83	0.025	0.00051	0.75	< 0.000005		0.129	0.00134	0.0046	0.0062
27-Oct-11	34.3	0.000119	0.216	0.00162	7.2	0.0528			< 0.000005	2.48	0.155	0.0018	0.0101	0.0533

Table C.37: Water quality data and summary statistics for mine exposed station X3, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
15-Nov-11	103	0.03	200	117	0.172	2.21	2.28		22.2	144	< 1	0.53	0.000019	0.000021
7-Dec-11	118	0.059		129	0.19	1.55	1.86	7.56	25.5	162		1.04	0.000012	0.000013
18-Jan-12	118	0.072	278	143	0.218	1.7	3.11	7.65	26.5	160	1.3	0.85	0.000023	< 0.000005
7-Feb-12	128	0.076	310	150		1.46		7.6	27.7	168	< 1	1.05	0.00002	0.00007
5-Mar-12	130	0.017	308	153	0.272	1.25	1.16	7.79	27.8	174	< 1	0.88	0.000016	0.00002
18-Apr-12			347					7.63				1.05		
16-May-12	95.6		219	107	0.097	6.86	6.47	7.94	16.4	134				0.0000353
12-Jun-12	30.3	0.014	70	35	< 0.02	5.37	4.56	7.65	5.79	40	7.3		0.0000207	0.0000137
12-Jul-12	57.6		125	65.1	0.022	4.43	5.24		9.5	84	3.5	1.57	0.0000175	0.0000083
7-Aug-12	83.2	0.008	199	99.8		2.54	2.91	8.05	14.8	100	1.3	0.54	0.000016	0.000011
5-Sep-12	78.3	0.0062	246	89.6	0.024	3.3	3.17	7.74		116	< 1	0.57	0.000008	0.000008
10-Oct-12	85.8	0.013	248	95.5	0.057	2.45	2.6	8.07	17.4	116	< 1	0.7	0.000015	0.000013
8-Nov-12	104	0.019	252	110	0.156	2.97	2.06		20.6	158			0.000019	0.000018
4-Dec-12	122	0.32	274	145	0.241		1.21	7.3	26.1	154	< 1	0.93		0.000026
n	37	53	44	59	24	44	42	52	57	44	53	37	46	55
minimum	30.3	0.0062	65	35	<0.02	1	0.9	6.86	5.4	40	<1	0.13	<0.000005	<0.000005
maximum	150	0.77	347	172	0.29	14.9	16.4	8.3	40	210	13	3.5	0.0003	0.0003
median	97	0.030	222	115	0.15	2.3	2.2	7.68	20	132	<1	0.82	0.0000180	0.000021
mean [a]	94	0.051	210	112	0.13	2.9	3.0	7.69	20	133	2	0.93	0.0000262	0.000046
standard deviation (SD) [a]	34	0.11	79	41	0.09	2.6	2.8	0.32	9	44	3	0.59	0.0000436	0.000051
max detection limit	-	0.05	-	-	0.02	-	-	-	-	-	4	-	0.0001	0.0002
# < detection limit	-	9	-	-	3	-	-	-	-	-	39	-	4	15
% < detection limit	-	17%	-	-	13%	-	-	-	-	-	74%	-	9%	27%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	15%	18%	17%	29%	0%	2%	0%	46%	7%	0%	3%	2%	31%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	0	0	0	1	1	0	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00018	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	2	-	-	0	0	0	0	0	-	0	0	1	-
% > current water quality criterion	-	4%	-	-	0%	0%	0%	0%	0%	-	0%	0%	2%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.37: Water quality data and summary statistics for mine exposed station X3, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
15-Nov-11	34.6	0.000096	0.123	0.000429	7.37	0.0483	0.00054	0.99	< 0.000005	2.46	0.165	0.00186	0.0138	0.0142
7-Dec-11	38.2	0.000096	0.207	0.00028	8.2	0.0505	0.00045	1	< 0.000005		0.177		0.0096	
18-Jan-12	42.8	0.000103	0.187	0.000464	8.78		0.00046		< 0.000005	3.05	0.185	0.0024	0.0113	
7-Feb-12	42.8	0.000116	0.172	0.000213	9.33	0.0548	0.00051	1.12	< 0.000005	3.21	0.186	0.00257	0.0146	0.0351
5-Mar-12	45.1	0.000133	0.152	0.000141	9.73	0.056	0.00056		< 0.000005	3.27	0.192	0.00253	0.0168	0.0173
18-Apr-12														
16-May-12	31.7		0.605	0.00118	6.78	0.0906	0.00108	1.46	< 0.000005	2.17	0.139	0.00162	0.0231	0.0203
12-Jun-12	10.7	0.000136	0.26	0.00114	2	0.0163	0.000681	0.564	0.0000076		0.0521	0.000516	0.00481	0.00546
12-Jul-12	18.7	0.0000684	0.173	0.000482	4.22	0.0138	0.000694	0.517	< 0.000005	1.5	0.0899	0.000796	0.00322	
7-Aug-12	30.6	0.000095	0.281	0.000951	5.7	0.0324	0.000599	0.769		1.98	0.13	0.00127	0.00583	0.00669
5-Sep-12	27.2	0.000049	0.171	0.000181	5.28	0.022	0.000365	0.724	< 0.000005	1.97	0.121	0.00113	0.004	0.00349
10-Oct-12	27.5	0.000113	0.216	0.000412	5.78	0.0486	0.000401	0.737	< 0.000005	2.02	0.126			0.00704
8-Nov-12	32.1	0.000123	0.158	0.000803	7.17	0.0548	0.000646		< 0.000005	2.44	0.16	0.00181	0.0125	0.0147
4-Dec-12	42.7	0.00022		0.00048	9.4	0.0788	0.000868	1.15	< 0.000005	3.24	0.189	0.00247	0.0286	0.0168
n	53	40	58	59	57	57	55	48	36	51	56	52	56	55
minimum	10.6	0.000047	0.07	0.00011	2	0.0138	0.000365	0.5	<0.000005	0.78	0.0514	<0.0005	0.00322	0.0029
maximum	48	0.000313	0.86	0.00338	12.1	0.16	0.00202	1.6	0.000013	4.27	0.216	0.0033	0.14	0.159
median	33.5	0.000102	0.17	0.000600	7.17	0.0505	0.00062	1.00	<0.000005	2.44	0.157	0.00171	0.014	0.015
mean [a]	32.0	0.000107	0.21	0.000619	7.18	0.0555	0.00072	0.96	0.000003	2.47	0.147	0.00176	0.027	0.030
standard deviation (SD) [a]	11.9	0.000051	0.15	0.000606	2.94	0.0339	0.00041	0.30	0.000002	0.86	0.049	0.000812	0.031	0.033
max detection limit	-	-	-	0.001	-	-	0.001	-	0.000005	-	-	0.0005	-	-
# < detection limit	-	-	-	13	-	-	6	-	33	-	-	1	-	-
% < detection limit	-	-	-	22%	-	-	11%	-	92%	-	-	2%	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	11%	3%	5%	5%	12%	67%	13%	10%	0%	31%	39%	27%	50%	44%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.1	0.11	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	0	-	0	0	0	0	-	-	0	13	-
% > current water quality criterion	-	0%	0%	0%	-	0%	0%	0%	0%	-	-	0%	23%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.38: Water quality data and summary statistics for mine exposed station X10, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
8-Jan-08	115	0.03		151				7.6	30.9		< 1	1.1	< 0.0002	< 0.0002
24-Jan-08	130	< 0.005	323	164	0.26	0.8	1.1	7.5	35.3	190	< 1		0.000016	0.000018
19-Feb-08	153	0.02		181				7.5	36.4		< 1	0.5	< 0.0002	< 0.0002
20-Feb-08	160	< 0.005	406	181	0.3	1.1	0.7	7.16	44.9	210	< 1		0.000019	0.000017
11-Mar-08	140	< 0.005	313	176	0.28	1.3	1.3	6.36	38	220	< 1		0.00002	0.000019
18-Mar-08	155	0.01		152				7.6	36.4		< 1	0.68	< 0.0002	< 0.0002
15-Apr-08	< 0.5	0.03		172				7.8	35.9		< 1	1.6	< 0.0002	< 0.0002
29-Apr-08	120			151	0.21	2.1	2.5	7.84	37	180	1		0.000029	0.000032
15-May-08	37.8	0.04		53				8.6	8.41			3	< 0.0002	< 0.0002
22-May-08	38	< 0.005	87.1	46.2	< 0.02	12.6	13.5	7.67	< 0.5	38	8		0.00005	0.000029
16-Jun-08	< 0.5	< 0.01		53				7.7	9.24			2	< 0.0002	< 0.0002
24-Jun-08	28	< 0.005	80.9		< 0.02	5.1	5.9	7.13	5	64	27		0.000078	0.000039
14-Jul-08	73.1	0.03		73				8.1	9.58		1	0.8	0.0003	< 0.0002
30-Jul-08	80	< 0.005	188	92.6	0.05	4.2	3.9	8.46	14	98	< 1		0.000014	0.000012
11-Aug-08	75.9	0.03		94				8.4	14.7				< 0.0001	< 0.0002
15-Sep-08	85.9	0.04		86				8	13.8				< 0.0002	< 0.0002
18-Sep-08	78	< 0.005	198.7		0.02	2.6	2.8	7.48	14	130	2		0.000014	0.000013
7-Oct-08	95	< 0.005		107	0.05	2.2		8.15	21	130	2		0.000019	0.000058
15-Oct-08	107	< 0.01		103				7.9	17.6		< 1	0.57	< 0.0002	< 0.0002
4-Nov-08	95.1	0.02		130				7.4	23.1		5	2	0.0004	0.0005
1-Dec-08	108							7.8	25.6		< 1	1.2	< 0.0002	< 0.0002
10-Dec-08	120	< 0.005	387	144	0.16		1.9		28	190	1		0.00002	0.00002
12-Jan-09	141	0.03		170				7.5			< 1	1.6	< 0.0002	< 0.0002
22-Jan-09	140	0.013		160					40	180			0.000034	0.000028
2-Feb-09	143	0.02		160				7.9	35.9		< 1	1.4	< 0.0002	< 0.0002
25-Feb-09	140	< 0.005			0.24					190	< 1		0.00003	0.000034
3-Mar-09	140	< 0.01	278	171			1.4	8.1	36	210	< 1		0.000027	0.000024
27-Mar-09	140	0.026	343	167	0.27				40	190	3		0.000025	
7-Apr-09		< 0.01	183.2	167		1.8	1.5	7.61	32	210	< 1		0.000021	0.00002
4-May-09	31	0.03		37.6		18.6	18		4.1	82	27		0.000327	0.000702
10-Jun-09	47	< 0.005	97	50.7		3.8	3.8		9.2		3		0.000011	
13-Jul-09	82	0.06	179	96.8		2.4	2.4	8.1	17	110	< 1		0.00003	0.000029
6-Aug-09	100		220	120		2.8	2.8	8.4	22	140	< 1		0.00002	0.000021
3-Sep-09	85	< 0.01	130	94.4		2.5	3.1	8.4	15	110	< 1		0.00001	0.000012
4-Oct-09	99	0.03	170	115		2.6	2.6	8.2	18	160	< 4		0.000012	0.000015
17-Oct-09			220					8.35						
4-Nov-09	110	0.02	220	125		2.2	2.1		23	110	< 1		0.000015	0.000011
1-Dec-09	120	0.02	262	152		1.7	1.3	7.64	26	150	< 1		0.000009	0.000011
11-Jan-10		< 0.01	286	166		1	0.8	7.13	26	220	< 1	0.8	0.000016	
22-Feb-10	150	< 0.01	280	167		1.3	1.3	7.46	30	220	< 1	0.5	< 0.000005	
10-Mar-10	150	< 0.01	292	163		1.4	1.6	7.51	26	210	< 1		0.00001	0.00001
13-Apr-10	150	< 0.01	310	162		1		7.55	30	200			0.00002	0.000014
3-May-10	59	< 0.01	112	67.8		11.7		7.79	9.4	74	5		0.000039	0.000026
4-Jun-10	45	< 0.05	111	54.1		2.8	2.5	8.05	9	62	3		0.00001	0.000023
8-Jul-10	62	< 0.05	128	68.7		3	2.9	8.09	12	82	2		0.00001	0.000017
3-Aug-10	95	< 0.05	205	96.8		2.4	2.3	8.01	17	120	< 1		0.000008	0.000023
2-Sep-10	88	0.12	194	101	< 0.02	2.7	3	7.42	17	120	< 1	0.7	0.000008	0.000018
21-Oct-10	110	0.061	244	123	0.09	2	1.7	7.93	24	150	10	1.7	0.000027	0.000012
9-Nov-10	120	0.044	268	135	0.16	1.7	2.4	7.52	25	170	< 4	1.02	0.000024	0.000015
1-Dec-10	120		240	138	0.17	2	1.9	7.87	27	140	< 4		0.000013	
18-Jan-11	140		311	170	0.27	1.6	1.4	7.77	28	190	< 1	0.67	0.000016	0.00002
1-Feb-11	130	< 0.05	150	171	0.23	1.9	1.1	7.95	27	170	< 1	0.75	0.000011	
14-Mar-11	150	0.017	170	185	0.29	1	0.9	7.45	29	220	< 1	0.37	0.00002	0.000019

Table C.38: Water quality data and summary statistics for mine exposed station X10, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8-Jan-08	43.2	< 0.001	0.2	< 0.001	10.5	0.042	< 0.001	1.1		2.96	0.19	0.002	0.064	0.039
24-Jan-08	47.6	0.000058	0.157	0.000097	11.1	0.0386	0.00089	1.12	< 0.000005	3.14	0.2	0.00243	0.0667	0.0644
19-Feb-08	51.3	< 0.001	0.14	< 0.001	12.8	0.038	0.001	1.4		3.52	0.22	0.0018	0.076	0.05
20-Feb-08	51.3	0.000048	0.09	0.000087	13	0.0347	0.00112	1.24	< 0.000005	3.48	0.213	0.00283	0.0701	0.0728
11-Mar-08	50.2	0.000039	0.129	0.000085	12.3	0.0295	0.00111	1.22	< 0.000005	3.5	0.21	0.00274	0.0807	0.083
18-Mar-08	40		0.12	< 0.001	12.7	0.025	0.001	1.1	< 0.00025	3.99	0.18	0.0032	0.069	0.042
15-Apr-08	48.5		0.23	0.001	12.3	0.035	0.001	1.3	< 0.00025	3.6	0.22	0.0028	0.073	0.044
29-Apr-08	43.6	0.00009	0.272	0.000479	10.2	0.0404	0.00135	1.32	< 0.000005	3.02	0.196	0.00249	0.103	0.0946
15-May-08	15.4	< 0.001	0.69	0.002	3.59	0.081	0.002	1.4	< 0.00025	1.3	0.067	0.0006	0.049	0.031
22-May-08	13.2	0.00023	0.502	0.0036	3.2	0.0454	0.00153	1.21	0.000008	0.9	0.0564	0.000482	0.0225	0.0184
16-Jun-08	15.1	< 0.001	0.15	< 0.001	3.8	0.017	< 0.001	0.5	< 0.00025	1.27	0.062	0.0006	0.014	0.008
24-Jun-08	10.3	0.000307	0.59	0.00332	2.28	0.0563	0.00121	0.53	0.000006	1.05	0.0498	0.000543	0.0158	0.0096
14-Jul-08	20.2		0.23	< 0.001	5.47	0.021	< 0.001	0.6	0.0003	1.46	0.081	0.0009	0.021	0.011
30-Jul-08	26.7	0.000081	0.23	0.00041	6.34	0.031	0.00062	0.61	< 0.000005	2.65	0.113	0.00113	0.0206	0.0189
11-Aug-08	25.8	< 0.001	0.29	< 0.001	7.28		< 0.001	0.7	< 0.00025	1.98	0.11	0.0012	0.022	0.014
15-Sep-08	24.4	< 0.001	0.23	< 0.001	5.96		< 0.001	0.6	< 0.00025	1.68	0.13	0.0013	0.017	0.014
18-Sep-08	26.1	0.000073	0.196	0.000551	6.25	0.0287	0.00056	0.65	< 0.000005	1.73	0.115	0.00113	0.0183	0.0179
7-Oct-08	30.5	0.000144	0.281	0.000515	7.45	0.0644	0.00071	0.31	0.000005	1.94	0.133	< 0.000002	< 0.0001	0.0302
15-Oct-08	30.2	< 0.001	0.3	< 0.001	6.65	0.061	< 0.001	0.7	< 0.00025	1.76	0.13	0.0014	0.035	0.049
4-Nov-08	37.4	< 0.001	0.83	0.004	9		0.002	1.2	< 0.00025	3.03	0.15	0.0016	0.091	0.045
1-Dec-08	43.8	< 0.001		< 0.001	11.2	0.09	0.001	1.1	< 0.00025	3.16	0.17	0.0016	0.076	0.065
10-Dec-08	41.5	0.000135	0.237	0.000306	9.7	0.0722		0.99	< 0.000005	2.65	0.177	0.0022	0.0723	0.0685
12-Jan-09	47.6	< 0.001	0.23	< 0.001	12.5	0.081	0.001		< 0.00025		0.2	0.0025	0.13	0.12
22-Jan-09		0.000132	0.355	0.000444	10.8	0.0921	0.00126	1.13	< 0.000005	3.87	0.206	0.00268	0.12	0.119
2-Feb-09	45.5	< 0.001	0.31	< 0.001	11.2	0.081		1.1	< 0.00025	3.06	0.21	0.0024	0.12	
25-Feb-09	47.9	0.000116	0.236	0.000151	11.1	0.0767	0.00145	1.11	< 0.000005		0.206			0.15
3-Mar-09		0.000114	0.218	0.000198	11.6	0.0657	0.0012	1.15	< 0.000005	3.05		0.00274	0.116	0.114
27-Mar-09	47.7	0.000114	0.351	0.000442	11.8	0.0574	0.00119	1.15	< 0.000005	3.14	0.208	0.00291	0.105	0.096
7-Apr-09	47.2	0.000066	0.232	0.000136	11.5	0.0394	0.00103	1.16	< 0.000005		0.207	0.0029	0.0877	0.0873
4-May-09	10.5	0.000582	0.932	0.0101	2.68	0.0986	0.00216		0.000008		0.05		0.118	
10-Jun-09	12.5	0.000046	0.12	0.000401	2.93	0.011	0.00036	0.43	< 0.000005	0.97	0.0545	0.000494	0.0083	0.0101
13-Jul-09	26.2	0.000079	0.261	0.0008		0.0318	0.00058	0.67	0.000006	1.87	0.111	0.00112	0.0218	0.0243
6-Aug-09	34.9	0.000067	0.34	0.000381	7.49	0.0315	0.00051	0.85	< 0.000005	2.15	0.157	0.00168	0.0262	0.0212
3-Sep-09	26.7		0.276	0.000241		0.0272	0.00049	0.65	< 0.000005	1.94	0.117	0.0011	0.0184	0.0176
4-Oct-09	29.5	0.000098	0.276	0.000252	7.47	0.0355	0.00059	0.66	< 0.000005	2.02	0.136	0.0014	0.0229	0.0199
17-Oct-09													0.027	
4-Nov-09	37.2	0.000098	0.209	0.000255	7.93	0.0501		0.88		2.21	0.157	0.00174	0.0312	0.0316
1-Dec-09	40.1	0.000098	0.208	0.000154	8.88	0.0441	0.00055	0.93		2.55	0.178	0.00206	0.0355	0.0356
11-Jan-10		0.000049	0.104	0.000145	11.5	0.0264	0.00079	1.12	< 0.000005	3.03	0.192	0.00253	0.0447	0.0436
22-Feb-10	48.3	0.000024		0.000162	11.3	0.0116	0.00068	1.19	< 0.000005	3.06	0.202	0.00271	0.0268	0.0252
10-Mar-10	47	0.00003	0.08	0.000076	11.1	0.0146	0.00073	1.13	< 0.000005	3.09	0.201	0.00287	0.0293	0.0294
13-Apr-10	47.6	0.000041	0.091	0.000572	10.5	0.016	0.00066		< 0.000005	2.99	0.204	0.00292	0.0457	0.0434
3-May-10	19.3	0.000187	0.489	0.00176	4.43	0.0518	0.00175	1.22	< 0.000005	1.39	0.086	0.000851	0.0229	0.0184
4-Jun-10	15.3		0.206	0.000761		0.0205	0.0005	0.56	< 0.000005	1.47	0.0659	0.000578	0.0117	0.0173
8-Jul-10	20.4	0.000068	0.264	0.000721	4.31	0.0228		0.51	< 0.000005	1.63	0.0898	0.000743	0.0135	0.0143
3-Aug-10	27.9	0.000055	0.319	0.000586	6.24	0.0267	0.00049	0.71	< 0.000005			0.00125	0.0198	0.0241
2-Sep-10	29	0.000073	0.335	0.0002	6.64	0.0271	0.00051	0.71	< 0.000005	2.17	0.13	0.00123	0.0216	0.0342
21-Oct-10	35.3	0.000141	0.395	0.000801	8.37	0.0481	0.00061	0.87	< 0.000005	2.32	0.166	0.00184	0.0271	0.023
9-Nov-10	40	0.000093	0.203	0.000772	8.66	0.0451	0.00075	0.98	< 0.000005	2.45	0.179		0.0414	0.037
1-Dec-10	40.7		0.18	0.000139	8.57	0.0426	0.00065	1	< 0.000005	2.62	0.176	0.00185	0.0421	0.0431
18-Jan-11	44.2	0.000045	0.113	0.000123	10.2	0.0173		1.09		3	0.199	0.00269	0.0334	0.0345
1-Feb-11	48.4	0.000033	0.117	0.000151	10.4	0.0134	0.00058	1.15			0.203			0.0309
14-Mar-11	46	0.000017	0.07	0.000116	12.8			1.35	< 0.000005	3.71	0.225	0.00308	0.0351	0.0331

Table C.38: Water quality data and summary statistics for mine exposed station X10, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
13-Apr-11	150	0.022	315	172	0.22	1.2			27	190	< 1	0.5	0.000018	0.000019
5-May-11	130	0.024	250	140		2.2	2.2	7.96	26	170	< 1	0.99	0.000027	0.000042
20-Jun-11	51	0.032	115	52.6	< 0.02	3.1	3		8.8	76	3	1.07	0.000024	0.000017
14-Jul-11	82	0.025	180	90.9	< 0.02		3.4	7.67	14	100	< 1	0.48	0.000015	0.000013
24-Aug-11	78	0.042	182	89.4	< 0.02	3.1	3.3	7.71	13	110	< 1	0.49	0.000006	
21-Sep-11	95		226	110	0.03	2.4		7.29	19	130	< 1	0.85	0.000022	0.000014
20-Oct-11	110	0.01		134	0.09	2	1.9	7.5	23.2	140	< 1	1.73	0.000015	0.000037
15-Nov-11	116	0.03	216	124	0.175	2.46	2.43	7.83	25.6	172		0.78	0.000017	
6-Dec-11	119	0.049	270	138	0.181	1.62	1.62	7.73	24	146		1.21	0.000015	0.000016
18-Jan-12	123	0.051	205	143	0.217	3.04	3.14	7.73	27.1	138		1	0.000014	0.000013
7-Feb-12	135	0.027	320	154	0.251	1.06	1	8.03	28.2	158	< 1	1.21	0.000016	0.000033
5-Mar-12	138	0.017		169	0.282	1.95	0.91	8.03	29.1	180	1.4		0.000014	0.00002
18-Apr-12			322					8.04				0.92		
15-May-12	88.2	0.05	210	104	0.07	7.18	7.64	8.31	15	132	1.1		0.000027	0.0000394
12-Jun-12	33.6		73	38.1	< 0.02	4.47	4.56		5.96	52	6		0.0000242	0.0000278
11-Jul-12	60.8	0.03	170	69.7	< 0.02	4.83	5.53	7.26	9.34	76	9.4	2.73	0.0000228	0.0000187
7-Aug-12	90	0.02	213	107	0.024	2.38	3.09	8.37	15	114	1.2	0.73	0.000018	0.000015
4-Sep-12	89	0.013	180	105	0.023		2.56	8.22			< 1	0.64	0.000014	0.000009
10-Oct-12	89.8	0.01	272	101	0.048			8.09	17.9	128	< 1	0.79	0.000017	0.000012
8-Nov-12	110	0.017	139	129	0.159	1.47	1.35	7.77	22.3	162	< 1		0.000023	0.000023
4-Dec-12	124	0.14	293	152	0.229	1.49		7.63	26.5	162	< 1	1.39	0.000018	0.000022
n	70	65	53	68	38	50	48	64	69	56	63	37	72	64
minimum	<0.5	<0.005	73	37.6	<0.02	0.8	0.7	6.36	<0.5	38	<1	0.37	<0.000005	0.000009
maximum	160	0.14	406	185	0.3	18.6	18	8.6	44.9	220	27	3	0.0004	0.000702
median	109	0.020	216	130	0.16	2.2	2.4	7.80	23.2	148	<1	0.92	<0.00002	0.0000225
mean [a]	101	0.024	221	123	0.13	3.1	3.0	7.80	22.2	146	2	1.09	0.0000459	0.0000555
standard deviation (SD) [a]	39	0.025	80	42	0.11	3.2	3.1	0.39	10.2	49	5	0.61	0.0000700	0.000106
max detection limit	0.5	0.05	-	-	0.02	-	-	-	0.5	-	4	-	0.0002	0.0002
# < detection limit	2	25	-	-	8	-	-	-	1	-	42	-	13	13
% < detection limit	3%	38%	-	-	21%	-	-	-	1%	-	67%	-	18%	20%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	4%	6%	23%	29%	37%	0%	2%	3%	57%	27%	3%	5%	19%	23%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	0	1	1	1	1	0	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00020	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	0	0	0	0	-	2	0	3	-
% > current water quality criterion	-	0%	-	-	0%	0%	0%	0%	0%	-	3%	0%	4%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	2%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.38: Water quality data and summary statistics for mine exposed station X10, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
13-Apr-11	47.1	0.000023	0.079	0.000319	12.2		0.00068	1.44	< 0.000005	3.74	0.225	0.00303	0.0251	0.0269
5-May-11	40.7	0.000043	0.235	0.000233	9.02	0.0151	0.00081		< 0.000005	2.96	0.181		0.033	0.0363
20-Jun-11	14.9		0.187	0.000739	3.77	0.0211	0.00058	0.47	< 0.000005	1.3	0.0676		0.0076	
14-Jul-11	26.2	0.000075	0.218	0.000285	6.18	0.0255	0.00054	0.58	< 0.000005	1.65	0.113	0.00107	0.0117	0.0126
24-Aug-11	25.9	0.000116	0.237	0.000896	6	0.0327	0.00057	0.61	< 0.000005	1.66	0.113	0.000989	0.0131	0.0113
21-Sep-11	31.7	0.000073	0.286	0.000696	7.22	0.031	0.00056	0.77	< 0.000005		0.136	0.00142	0.0217	0.0143
20-Oct-11	37.3		0.482	0.00201	8.74	0.0602	0.00065	0.88	< 0.000005	2.39	0.162		0.0299	0.0491
15-Nov-11	34.2	0.000096	0.147	0.000281	8.2	0.0485	0.00064	1.01	< 0.000005	2.38		0.00188	0.0374	0.0383
6-Dec-11	40.5	0.000068	0.207	0.000253	8.9	0.0378	0.00051	1	< 0.000005	2.65	0.17	0.00219	0.028	0.03
18-Jan-12	42.2	0.000063		0.000125	9.1	0.0313	0.00054	1.1	< 0.000005	2.81	0.193	0.00234	0.0307	0.0315
7-Feb-12		0.000042	0.164	0.000515	10.2	0.0241	0.00052	1.15	< 0.000005	3.02		0.00263		0.04
5-Mar-12	49.5	0.00004	0.146		11	0.0196	0.00067	1.27	< 0.000005		0.207	0.00265	0.0274	0.0306
18-Apr-12														
15-May-12	30.4	0.000137	0.611	0.000591		0.052	0.00101	1.38	< 0.000005		0.134	0.00136	0.0262	0.0284
12-Jun-12	11.2	0.000135	0.256	0.00213	2.48	0.0176	0.000845	0.533	0.0000119	0.921	0.0501	0.000412	0.00944	0.00779
11-Jul-12	19.1	0.000179	0.273	0.000861	4.75	0.0218	0.00088		0.0000066	1.39	0.0809	0.000689	0.00838	0.00813
7-Aug-12	31.7	0.000102	0.368	0.000402	6.81	0.0348	0.000554	0.749	< 0.000005	1.93	0.13	0.00126	0.0177	0.0167
4-Sep-12	27.4	0.000112	0.33	0.000326		0.0359	0.000524	0.82	< 0.000005	2.25	0.129	0.00118	0.0194	0.0184
10-Oct-12	29	0.000139	0.356	0.000314	6.88	0.0556	0.000458	0.741	< 0.000005	2.05	0.126	0.00128	0.0257	
8-Nov-12	38.1	0.000215	0.34	0.000352	8.22	0.0828		0.983	< 0.000005	2.38	0.167	0.00185	0.0472	0.0472
4-Dec-12	44.3	0.000126	0.242	0.00019	10.2		0.000774	1.13	< 0.000005	3.02	0.201	0.00255	0.0405	0.0438
n	68	53	69	71	67	66	65	67	55	63	68	65	70	68
minimum	10.3	0.000017	0.07	0.000076	2.28	0.011	0.00036	0.31	<0.000005	0.9	0.0498	<0.000002	<0.0001	0.00779
maximum	51.3	0.000582	0.932	0.0101	13	0.0986	0.00216	1.44	0.0003	3.99	0.225	0.0032	0.13	0.15
median	36.3	0.0000810	0.24	0.000479	8.74	0.0353	0.00075	1.00	<0.000005	2.39	0.164	0.00174	0.029	0.031
mean [a]	34.1	0.000103	0.27	0.000768	8.45	0.0410	0.00082	0.94	0.000009	2.41	0.151	0.00176	0.042	0.039
standard deviation (SD) [a]	12.1	0.000088	0.16	0.00136	3.01	0.0220	0.00040	0.29	0.000040	0.81	0.053	0.000845	0.033	0.030
max detection limit	-	-	-	0.001	-	-	0.001	-	0.000005	-	-	0.000002	0.0001	-
# < detection limit	-	-	-	11	-	-	6	-	47	-	-	1	1	-
% < detection limit	-	-	-	15%	-	-	9%	-	85%	-	-	2%	1%	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	24%	4%	12%	7%	28%	45%	20%	4%	2%	19%	44%	28%	86%	79%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.2	0.12	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	0	1	-	0	0	0	1	-	-	0	33	-
% > current water quality criterion	-	0%	0%	1%	-	0%	0%	0%	2%	-	-	0%	47%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.39: Water quality data and summary statistics for mine exposed station W8, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
1-Jun-08		0.02		25				7.7	2.99		< 1		< 0.0002	< 0.0002
29-Sep-08		0.02		52				7	6.56		1		< 0.0002	
15-Jun-09	43	< 0.01	76	40.8		5.2	4.7	8.1	6.5	52	< 1		0.000048	0.000049
5-Sep-09	67	0.03	110	72.1		2.3	2	7	6.8	86	< 1		0.000038	0.000047
10-Dec-09	59		120	61.4		2.7	1.6	7.56	7.8				0.000133	
17-Jun-10	55	< 0.1		53.7		3	3.4	7.72	8.6	68	4		0.000035	
n	4	5	3	6	0	4	4	6	6	3	5	0	4	2
minimum	43	<0.01	76	25	-	2.3	1.6	7	2.99	52	<1	-	0.000035	0.000047
maximum	67	0.1	120	72.1	-	5.2	4.7	8.1	8.6	86	4	-	0.000133	0.000049
median	57	0.020	110	53	-	2.9	2.7	7.63	6.7	68	<1	-	0.0000430	-
mean [a]	56	0.025	102	51	-	3.3	2.9	7.51	6.5	69	1	-	0.0000635	-
standard deviation (SD) [a]	10	0.017	23	16	-	1.3	1.4	0.44	1.9	17	2	-	0.0000467	-
max detection limit	-	0.1	-	-	-	-	-	-	-	-	1	-	-	-
# < detection limit	-	2	-	-	-	-	-	-	-	-	3	-	-	-
% < detection limit	-	40%	-	-	-	-	-	-	-	-	60%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	20%	0%	0%	-	0%	0%	0%	0%	0%	0%	-	25%	0%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	0	1	-	1	1	0	0	1	0	-	1	-
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	218	-	25	4.23	0.00009	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	-	0	0	0	0	-	0	-	1	-
% > current water quality criterion	-	0%	-	-	-	0%	0%	0%	0%	-	0%	-	25%	-
# < current water quality criterion	-	-	-	-	-	0	0	0	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	0%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.39: Water quality data and summary statistics for mine exposed station W8, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
1-Jun-08	8.29	< 0.001	0.07	0.003	1.09	0.01	0.001	0.5	< 0.00025	1.58	0.028	< 0.0005	0.04	0.024
29-Sep-08	16.7	< 0.001		< 0.001	2.56	0.009	< 0.001	0.7	< 0.00025	1.98	0.061	< 0.0005	0.017	0.023
15-Jun-09	13.2	0.00004	0.053	0.00171	1.85	0.00779	0.00049			1.48	0.0457	0.000151		
5-Sep-09	21.4	0.00004	0.067	0.000263	3.29	0.0206	0.00036	0.83	< 0.000005	2.06	0.0781	0.00024	0.0144	0.0131
10-Dec-09	19.6	0.000339	1.79	0.00729	2.99	0.155	0.00067	0.78	0.000014	1.99	0.0699	0.000197	0.0311	0.0099
17-Jun-10	16.9	0.00004	0.058	0.000789		0.0127	0.0004	0.7	< 0.000005	1.73	0.0643	0.000193	0.015	0.0131
n	6	4	5	6	5	6	6	5	3	6	6	6	5	5
minimum	8.29	0.00004	0.053	0.000263	1.09	0.00779	0.00036	0.5	<0.000005	1.48	0.028	0.000151	0.0144	0.0099
maximum	21.4	0.000339	1.79	0.00729	3.29	0.155	0.001	0.83	0.000014	2.06	0.0781	0.0005	0.04	0.024
median	16.8	0.000040	0.07	0.00136	2.56	0.0114	0.00058	0.70	<0.000005	1.86	0.0627	0.000219	0.017	0.013
mean [a]	16.0	0.000115	0.41	0.00226	2.36	0.0358	0.00057	0.70	0.000006	1.80	0.0578	0.000214	0.024	0.017
standard deviation (SD) [a]	4.7	0.000150	0.77	0.00266	0.89	0.0586	0.00024	0.13	0.000007	0.24	0.0181	0.0000399	0.011	0.006
max detection limit	-	-	-	0.001	-	-	0.001	-	0.000005	-	-	0.0005	-	-
# < detection limit	-	-	-	1	-	-	1	-	2	-	-	2	-	-
% < detection limit	-	-	-	17%	-	-	17%	-	67%	-	-	33%	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	0%	25%	20%	33%	0%	17%	0%	0%	0%	0%	0%	0%	80%	40%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	0	1	1	1	1	1	0	1	0	0	1	1
current water quality criterion [b]	-	0.0025	1	0.005	-	0.8	0.059	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	1	1	-	0	0	0	0	-	-	0	2	-
% > current water quality criterion	-	0%	20%	17%	-	0%	0%	0%	0%	-	-	0%	40%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
8-Jan-08	141	0.09		299				7.7	172		< 1	2.1	< 0.0002	< 0.0002
24-Jan-08	160	0.097	696	364		1	0.8	7.5	191	460	1		0.00005	0.000046
19-Feb-08	194	0.16		406				7.6	254		3	3.5	< 0.0002	< 0.0002
20-Feb-08	200	0.128	925	422	0.22	1.3	0.9	7.3	279	570	2		0.000062	0.000053
11-Mar-08	190	0.138	834	437	0.22	1.3	1.5	6.36	303	590	1		0.000061	0.000054
18-Mar-08	< 0.5	0.15		399				7.5	275		1	3.1	< 0.0002	< 0.0002
14-Apr-08	197	0.38		619				7.5	466		12	6.2		< 0.0002
15-Apr-08	204	0.37		607				7.7	467		8	4.3		< 0.0002
22-Apr-08	205	0.37		613				7.6	504		3	3	< 0.0002	< 0.0002
29-Apr-08	170	0.3		570	0.16	0.8	0.9	7.9	472	830	7	2.6	0.000119	0.000104
6-May-08	89.8	0.21		343				7.9	269		6	7	< 0.0002	
13-May-08	45.7	0.07		145				8.6	97.2		9	3.6	< 0.0002	
15-May-08	50.2	0.09		160				8.5	108		7	3.5	< 0.0002	< 0.0002
20-May-08	34.5	0.04		80				8.4	39.5		7	6.1	< 0.0002	< 0.0002
22-May-08	39	0.006	181.3		0.02	12.2	12.3	7.5	44	130	13		0.000051	0.000033
26-May-08	29	0.14		72.4	0.03	8.2	9.4		30	110	33		0.000079	
27-May-08	27	0.02		52					19.5		6	12	< 0.0002	< 0.0002
3-Jun-08	40.9	0.03		88				8.3	45.9		< 1	3	< 0.0002	< 0.0002
10-Jun-08	50.4	0.04		103				8.3	47.6		4	2.5	< 0.0002	
16-Jun-08	54.3	0.04		114				8	56.1		2	2	< 0.0002	< 0.0002
17-Jun-08	52.2	0.05		102				7.9	56.8		< 1	2.5	< 0.0002	< 0.0002
24-Jun-08	34.6	0.03		65.4	0.04	5.1	5.1	7.1	33	100	29	12	< 0.0002	0.000049
1-Jul-08	63.6	0.07		143				8	78.3		1	0.63	< 0.0002	< 0.0002
8-Jul-08	< 0.5	0.03		119				8.4	59		< 1	0.7	< 0.0002	< 0.0002
14-Jul-08	81	0.03		104				7.9	40.7		2	0.8	< 0.0002	< 0.0002
16-Jul-08	59.8	0.03		95				7.9	33.6		9	6		< 0.0002
22-Jul-08	80.9	0.05		128				7.8	48.2			1	< 0.0002	< 0.0002
30-Jul-08	89	0.034	327	157	0.04	3.6	3.5	7.95	66	190	1		0.000029	0.000018
31-Jul-08	106	0.07		139				8.1	76.6		< 1	0.71	< 0.0002	< 0.0002
5-Aug-08	108	0.09		178				8	93.8		1	0.75	< 0.0002	< 0.0002
11-Aug-08	91.9	0.07		171				8	86.3		< 1	0.75	< 0.0002	
12-Aug-08	109			172				7.9	82.8		< 1	0.71	< 0.0002	< 0.0002
19-Aug-08	112	0.06		168				7.9	75.9		2	0.78	< 0.0002	
28-Aug-08	82.2			116				7.7	34		3	2	< 0.0002	< 0.0002
2-Sep-08	99.5			138				8	60.1		1	1.3	< 0.0002	
9-Sep-08	85.9							8.1	49.8		3	2.1	< 0.0002	< 0.0002
15-Sep-08	91.9	0.07						7.8			1	0.73	< 0.0002	< 0.0002
16-Sep-08	91.1	0.06		138					66.8		1	0.48	< 0.0002	< 0.0002
18-Sep-08	84	0.036	328	154	0.04	2.7		7.31	69	230	1		0.000029	0.000025
23-Sep-08	89.7	0.06		161				7.8	84.3		< 1	0.66	< 0.0002	< 0.0002
30-Sep-08		0.08		160				7.7	79.8		< 1	0.62	< 0.0002	< 0.0002
7-Oct-08	100	0.07		171	0.05	2.3	2.1	8.2	79.7		3		0.000086	0.000038
14-Oct-08	129	0.08		204				8.1	122		1	1.5		< 0.0002
15-Oct-08	121	0.09		202				7.8	111				< 0.0002	< 0.0002

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8-Jan-08	88.1	0.001	0.4	< 0.001	19.2	1.97	0.004	1.9	< 0.00025	7.46	0.31	0.0024	0.049	0.032
24-Jan-08	110	0.00158	0.366	0.000137	21.8	2.45	0.00415	2	< 0.000005	8.67	0.32	0.00307	0.0498	0.0468
19-Feb-08	120	0.002	0.53	< 0.001	25.6	3.26	0.006	2.5	< 0.00025	10.7	0.4	0.0023	0.052	0.032
20-Feb-08	125	0.00217	0.386	0.000204	26.5	3.36	0.00546	2.41	0.000005	11.3	0.383	0.00379	0.0481	0.0464
11-Mar-08	130	0.00243	0.407	0.000186	27.3	3.57	0.00586	2.42	< 0.000005	11.9	0.387	0.00368	0.0555	0.0554
18-Mar-08	113	0.002	0.39	0.001	28.1	3.27	0.006	2.3	< 0.00025	13.7	0.36	0.0043	0.058	0.029
14-Apr-08	181	0.007	0.77	0.002	40.5	7.38	0.016	3.8	< 0.00025	18.4	0.58	0.0043	0.1	0.046
15-Apr-08	176	0.007	0.72	0.002	40.6	7.32	0.015	3.7	< 0.00025	19.2	0.58	0.0044	0.096	0.083
22-Apr-08	191	0.008	0.42	0.001	32.6	8.13	0.016	3.4	< 0.00025	15.3	0.64	0.0036	0.089	0.04
29-Apr-08	174	0.00638	0.45	0.00193	35.3	6.15	0.014	3.4	< 0.000005	15.6	0.54	0.00346	0.13	0.118
6-May-08	101	0.003	0.53	0.002	21.8	2.46	0.007	3.2	< 0.00025	9.42	0.35	0.0019	0.12	0.069
13-May-08	44.5	0.001	1	0.004	8.23	1.13	0.004	2	< 0.00025	3.42	0.17	0.0008	0.071	0.043
15-May-08	49	0.001	0.65	0.003	9.13	0.99	0.004	2	< 0.00025	3.88	0.16	0.0009	0.059	0.045
20-May-08	23.5	< 0.001	0.75	0.003	5.28	0.34	0.002	1.6	< 0.00025	1.91	0.084	< 0.0005	0.034	0.02
22-May-08	23.8	0.000534	0.592	0.00378	5.08	0.316	0.0021	1.37	0.000009	1.8	0.0874	0.00059	0.0266	0.0211
26-May-08	22.5	0.000862	0.875	0.0069	3.97	0.482	0.0026	1.12	0.000011	1.62	0.0669	0.00055	0.0934	
27-May-08	14.9	< 0.001	0.91	0.006	3.57	0.2	0.002	1.1	< 0.00025	1.49	0.055		0.025	0.009
3-Jun-08	26.2	< 0.001	0.28	0.002	5.49	0.24	0.001	1	< 0.00025	2.33	0.092	0.0006	0.015	0.007
10-Jun-08	29.1	< 0.001	0.31	0.001	7.25	0.51	0.002	0.9	0.0003	2.88	0.093	0.0006	0.025	0.013
16-Jun-08	31.7	< 0.001	0.16	< 0.001	8.56	0.3	0.001	1	< 0.00025	3.39	0.12	0.0008	0.021	0.021
17-Jun-08	30.5	< 0.001	0.19	< 0.001	6.22	0.34	< 0.001	0.9	< 0.00025		0.1	0.0007	0.018	0.009
24-Jun-08	19.4	0.001	1.1	0.005	4.13	0.561	0.0024	0.8	0.000007	1.89	0.0744	0.000661	0.0228	0.0145
1-Jul-08	41.2	0.001	0.24	< 0.001	9.82	1.14	0.004	1.1	< 0.00025	3.84	0.15	0.0009	0.041	0.025
8-Jul-08	35	< 0.001	0.13	< 0.001	7.62	0.64	0.002	0.9	< 0.00025	2.79	0.13	0.0009	0.026	0.014
14-Jul-08	30.3		0.3	< 0.001	6.94	0.46	0.002	0.7	< 0.00025	2.43	0.11	0.0008	0.022	0.14
16-Jul-08	28.1	< 0.001	0.57	0.003	6.08	0.47	0.003	0.9	< 0.00025	2.37	0.1	0.0006	0.031	0.012
22-Jul-08	37	< 0.001	0.24	< 0.001	8.69	0.46	0.002	0.9	< 0.00025	3.04	0.14	0.001	0.022	0.01
30-Jul-08	47.1	0.000879	0.235	0.000458	9.51	0.764	0.0022	1.07	< 0.000005	4.08	0.179	0.00134	0.0246	0.0237
31-Jul-08	41.2	< 0.001	0.23	< 0.001	8.66	0.76	0.002	1	< 0.00025	3.63	0.17	0.0013	0.027	0.017
5-Aug-08	52.2	0.001	0.32			1	0.003	1.3	< 0.00025	4.28	0.18	0.0013	0.033	0.014
11-Aug-08	48.1	0.001	0.37		12.3	1.14	0.003	1.3	< 0.00025	4.34	0.18	0.0015	0.028	0.018
12-Aug-08	48.8	< 0.001		< 0.001	12.2	0.79	0.003	1.3	< 0.00025	4.34	0.19	0.0014	0.032	0.016
19-Aug-08	48	0.001	0.37	< 0.001	11.6	0.97	0.003	1.3	< 0.00025	4.17	0.18	0.0012	0.031	0.016
28-Aug-08	33.8	< 0.001	0.3	< 0.001	7.65	0.38	0.002	0.9	< 0.00025	2.52		0.0008	0.018	0.009
2-Sep-08	41.3	< 0.001	0.21	< 0.001	8.54	0.53	0.002	1.1	< 0.00025	2.9	0.15	0.0009	0.023	0.025
9-Sep-08	34.2	< 0.001	0.17	< 0.001	7.45	0.33	0.002	0.9	< 0.00025	2.79	0.13	0.0008	0.016	0.008
15-Sep-08		< 0.001	0.23	< 0.001	9.05	0.51	0.002	1.1	< 0.00025		0.19	0.0014	0.025	0.013
16-Sep-08	41.3	< 0.001	0.26	< 0.001	8.48	0.49	0.002	1	< 0.00025	3.01	0.18	0.0014	0.023	0.012
18-Sep-08	46.6	0.000633	0.211	0.000506	9.14	0.489	0.00163	1.11	< 0.000005	3.2	0.176	0.00117	0.0249	0.023
23-Sep-08	48.2	< 0.001	0.24	< 0.001	9.86	0.62	0.002	1.1			0.22	0.0015	0.031	0.017
30-Sep-08	49.9		0.21	< 0.001	8.7	0.72	0.002	1.1		2.98	0.19	0.0013	0.036	0.032
7-Oct-08	50.3	0.000715	0.304	0.000586	10.9	0.78	0.002	0.32	0.000005	3.6	0.18	0.0014	0.044	0.0362
14-Oct-08	61.5	0.002	0.25	< 0.001	12.3		0.005	1.3	< 0.00025	4.23	0.22	0.0015	0.059	0.025
15-Oct-08	61.8	0.002	0.24	0.001	11.6		0.004	1.3	< 0.00025	4.05	0.23	0.0015	0.06	0.045

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
21-Oct-08	138	0.07		220				7.8	130		4	2	< 0.0002	< 0.0002
4-Nov-08	105	0.03		158				7.5	51.2		< 1	0.77	< 0.0002	
1-Dec-08	121	0.05		236				7.9	79		< 1	1.4	< 0.0002	< 0.0002
10-Dec-08	130	0.032	613	221	0.15	2.1	1.9		77	320	2		0.000036	
22-Jan-09	160			307	0.17				140	360	3		0.000053	0.000064
2-Feb-09	173	0.09		294				7.7	161		2	2.7	< 0.0002	< 0.0002
25-Feb-09	190	0.152		421	0.17				280		4		0.000096	0.000081
3-Mar-09	170	0.1	588	364		1.7	1.8	8.1	190	470	3		0.000083	0.000081
27-Mar-09	180	0.124	756	368	0.19				210	510	2		0.000069	0.000071
2-Apr-09	200	0.57	1125	709		2.3	2.2			980	7		0.00013	0.000099
8-Apr-09	210	0.39	1276	723		1.5	1	7.4	360	760	5		0.00015	0.00011
16-Apr-09	220	0.4	1368	787		2.1	1.5	7.8	710	1200	4		0.00011	0.00011
23-Apr-09	220	0.34	1378	754		2.5	2.2	7.7	650		2		0.0001	0.000111
29-Apr-09	210	0.18	1352	814			0.9	7.5	710	1100	3			0.00009
7-May-09	35	0.05	170	78.5		15.2	15.3	8.1	45		22		0.000209	0.000085
14-May-09	77	0.09	389	193		10	8.9	7.9	110	270			0.000056	0.000057
21-May-09	53		195	98.4		7.5	7.6	8	51	170	27		0.000083	0.000038
31-May-09	50	0.05	167	80.2		4.7	5.7	8.1	41	160	17		0.000034	0.000018
7-Jun-09	39	< 0.01	137	60.8		4.2	5.6	7.8		90	8		0.000016	0.000019
8-Jun-09	38	0.05	138	63.9		4.6	4.4	7.7	30		6			0.000016
14-Jun-09	68	0.04	241	125		3.1	3.1	7.9	64		3		0.00004	
21-Jun-09	86	0.11	357	175			2.1	7.8		210	2		0.000046	0.000037
28-Jun-09	79	0.07	167	167		3.1	3.1	8.1		240	< 1		0.000043	0.000041
5-Jul-09	89	0.04	329	157		2.6		8.2	77	190			0.00005	0.00003
12-Jul-09	89	0.03	338	160		2.5	2.3	8	88	220	< 1		0.000037	0.000035
13-Jul-09	91	0.06	353	178		2.4	2.3	7.6	89	220	2		0.000053	0.000031
19-Jul-09	100		370	269		1.7	1.8	8	170	380	5		0.000057	
26-Jul-09	110	0.15	520	264		2.4	2.5	7.9	170	390	2		0.000078	0.000077
2-Aug-09	120	0.17	480	266		2.5	2.3	8.1	150	350	< 1		0.00006	0.000065
9-Aug-09	110	0.12	520	273		1.9	2.1	8	160	310			0.000052	0.00005
15-Aug-09	110	0.1	500	259		2.9	2.2	8	150	350	< 4		0.00005	0.000048
23-Aug-09	92	0.06	310	180				8	88	240	< 1		0.000033	0.000028
30-Aug-09	92	0.07	370	196		3.5	2.9	7.9	110	270	2		0.000037	0.000041
2-Sep-09	94	0.09		214		2.7	2.8	7.9	110	290			0.000041	0.000044
3-Sep-09														
6-Sep-09	94	0.17	430	226		2.4	2.3	7.8	120	300			0.000049	0.000043
13-Sep-09	99	0.1	470	247		2.4	2.4		130	360	< 1		0.00006	0.000067
20-Sep-09	95	0.1	470	258			2.5			330	< 1		0.000065	0.000066
24-Sep-09	87	< 0.01		123		3.4	3.4	7.5		150	3		0.000021	0.000022
7-Oct-09	98	0.14	550	280		1.9	2.2	8.04	160	240	< 1		0.00008	0.000072
8-Oct-09			550					7.98						
9-Oct-09			560					8.29						
10-Oct-09			580					7.9						
11-Oct-09			570					7.95						

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
21-Oct-08	65	0.003	0.52	< 0.001	13.9		0.01	1.3	< 0.00025	5	0.24	0.0019	0.076	0.035
4-Nov-08	44.5	< 0.001	0.26	< 0.001		0.49	0.002	1.2	< 0.00025	3.52	0.16	0.0017	0.062	0.036
1-Dec-08	67	< 0.001	0.42	< 0.001	16.6	1.12	0.002	1.5	< 0.00025	5.62	0.24	0.002	0.075	0.058
10-Dec-08	64.8	0.000811	0.339		14.4	1.03	0.00233	1.37	< 0.000005	4.85	0.233	0.00256	0.0624	0.0611
22-Jan-09	92.5	0.0013		0.000276	18.5	2.06	0.00364	1.74	< 0.000005	7.31	0.291	0.00301	0.087	0.0916
2-Feb-09	85.7	0.002	0.66	< 0.001	19.4	2.33	0.005	1.8	< 0.00025	7.12	0.32	0.0029	0.1	0.09
25-Feb-09	125	0.0027	0.632	0.000434	26.1	3.85	0.00636	2.37	< 0.000005	9.9	0.399	0.00362	0.0938	0.0943
3-Mar-09	108	0.00199	0.476	0.000458	23.2	2.75	0.005	2.14	< 0.000005		0.351	0.00338	0.088	0.0837
27-Mar-09	108	0.00205	0.474	0.000208	23.7	2.91	0.00494			8.94	0.354	0.00349		0.066
2-Apr-09	215	0.00909	0.36	0.00067	41.9	7.92	0.0179	4.03	< 0.00003	17.2	0.588	0.00369	0.131	0.109
8-Apr-09	213	0.0143	0.316	0.00034	44.8	10.6	0.0288		< 0.00003		0.614		0.146	0.144
16-Apr-09	215	0.0182	0.452		46.1	12.7	0.0337	3.58	< 0.00003	18.1	0.609	0.00419	0.156	0.162
23-Apr-09	212	0.0191	0.38	0.00094	48.2	13.3	0.0368		< 0.00003	18.3	0.614	0.00418	0.16	0.148
29-Apr-09	222	0.0214	0.416			14.2	0.0371	3.65	< 0.00003	18.5	0.612	0.0036	0.183	0.179
7-May-09	22.2	0.000899		0.012	4.44	0.359	0.00252	1.51	0.000006	1.63	0.0825	0.000575	0.143	0.0703
14-May-09	59.4	0.00126	0.376	0.00134	10.8	1.02	0.00324	1.75	< 0.000005	3.82	0.19	0.00113	0.0506	
21-May-09	29.1	0.00086	1.01	0.00782	6.29	0.455	0.00242	1.17	0.000014		0.106	0.000855	0.0439	0.0253
31-May-09	23.3	0.000368	0.259	0.00157	5.03	0.246	0.00117	0.84	0.000007	1.55	0.0861	0.000665	0.0176	0.0159
7-Jun-09	18.4	0.000307	0.189	0.000892	3.63	0.212	0.00088	0.6	< 0.000005	1.36	0.0688	0.00052	0.0132	0.0119
8-Jun-09	18.9	0.000397	0.195			0.263	0.00111	0.67	< 0.000005	1.54	0.0687	0.000555	0.0182	0.0124
14-Jun-09	36.9	0.000617	0.188		7.96	0.497	0.00143	0.85	< 0.000005	2.48	0.128	0.00103	0.0221	0.0195
21-Jun-09		0.00135	0.222	0.000487	10.9	0.971	0.00268	1.09		3.57		0.00123	0.0375	0.0362
28-Jun-09	46.1	0.00146	0.206	0.000472	11.5		0.00298	1.01	< 0.000005	3.8	0.156	0.00111	0.0379	0.0361
5-Jul-09	47.2	0.001	0.291	0.0006	10.7	0.79	0.002	1.11	< 0.00002	3.33	0.172	0.0012	0.033	0.035
12-Jul-09	47	0.000813	0.264	0.00039	10.2	0.672	0.00178	1.05	< 0.000005	3.41	0.168	0.00119	0.03	0.0334
13-Jul-09	52.1	0.00103	0.298	0.000679	11.7	0.823		1.24		3.9	0.187	0.00138	0.0402	0.0351
19-Jul-09	78.5	0.00262	0.397	0.00127	17.8	1.78	0.0049	1.7	< 0.000005	5.81		0.00163	0.0607	0.0557
26-Jul-09	73.8	0.00223	0.377	0.00188	17.9	1.67	0.00437	1.72	< 0.000005		0.262	0.00174		
2-Aug-09	74.2	0.00198	0.385	0.000953	16.6	1.44	0.00385	1.71	< 0.000005		0.258	0.00195	0.07	0.0418
9-Aug-09	75.8	0.00231	0.377	0.000392	17.4	1.71	0.00451	1.71	< 0.000005		0.258	0.00183	0.0457	0.0438
15-Aug-09	72.9		0.384	0.000439	17.4	1.69	0.00523		< 0.000005	5.8	0.253		0.0483	0.0437
23-Aug-09	52.7	0.00127	0.292	0.000291	11.8	0.992	0.00264	1.2	< 0.000005		0.176	0.00121	0.0327	0.0294
30-Aug-09	51.3	0.00141	0.278	0.000369	12.7	1.01	0.0028	1.26	< 0.000005		0.185	0.0012	0.0407	0.0388
2-Sep-09	57.4	0.00194	0.324	0.000258	14	1.25	0.00344	1.4	< 0.000005	4.71	0.204	0.00135	0.042	
3-Sep-09													0.042	
6-Sep-09	60.1	0.00192		0.00023	14.6	1.29	0.00349	1.45	< 0.000005	4.98	0.21	0.00128	0.0511	0.0452
13-Sep-09	67.8	0.00171	0.319	0.000428	15	1.26	0.0032	1.61	< 0.000005	5.13	0.239	0.00132	0.0577	0.0549
20-Sep-09	72.9	0.00149	0.3	0.000373	15.9	1.14	0.00285	1.65	< 0.000005	5.28	0.25	0.00131	0.0611	0.057
24-Sep-09	35.9	0.000266	0.277	0.000433	8.11	0.322	0.00095	0.84	< 0.000005	2.68	0.137	0.00122	0.0159	0.07
7-Oct-09	78.9	0.00177		0.00025	18.8	1.26	0.0061	1.76	< 0.00003	5.69	0.274	0.00169	0.0836	0.0766
8-Oct-09													0.097	0.075
9-Oct-09													0.094	0.098
10-Oct-09													0.056	0.082
11-Oct-09													0.102	0.036

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
12-Oct-09			380					8.11						
16-Oct-09			460					7.81						
17-Oct-09	110	0.13	610	320		2	2.5	8.35	190	370	7		0.00008	0.000088
18-Oct-09			280					7.7						
19-Oct-09			570					7.87						
20-Oct-09			510					7.81						
21-Oct-09			580					8.32						
22-Oct-09			620					8.06						
23-Oct-09			620					7.46						
24-Oct-09			634					8.2						
25-Oct-09	120	0.11	639	334		1.5	1.3	7.71	230	440	< 1		0.000077	0.000072
26-Oct-09			559					7.9						
27-Oct-09			657					7.93						
28-Oct-09			670					7.91						
29-Oct-09			610					7.52						
30-Oct-09			700					7.89						
31-Oct-09			630					8.05						
1-Nov-09	130	0.15	680	325		2.6	2.4	7.93	200	490	2		0.000091	
4-Nov-09	120	0.03	350	188		2.3	2.5	7.81	70	210	< 1		0.00003	0.000014
1-Dec-09	140	0.06	443	241		1.1	0.8		77	280	< 1		0.00003	0.000019
11-Jan-10	190	0.1	624	379		1.4		6.76		540	2	2.7	0.000054	0.000058
22-Feb-10	190	0.1	720	425		1.3	1.5	6.91	220	580	< 1	3.2	0.00006	0.000062
10-Mar-10		0.1	757	458		1.3	1.2	7.71	240	590	< 1	4.3	0.000073	0.000064
22-Mar-10		0.14	749	498		1.9	1.5	7.49	260		< 1	4.2	0.000075	0.000074
23-Mar-10														
24-Mar-10														
25-Mar-10														
26-Mar-10														
27-Mar-10														
28-Mar-10														
29-Mar-10														
30-Mar-10	200	0.28	1030	591		2.2	2.4	7.37	290	840		3.8	0.000096	0.000081
31-Mar-10														
1-Apr-10														
5-Apr-10														
6-Apr-10	210	0.29	1100	657		1.3	1	7.4	490	880	< 1		0.000095	0.000102
7-Apr-10														
8-Apr-10														
9-Apr-10														
10-Apr-10														
11-Apr-10														
12-Apr-10														
13-Apr-10	200	0.27	1027	588		1.2	1.5	7.85	470	870	< 1	2.5	0.0001	0.000089
14-Apr-10														

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12-Oct-09													0.055	0.89
16-Oct-09													0.071	
17-Oct-09	94.2	0.00195	0.32	0.000587	20.7	1.42	0.00361	2.11	< 0.000005	6.63		0.00182	0.115	0.0845
18-Oct-09													0.12	
19-Oct-09													0.096	
20-Oct-09													0.091	
21-Oct-09													0.101	
22-Oct-09													0.111	
23-Oct-09													0.112	
24-Oct-09													0.125	
25-Oct-09		0.00292	0.369	0.000653	20.2	1.86	0.00501	1.93	< 0.000005	6.55	0.312	0.00192	0.118	0.0915
26-Oct-09													0.089	
27-Oct-09													0.121	
28-Oct-09													0.099	
29-Oct-09													0.09	
30-Oct-09													0.089	
31-Oct-09													0.078	
1-Nov-09	95.9	0.0032	0.301			2.19	0.00567	1.97	< 0.000005	6.87	0.326	0.00209	0.095	0.0904
4-Nov-09	56.6		0.255	0.000403	11.3	0.72		1.22	< 0.000005	3.63	0.201	0.002	0.03	0.0299
1-Dec-09	65.6		0.245	0.000151	13.9	1.06		1.34	< 0.000005	4.71	0.237	0.00244	0.0331	0.0327
11-Jan-10	111	0.00181	0.357	0.00071	24.6	2.66	0.00485		< 0.000005	8.96	0.342	0.00353	0.0431	0.0408
22-Feb-10	124	0.00268	0.404	0.000129	27.8		0.00617	2.24	< 0.000005	9.99	0.386	0.00377	0.022	0.0213
10-Mar-10	136	0.00304	0.466	0.000094	28.6	3.98	0.00661	2.4	< 0.000005		0.4	0.00395	0.0241	0.0237
22-Mar-10		0.00337	0.601	0.000118	28.1	4.15	0.00699	2.31	< 0.000005	10.6	0.39	0.00374	0.0321	0.0345
23-Mar-10													0.055	0.048
24-Mar-10													0.147	0.142
25-Mar-10													0.087	
26-Mar-10													0.099	0.088
27-Mar-10													0.082	0.08
28-Mar-10													0.093	0.085
29-Mar-10													0.091	0.079
30-Mar-10	171	0.00716	0.441	0.000119	38.8	5.92	0.0124	3.14	< 0.000005	14.2	0.509	0.00451	0.101	0.106
31-Mar-10													0.08	0.072
1-Apr-10													0.081	0.073
5-Apr-10													0.06	0.023
6-Apr-10	193	0.00896	0.442	0.000129	41.2	7.24	0.0152			15.1	0.585	0.00446	0.11	0.085
7-Apr-10													0.09	0.082
8-Apr-10													0.09	0.083
9-Apr-10													0.095	0.081
10-Apr-10													0.089	0.09
11-Apr-10													0.064	0.057
12-Apr-10													0.063	0.052
13-Apr-10	180	0.00634	0.432	0.00016	33.8	5.35	0.0104	3.1	0.00006		0.542	0.0042	0.0925	0.0821
14-Apr-10													0.059	0.056

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
15-Apr-10														
20-Apr-10	140	0.26	1914	458		2.5	3.1	7.44	360	620		10	0.000091	0.000073
23-Apr-10														
25-Apr-10														
26-Apr-10														
27-Apr-10	86	0.13	357	175		5.4	5.3	7.3		230	5		0.000057	0.000045
29-Apr-10														
2-May-10														
3-May-10														
4-May-10	90	0.085	506	296		7.9	8.9	7.53	230		2	2.5	0.000058	0.000051
5-May-10														
6-May-10														
7-May-10														
8-May-10														
9-May-10														
10-May-10														
11-May-10	91	0.085	471	240		6.1	5.3	7.65	180	360	4	2.5	0.000045	0.000037
12-May-10														
13-May-10														
14-May-10														
15-May-10														
16-May-10														
17-May-10														
18-May-10	73		360	181		7.4	5	8.02	120	280	4		0.000052	0.000072
19-May-10	64	0.038		127	0.04			7.38	80	190			0.000063	
20-May-10														
21-May-10														
22-May-10														
23-May-10														
25-May-10		< 0.005	243	105		5.3	5.6	8.01	63	180	6	2.6		0.000024
26-May-10														
27-May-10														
1-Jun-10	55	< 0.005	345	141			2.7	8.14	99	230	2		0.000038	
8-Jun-10	70	0.018	380	177		3.1	2.7	7.93	130	250	< 1		0.000045	0.000089
15-Jun-10		0.06	420	211		3.1	2.7	7.87	160	330	< 1	0.7	0.000038	0.00004
22-Jun-10	81	0.02	438	210			2.3	7.75	150	310	< 1	1.1	0.000045	0.000033
24-Jun-10														
29-Jun-10	84	0.1	501	258		2.3		7.35	180	370	< 1	0.9	0.000036	0.000032
6-Jul-10	67	0.058	395	184		3.5	3.7	8.01	130	250	< 1		0.000031	0.000026
13-Jul-10	80	0.058	456	250		2.3	2.4	8.19	170	340	< 1		0.000034	0.000038
20-Jul-10	96	0.15	563	279		2	2.7	7.76	180	410			0.000043	0.000046
27-Jul-10	97	0.16	606	322		3	1.9	8.11	250	430	2	1.3		0.000083
3-Aug-10	110	0.012	338	152	< 0.02	1.8	4.3	7.99	57	210	2	0.8	0.000027	0.000069
10-Aug-10	100	0.19	658	329		2.2	2.3	7.92	220	440	< 4	1.4	0.000064	0.000049

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
15-Apr-10													0.064	
20-Apr-10	140	0.00582	0.731	0.0041	26.2	4.2	0.0101	2.71	< 0.000005	9.96		0.00296	0.0738	0.062
23-Apr-10													0.056	
25-Apr-10													0.058	0.025
26-Apr-10													0.035	0.026
27-Apr-10	52.9	0.000939	0.567	0.00158	10.4	0.88	0.00239		< 0.000005	4.02	0.185		0.0427	0.0308
29-Apr-10													0.036	
2-May-10													0.051	0.028
3-May-10													0.047	0.053
4-May-10	91.9	0.00354	0.388	0.00114	16.1	2.44	0.00666	2.25	< 0.000005	5.93	0.274	0.00146	0.066	0.0575
5-May-10													0.064	0.057
6-May-10													0.085	0.062
7-May-10													0.058	0.047
8-May-10													0.06	0.052
9-May-10													0.065	0.041
10-May-10													0.059	0.049
11-May-10	70.8	0.00244	0.469	0.00133	14.5	1.71	0.00464	1.7	< 0.000005	4.79	0.241	0.00142	0.0454	0.0423
12-May-10													0.059	0.044
13-May-10													0.051	0.04
14-May-10													0.052	0.042
15-May-10													0.054	0.034
16-May-10													0.043	0.033
17-May-10													0.04	0.029
18-May-10	52.5		0.406	0.00191	11.5	1.32	0.00416		< 0.000005	3.73	0.188		0.0385	0.027
19-May-10	37.4	0.0015	0.991	0.00481	8.24	0.891	0.00329	1.16	< 0.000005	2.65	0.127	0.000867	0.0398	0.019
20-May-10													0.038	0.013
21-May-10													0.026	0.016
22-May-10													0.022	0.019
23-May-10													0.026	0.016
25-May-10	30.7	0.0009	0.375		6.97	0.583	0.00243	0.96	< 0.000005	2.44	0.107	0.000722	0.0226	0.0216
26-May-10													0.024	0.018
27-May-10													0.028	0.015
1-Jun-10	41.1	0.00157	0.233	0.00106	9.29			1.03	< 0.000005	3.81	0.133	0.000765	0.0426	0.0308
8-Jun-10	50.7	0.00215	0.215	0.000512	12.3	1.39	0.00372	1.12	< 0.000005	4	0.166	0.000996	0.0399	0.0359
15-Jun-10	59.7		0.245	0.000532	14.6	1.74	0.00441	1.39	< 0.000005	4.56	0.207		0.0484	0.046
22-Jun-10	59.3	0.00261	0.29	0.000469	15.1	1.59	0.00448	1.41		4.83	0.204	0.00104	0.0455	0.0436
24-Jun-10														0.065
29-Jun-10	71.2	0.00322	0.274	0.000369	17.1	1.86	0.00506		< 0.000005		0.236		0.0493	0.0459
6-Jul-10		0.00206	0.277	0.000544	12.1	1.29	0.00323	1.13		4	0.171	0.000821	0.048	0.0301
13-Jul-10	72		0.308	0.000644	16.9	1.76		1.59	< 0.000005	5.54	0.248		0.0429	0.0422
20-Jul-10		0.00399	0.327	0.000499	19.2	2.35	0.00583	1.85	< 0.000005	6.29		0.00125	0.0583	0.0565
27-Jul-10	94.1		0.382		21	2.33	0.00629	2.04	< 0.000005	6.59	0.316	0.00135	0.0726	0.0721
3-Aug-10	44.7	0.000409	0.369	0.000583	9.88	0.624	0.00139	1.02	< 0.000005	3.42	0.172	0.00155	0.019	0.0451
10-Aug-10	96.7	0.00345	0.428	0.00123	21.3	2.12	0.00552	2.15	< 0.000005	6.97	0.329	0.00152	0.0614	0.0576

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
17-Aug-10	110	0.35	614	333		2.4	2	7.92	270	460			0.000047	0.00006
24-Aug-10	94	0.07	423	249		2.5	2.5	8.67	160		< 1		0.00004	
31-Aug-10	100	0.11	650	314		3.7	3.7	7.96	220	420			0.000055	0.000029
7-Sep-10	99	0.29	532		0.06	2.7	2.6	8.27	170	340	< 1		0.000033	0.000039
21-Oct-10	130	0.11	426	228	0.11	2.3	1.7	7.8	110	290		1.8	0.000035	0.000046
3-Nov-10	130	0.022	235.4	203	0.12			7.83	95	260	< 4		0.000042	0.000029
9-Nov-10	140	0.078	500	234	0.14	1.1	1.9	7.89	120	330	< 4	1.62	0.000044	0.000042
17-Nov-10														
18-Nov-10	170	0.2	1010	641		1.7	1.3	7.75	420	800	6	3.18	0.000115	0.00009
19-Nov-10														
20-Nov-10														
21-Nov-10														
22-Nov-10														
23-Nov-10														
24-Nov-10														
25-Nov-10	170	0.16	1008	546	0.15	1.9	2	8.21	390	780	< 4	2.5	0.00007	0.00007
26-Nov-10														
27-Nov-10														
28-Nov-10														
29-Nov-10														
30-Nov-10														
1-Dec-10														
2-Dec-10	170		1000	544	0.16	1.8	1.8	7.7	380	690	< 1	2.21		0.00005
18-Jan-11	170		719	385	0.22	1.6	1.3	7.35	190	500	2	< 0.25	0.000066	0.00006
1-Feb-11	170	0.048	150	394	0.16	1.5	1.3	7.97	190	460	< 1	2.81	0.000058	0.000066
14-Mar-11	200	0.14	590	589	0.2	1.4	1.3	7.16	350		< 1	0.42	0.00011	0.000118
24-Mar-11	240		1435	902	0.21	1.4	1.5	7.69		1300	5	2.49	0.00013	
29-Mar-11	220	0.33	1410	784	0.22	2	1.6	7.69	550			5.08	0.00013	0.00011
5-Apr-11	220	0.31	1471	749	0.19	1.8	1.4	7.58	580	1100		2.19	0.00013	0.00014
12-Apr-11	220	0.32	1430	810	0.18	1.7	1.3	7.36	580	1100	2	2.03	0.00012	0.0001
19-Apr-11	220	0.29	1323	853	0.16	1.3	1.3	7.49	580	1100	< 1	3.16		0.00006
26-Apr-11	210	0.26	1303	694	0.15	1.8	1.8	7.4	530	1000	2	2.43		
3-May-11	240	0.42	1935	1110	0.11	2	2.3	6.99	940	1600	4		0.00015	0.0001
4-May-11	160	0.25	1134	552	0.16	1.8	1.6	7.49	430	820	2	1.88	0.000109	0.000097
10-May-11		0.28	1043	499	0.16		4.4	7.95	380	710	3	1.84	0.000119	0.000108
17-May-11	77	0.072	456	215	0.13	14.6		7.73	150	290	11	3.29		0.000079
18-May-11	41	0.061		84.3	0.05	19.6	19	7.36	46	130	55	3.99	0.00019	0.000057
24-May-11	25		117	43.5	< 0.02	12.5	13.1	8.07	19	62	22		0.000085	0.00004
31-May-11	32	0.076	133	57.9	< 0.02	5.1		8.8	31	100	9	3.29	0.000042	0.000036
7-Jun-11		0.063	280	116	0.04	3.3	3.1	7.63	72	170	2	1.15	0.00012	0.000024
14-Jun-11	65	0.037	256	139	0.03	3.9	4.5	7.91	78	200	< 1	0.61	0.000021	
21-Jun-11	58	0.055	220	93.7	< 0.02	4.1	4.2	7.5	55	72	8		0.000036	0.000036
28-Jun-11	65		260	120	0.03	3.9	3.8	8.18		160	2	0.93	0.000024	0.00003
5-Jul-11	77	0.078	273	143	0.03	3.9	4.6	7.97	68	200	2	1.39	0.000032	0.000036

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
17-Aug-10	89.7	0.00269	0.392		20.2	1.8	0.00444	2.06	< 0.000005	6.55	0.315	0.00138	0.052	0.0517
24-Aug-10	73.1	0.00211	0.4	0.00054	16.2	1.38	0.00344	1.63	< 0.000005	5.53		0.00125	0.0424	0.0399
31-Aug-10	86	0.00276	0.441	0.000573	19.7	1.84	0.00423	2.06	< 0.000005	6.08	0.314	0.00119	0.0496	0.042
7-Sep-10	65.2	0.00218	0.369	0.000376	15.4	1.47	0.00358	1.52	< 0.000005	5.1	0.259	0.00146	0.0411	0.0378
21-Oct-10	67.3	0.00091	0.418	0.000282	14.5	1.39	0.00245	1.3	< 0.000005	4.67	0.24	0.00239	0.0239	0.0239
3-Nov-10	59.1	0.0009	0.306	0.000179	13.4	1.2	0.00248	1.24	< 0.000005	4.43	0.224	0.00224	0.0347	0.0306
9-Nov-10	68.8	0.00105	0.305	0.000301	14.6	1.49		1.35	< 0.000005	4.69	0.254		0.036	0.0382
17-Nov-10													0.118	0.107
18-Nov-10	174	0.0134	1.02	0.000978	39.8	8.78	0.0195	3.18	< 0.000005	12.7	0.516	0.00315	0.135	0.123
19-Nov-10													0.109	0.107
20-Nov-10													0.109	0.105
21-Nov-10													0.104	
22-Nov-10													0.104	0.089
23-Nov-10													0.101	0.096
24-Nov-10													0.1	0.092
25-Nov-10	143		0.373	0.00026	33.1	8.45		2.6	< 0.00003	10.3	0.464		0.13	0.119
26-Nov-10													0.093	0.091
27-Nov-10													0.089	0.078
28-Nov-10													0.088	0.086
29-Nov-10													0.091	0.086
30-Nov-10													0.09	0.083
1-Dec-10													0.085	0.084
2-Dec-10	154	0.0138	0.384		33		0.0181	2.5	< 0.00003		0.468	0.00285	0.108	0.114
18-Jan-11	98.7	0.00206	0.386	0.000197	23.1	2.99	0.00536	1.96	0.000037	7.63	0.34	0.00352	0.0296	0.035
1-Feb-11	118	0.00217	0.412	0.000229	24.4	3.1	0.00517	2.12	< 0.000005	8.16	0.36	0.00349	0.0256	0.0266
14-Mar-11	168	0.00456	0.612	0.000107	39.1	6.05	0.0107	3.08	< 0.000005	13.4	0.497	0.00447	0.0259	0.026
24-Mar-11	242		0.809	0.00078	55.3	14.4		3.7	< 0.00003	17.9	0.708	0.00485	0.125	0.132
29-Mar-11		0.0127	0.514	0.00035	52.1	9.89	0.0209	4.2	< 0.00003	17.1	0.669	0.00524		0.106
5-Apr-11	220	0.0159	0.415	0.00033	48.5	10.3	0.023		< 0.00003	16	0.64	0.00491	0.109	0.115
12-Apr-11	217	0.0183	0.41	0.00021	47.8	11.1	0.0251	3.6	< 0.00003		0.611	0.00459		0.11
19-Apr-11	246			0.00012		12.2	0.0268	3.9	< 0.00003	17.3	0.666	0.00461	0.107	0.108
26-Apr-11	213	0.0179	0.474			11.3	0.0237	3.7	< 0.00003	14.8	0.587	0.00415	0.0975	0.105
3-May-11	322	0.0504	0.983	0.00103	70.6	25.5	0.0562		< 0.00003	21.6	0.867		0.189	0.177
4-May-11		0.00946	0.454	0.00126	34.7	6.12	0.0129	3.38	< 0.000005	11.5		0.0031	0.0628	0.065
10-May-11	155	0.0069		0.00077	34.3	4.41	0.00992	4.16	< 0.000005	10.9	0.496	0.00231	0.0997	0.0907
17-May-11	57.4	0.00283		0.00304	13.4	1.58	0.00468	2.28	0.000006		0.191	0.0011	0.0625	0.0516
18-May-11	24.4	0.00272	3.84	0.0144	5.7	1.05	0.0055	1.9	0.000036	1.7	0.0935	0.000706	0.081	0.0276
24-May-11		0.000705	0.605	0.00619	2.72	0.315	0.00181	1.1	0.000011	0.95	0.0468	0.000481	0.0226	
31-May-11		0.00052	0.261	0.00307	3.99	0.289	0.00141	0.72	0.000007	1.34	0.064	0.000491	0.0138	0.0108
7-Jun-11	33.4	0.00138	0.174	0.00685	7.72	0.842	0.00222	1.72	< 0.000005	2.32	0.121	0.000822	0.074	0.0194
14-Jun-11	36.7	0.0012	0.173	0.000437	9.06	0.754		0.86	< 0.000005	2.5	0.13	0.000943	0.0186	0.0202
21-Jun-11	25.7	0.0011	0.222	0.00123	6.65	0.62	0.00178	0.61	< 0.000005	2	0.0962	0.000714	0.0137	
28-Jun-11	32.4	0.000902	0.208	0.000996	9.42	0.601	0.00166	0.84	< 0.000005		0.121		0.0194	0.0182
5-Jul-11	38.7		0.226	0.00144		0.701	0.00193	0.81	< 0.000005	2.65	0.142	0.00103	0.0206	0.0242

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
12-Jul-11	82	0.09	292	161	0.03	4.6	4.6			250	< 1	0.77	0.000025	
19-Jul-11	82	0.077	335	161	0.03	4.1	3.8	7.85	91	230		0.87	0.000021	0.000029
26-Jul-11	88	0.073	375	183	0.04	2.9	3.6	8.06	110		< 1	0.82	0.00004	0.000038
2-Aug-11	87			194	0.04	3.3	3.2	9	110	240	< 1	1.13	0.000042	0.000047
9-Aug-11	95	0.099	351	201	0.04	2.7	2.4	7.82		300	< 1	0.97	0.00004	0.000031
16-Aug-11		0.094	341	179	0.04		3.6	8.27	95	300	< 1		0.000019	0.000026
23-Aug-11	82	0.095	346	163	0.03	4.4		7.97	98	230		0.68	0.000022	0.000021
25-Aug-11	85	0.073		173		2.9	3.8	7.71	98	260	2	0.63	0.000013	0.000015
30-Aug-11	91	0.067	390	202			3	8.03		290	< 4	0.71	0.000022	0.000016
6-Sep-11	99	0.076	422	236	0.06	3.3	3.6	7.85		350	< 1	0.91		0.000034
13-Sep-11	97	0.067	438	217	0.05	2.7	3.9	7.91	130		< 1	0.75	0.000029	0.000027
20-Sep-11	100	0.11	570	248	0.06	2.4	2.5	7.96	150	360	2			0.000029
27-Sep-11			525	244	0.06	2.3	2.9	7.58	170	390	< 1	1.16	0.00003	0.000035
25-Oct-11	120	0.032	445	195	0.1	2	1.8	7.55	70.8	230	< 1		0.000031	0.000033
23-Nov-11	168	0.23	998	525	0.184	< 5	< 5		349	750	5	1.74	0.000106	0.00009
29-Nov-11	177	0.28		601	0.142	1.37	1.75	7.37		882	2.1	1.81	0.0001	0.00008
8-Dec-11	179	0.4	1118	625	0.146	1.43	1.76	7.39	494	928	< 4	3.39		0.000065
18-Jan-12	145	0.12	240	292	0.193		3.4	7.59	160	372	1.3	2.44	0.000062	0.000049
2-Feb-12	165	0.1	681	342	0.213	1.83	2.01		191	440	1.3	1.71	0.000063	0.000069
5-Mar-12	183		771	440	0.226	1.87	1.08	7.9	241	566	2.2	5.55	0.000106	0.000092
19-Apr-12			1190					7.85				2.77		
24-Apr-12			1238					7.51				3.6		
1-May-12	184	0.28	1250	625	0.119	7.35		7.46	461		5.3		0.000098	0.000085
8-May-12	132	0.22		415		4.52	3.85	7.73	280	562	3.6		0.000078	0.000068
9-May-12	126	0.146		382	0.117				262	523		5.07	0.000072	0.000068
15-May-12	107	0.11	595	290	0.094	6.02		7.67	225	406	2.2		0.00006	0.0000847
22-May-12	73.4	0.054	488	150	0.063		9.45		91	228	22		0.0000765	0.0000345
28-May-12	47.9	0.039		72.3	0.0309		9.1		29.2	120	7.6		0.0000424	0.0000314
29-May-12	45.4	0.037	163	79.1	0.033	7.36		7.82		108	6.3		0.0000378	0.000025
30-May-12	48	0.0122		77.5		9.99				113	6.7		0.000031	< 0.000044
5-Jun-12	38.6	0.015	187	63.1	0.032	5.1	5.96	7.75	29.4	103	17.6	7.12	0.0000568	0.0000252
12-Jun-12	36.4		117	59.6		5.27	6.07	7.85	24.6	74	17.6		0.0000334	0.0000207
19-Jun-12	49.5	0.038	205	88.4	0.026	3.74	3.87	8.12		130	2.9		0.0000243	0.0000258
26-Jun-12	63.1	0.053	313	120	0.03	3.16	3.01	8.47	66.9	182	4.3		0.0000412	0.0000241
3-Jul-12	59.1	0.016	217	96.1	0.028	6.01	5.98		40.1	118	7		0.0000322	0.0000175
10-Jul-12	80.4	0.049	344	161	0.041			7.99	77.4	190	3.2		0.0000401	0.0000246
17-Jul-12	72.8	0.051	317	133	0.031	3.56	3.98	7.64	80.6	170	2.6	0.09	0.0000224	0.0000249
24-Jul-12	83.9	0.05	280	188	0.042	3.41	3.79	7.65	103	258	2.2	1.14	0.000036	0.0000338
26-Jul-12	93.1	0.0491		200	0.0392				110	271		1.49	0.000031	0.000026
31-Jul-12	90	0.067	510	242	0.054	3.2	2.97	7.97	135	302	1.1		0.000059	0.000054
7-Aug-12	99.8	0.086	500	258	0.058	2.61	2.92	7.66	161			1.47	0.000045	0.000186
9-Aug-12	109	0.0633		241	0.0516				140	297	< 3	1.54	0.000042	
14-Aug-12	89.4	0.064		207		4.05	3.77	8.41	121	292	1.5	1	0.000032	
21-Aug-12	98.4	0.082	535	249	0.051	2.64	3.43	8.14	149	338	1.7	1.58		0.00005

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12-Jul-11		0.000986		0.000394	10.4	0.687	0.00169	0.9	< 0.000005	2.82	0.158	0.000975	0.019	0.0214
19-Jul-11	44.3	0.00114	0.253	0.000736	11.4	0.779	0.0019	1.01	< 0.000005	3.13	0.173	0.00101	0.0223	0.0254
26-Jul-11	49.7	0.00136	0.291	0.000541	14.3	0.864	0.00223	1.19	< 0.000005	3.7	0.191	0.00112	0.0356	0.0276
2-Aug-11	55.2	0.00143	0.305	0.0011	13.5	0.954	0.00222	1.18	< 0.000005		0.2	0.0012	0.0351	0.0347
9-Aug-11	56.1	0.00163	0.315	0.000488	14.8	1.06	0.00233	1.36	0.000006	3.95	0.238	0.0014	0.0276	0.0254
16-Aug-11	50.8	0.000867		0.000289	12.6	0.667	0.00165	1.13	< 0.000005	3.56	0.186	0.00106	0.0161	0.0138
23-Aug-11	46.3	0.00136	0.233		11.5	0.846	0.002	1.01	< 0.000005	3.07	0.18	0.0011	0.0166	0.0176
25-Aug-11	49.3	0.00145	0.242	0.000732	12.2		0.00216		< 0.000005	3.28	0.187	0.00109	0.0166	0.0174
30-Aug-11	54.6	0.00138	0.29	0.000493	13.4	0.968	0.00212	1.17	< 0.000005	3.61	0.206	0.00124	0.0182	0.0183
6-Sep-11	66	0.00212	0.323			1.38	0.00286	1.41	< 0.000005	4.3	0.243	0.00145	0.0236	0.0245
13-Sep-11	61.2	0.00189	0.293	0.000892	15.5	1.18	0.00263	1.37	< 0.000005	3.98	0.224	0.00144	0.0211	0.0199
20-Sep-11	65.6		0.349	0.000731		1.51		1.51	< 0.000005	4.34	0.243	0.00161	0.0247	0.024
27-Sep-11	69.6			0.000216	16.2	2.63	0.00522	1.37	0.000013	4.45	0.239	0.00163	0.0296	0.0314
25-Oct-11	56.9		0.451	0.000687	12.8	0.861		1.17	< 0.000005	3.95	0.204	0.00209	0.0263	0.0246
23-Nov-11	184	0.0148		0.000864	38.8	7.94	0.0158	2.99	< 0.000005	11.8	0.486	0.00322	0.0861	0.0906
29-Nov-11	168	0.0197	0.501	0.00038	39.6	10.6	0.0203	3.1	< 0.00003	11.7	0.524	0.00333	0.102	0.0926
8-Dec-11	181	0.0227	0.709	0.000276	42.1	12		3.11	< 0.000005	12.7	0.579	0.00351	0.146	0.0885
18-Jan-12		0.00163	0.457	0.00053	18.8	2.25	0.00408	1.77	< 0.000005	6.17	0.291	0.00305		0.0325
2-Feb-12	102	0.00188	0.472	0.000138	21.2	2.84	0.00487	1.94	< 0.000005	6.83	0.323	0.00283	0.0281	0.0289
5-Mar-12	126		0.71	0.00144	29.6			2.46	< 0.000005	9.47	0.389	0.00349	0.0322	0.0288
19-Apr-12														
24-Apr-12														
1-May-12	170	0.0214	1.67	0.000418	42.8	11.8	0.021		< 0.000025	13.2		0.00365	0.0768	0.0792
8-May-12	125	0.00951	1.42	0.00133	24.7	5.31	0.00957	2.59		7.83	0.409	0.00265	0.0534	0.0509
9-May-12	113	0.00846	1.34	0.00184	21.9		0.0086	2.3	< 0.00002	6.6		0.00219	0.0615	0.055
15-May-12	87.9	0.00448	0.916		17.1	2.89	0.0113	2.1	< 0.000005	5.35	0.306	0.0017	0.0441	0.0613
22-May-12	45.9	0.00238	1.71	0.00352	8.6	1.31		1.55		2.73	0.161	0.00108		0.017
28-May-12	21.6	0.000363	0.426	0.00138	4.45	0.22	0.00137	1.11	0.0000085		0.0888	0.000569	0.0101	0.013
29-May-12	24.2	0.000318	0.379	0.00162	4.47	0.219		1.12		1.36	0.0892	0.000605	0.0106	0.00834
30-May-12	23.4	0.00039	0.582	0.00201	5.13	0.209	0.00155	0.947	0.000015	1.33	0.0895	0.00062	0.0121	< 0.0318
5-Jun-12	18	0.00065	0.745	0.00455	3.81	0.307	0.00197	0.889	0.0000132	1.47	0.0719	0.00056	0.0154	0.0129
12-Jun-12	17	0.000523	0.29	0.00254	3.61	0.277	0.00136	0.658	0.0000068	1.36		0.000484	0.0132	0.00849
19-Jun-12	26.4	0.00072	0.201	0.00114		0.464	0.00129	0.796	< 0.000005	1.83		0.000593	0.0127	0.0165
26-Jun-12	33.3	0.00117	0.295	0.00273	7.46	0.715	0.00184	0.868	0.0000074	2.44	0.136	0.000871	0.0199	
3-Jul-12	28.5	0.000718	0.32	0.00212	6.04	0.459	0.0015	0.67	0.0000085	1.81	0.11	0.000586	0.0125	0.00963
10-Jul-12	47.7	0.00119	0.294	0.00101	10.2	0.784		0.999	< 0.000005	2.79	0.159		0.0208	0.0197
17-Jul-12	38.3	0.00119	0.217	0.000553	9.04	0.759	0.00172	0.816	< 0.000005	2.58	0.147	0.000983	0.0161	
24-Jul-12	54	0.0019	0.295	0.00043		1.27	0.00223	1.16	< 0.000005	3.61		0.00114	0.0237	0.0235
26-Jul-12	56.9	0.0017	0.336		14.2	1.09	0.0021	< 2	< 0.00002	3.5		0.00119	0.0265	0.0243
31-Jul-12	69.9	0.00237	0.411	0.00116	16.2		0.00272	1.44	< 0.000005	4.33	0.243	0.00141	0.0364	0.0408
7-Aug-12	72	0.00312	0.448	0.00088	18	1.85	0.00317	1.65	< 0.000005	4.7	0.267	0.00145	0.0343	0.178
9-Aug-12	69.6	0.00225	0.426	< 0.0005	17.3	1.32	0.0024	< 2		4.3				0.0303
14-Aug-12	56.6	0.00203	0.38	0.000386	14.3	1.22	0.00228	1.28	< 0.000005	3.88	0.207	0.00112	0.0323	0.0311
21-Aug-12	71.3	0.00357	0.524	0.000333	17.1		0.00358	1.6	< 0.000005	4.69	0.263	0.00145	0.0387	0.035

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
28-Aug-12	103	0.092	485	241	0.051	4.3	4.09	8.45	142	346	1.4	7.65	0.000034	0.000054
4-Sep-12	97.1	0.071		261	0.06	1.48	3.06	8.3	166	356	< 1	1.66	0.000037	0.000035
13-Sep-12	95.7	0.0615	463	223	0.0463	3.3	3.02		135		1.4	1.22	0.000036	0.000034
18-Sep-12	97.1	0.078		241	0.055			8.64		360	1.7	1.45	0.000037	0.000039
20-Sep-12	105	0.058		271	0.0514	3			160	336	1.4	-4.5	0.000037	0.000029
25-Sep-12	94.5	0.034	284	149	0.041	2.64	2.65	8.06	59.9	184	< 1	0.78	0.000022	0.000018
10-Oct-12	98.7	0.026	296	141	0.052	2.57	3.06	7.66	57.4		< 1	0.85	0.000047	0.000042
24-Oct-12	129	0.04			0.0928		2.57		87	288	< 1	1.52		
8-Nov-12	126	0.046	483	205	0.137	1.64	1.35	7.37	90.8	266	< 1	1.77	0.000051	0.000051
4-Dec-12		0.13	568	295	0.114	1.18	1.38	7.66	150	368	< 1	2.24	0.000063	0.000059
n	186	179	155	191	88	135	135	193	176	141	175	115	179	143
minimum	<0.5	<0.005	117	43.5	<0.02	0.8	0.8	6.36	19	62	<1	0.09	0.000013	0.000014
maximum	240	0.57	1935	1110	0.226	19.6	19	9	940	1600	55	12	0.000209	0.000186
median	97	0.078	500	217	0.06	2.6	2.6	7.89	130	310	2	1.80	0.0000600	0.000046
mean [a]	110	0.11	582	282	0.09	3.5	3.4	7.84	179	399	4	2.39	0.0000679	0.000054
standard deviation (SD) [a]	53	0.10	360	199	0.07	2.9	2.7	0.35	159	281	7	2.15	0.0000350	0.000029
max detection limit	0.5	0.01	-	-	0.02	5	5	-	-	-	4	0.25	0.0002	0.000044
# < detection limit	2	4	-	-	4	1	1	-	-	-	62	1	35	1
% < detection limit	1%	2%	-	-	5%	1%	1%	-	-	-	35%	1%	20%	1%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	23%	72%	83%	72%	9%	1%	1%	5%	99%	84%	4%	40%	28%	29%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	1	1	1	1	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	429	-	25	4.23	0.00030	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	28	-	-	0	1	0	0	18	-	4	14	0	-
% > current water quality criterion	-	16%	-	-	0%	1%	0%	0%	10%	-	2%	12%	0%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	1%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.40: Water quality data and summary statistics for mine exposed station X14, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
28-Aug-12	70.9	0.00588	0.826	0.000259	16.6	3.01	0.00336	1.48	0.000006	4.52	0.245	0.00146	0.0355	0.0294
4-Sep-12	67.8	0.00312	0.483	0.000334	17.6	1.76	0.0032	1.52	< 0.000005	4.86	0.258	0.00131	0.044	0.0426
13-Sep-12	71	0.00289	0.379	0.000395	16.8	1.71	0.003	1.26	< 0.000005	4.4	0.224	0.00138	0.0428	0.0396
18-Sep-12	69.4	0.00344	0.405	0.000762	16.5	1.98	0.00318	1.43	< 0.000005	4.47	0.266	0.00133	0.0432	0.0404
20-Sep-12	76.1	0.00328	0.403	0.000192	16.1	1.89	0.00315	1.28	< 0.00001	4.14	0.247	0.00139	0.0396	0.036
25-Sep-12	41.7	0.000828	0.326	0.00134		0.677	0.00142	0.903	< 0.000005	2.9	0.168	0.00124	0.0218	0.0199
10-Oct-12	41.1	0.000492	0.379	0.000216	9.44	0.64	0.00144	0.956	< 0.000005	2.91	0.158	0.0015	0.0229	0.0216
24-Oct-12														
8-Nov-12	60.5	0.00103	0.457	0.000416	13	1.31	0.00292	1.34	< 0.000005	3.89		0.00223	0.0589	0.0432
4-Dec-12	87.1	0.00191	0.55	0.000807	18.9	2.42	0.00513	1.66	< 0.000005	5.88	0.288		0.0357	0.0345
n	183	178	183	178	182	183	179	182	148	175	179	180	263	243
minimum	14.9	0.000266	0.13	0.000094	2.72	0.2	0.00088	0.32	<0.000005	0.95	0.0468	0.000481	0.0101	0.007
maximum	322	0.0504	3.84	0.0144	70.6	25.5	0.0562	4.2	0.0003	21.6	0.867	0.00524	0.189	0.89
median	61.2	0.00171	0.38	0.000775	14.5	1.27	0.0032	1.38	<0.000005	4.34	0.224	0.00140	0.049	0.040
mean [a]	80.4	0.00355	0.45	0.00121	17.6	2.63	0.0060	1.66	0.000008	6.04	0.265	0.00187	0.058	0.053
standard deviation (SD) [a]	56.9	0.00582	0.36	0.00186	12.0	3.59	0.0077	0.84	0.000025	4.53	0.161	0.00121	0.036	0.064
max detection limit	-	0.001	-	0.001	-	-	0.001	2	0.00003	-	-	0.0005	-	0.0318
# < detection limit	-	19	-	24	-	-	1	2	124	-	-	1	-	1
% < detection limit	-	11%	-	13%	-	-	1%	1%	84%	-	-	1%	-	0%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	73%	100%	26%	12%	66%	100%	97%	49%	14%	74%	68%	26%	97%	86%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.6	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	55	8	3	-	74	0	0	1	-	-	0	191	-
% > current water quality criterion	-	31%	4%	2%	-	40%	0%	0%	1%	-	-	0%	73%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.41: Water quality data and summary statistics for mine exposed station R4, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
23-Jan-08	140	< 0.005		261	0.28	1.1	1.2		97.5	320	< 1		0.000011	0.000009
20-Feb-08	160	< 0.005	601	262	0.27	1.6	1.4	7.4	125	340	< 1		0.000007	0.000006
4-Mar-08	159	< 0.01		300				7.7	132		< 1	0.2	< 0.0002	
13-Mar-08	150	< 0.005	435	276	0.28	1.2	1.2	6.43	142	360	< 1		0.000025	0.000025
28-Apr-08	140		847	400	0.3	1.7	1.7	7.28	270		< 1		0.000057	0.000052
21-May-08	40	< 0.005	162.5	78	0.05	12.6	12.8	7.34	34	130	22		0.000046	0.000046
24-Jun-08			140.8	60.6	0.03	6.5	6.6	7.18	26	100	71		0.000139	0.00038
22-Jul-08	72	< 0.01		110					41		5		0.000026	0.000021
29-Jul-08	89	0.006	287	136	0.08	3.8	3.8	8.14	50	180	2		0.000022	0.000027
19-Aug-08	113	0.02		142				7.7	54.6		< 1	0.45	< 0.0002	< 0.0002
4-Sep-08	81	0.03		135					44		4		0.00003	0.000025
17-Sep-08	86	0.015	294	133			3.7	7.42			2		0.000032	0.000016
8-Oct-08	100	< 0.005		142	0.09	1.4	1.4		52	250	1		0.000036	0.000034
10-Dec-08	130	0.026	456	190	0.19		1.7	7.42	54	290	1			0.000018
22-Jan-09	140	0.035		229	0.2				85	270	< 1		0.000014	0.000019
24-Feb-09	150	0.012		155	0.21				24	180	1		0.00004	0.000259
26-Mar-09	150	0.055	526	256				7.2	120	320			0.000014	0.000018
20-May-09	69	0.006	748	129	0.07			7.44	69	180	9		0.000055	0.000061
23-Jun-09	89	0.005	814	133	0.08			8.19	56		4		0.000031	0.000128
30-Jul-09	110	0.006	411	213	0.06			8.3		270	< 1		0.000033	0.000039
25-Aug-09		< 0.005	315	156	0.07			8.24	66	200	4			0.000084
30-Sep-09	93	< 0.005	300	120	0.07			7.9	35	160	< 1		0.000038	0.000036
28-Oct-09	120	0.054		230	0.16				120	300	< 1		0.000048	0.000053
24-Nov-09	130		7.9	183	0.19			8.12	59	270	< 1		0.000013	0.000012
19-May-11	37	0.033			0.06	21.3	23.1	7.44	32	110	33	5.97	0.000156	0.000044
29-May-12	51.1			76.5			8.89		28.2	122	9.1	3.97		0.0000255
29-Aug-12				176									0.000032	0.000023
23-Oct-12	133	0.018			0.152				63.4	244		0.51		
n	25	23	15	26	20	9	12	18	25	20	25	5	22	26
minimum	37	<0.005	7.9	60.6	0.03	1.1	1.2	6.43	24	100	<1	0.2	0.000007	0.000006
maximum	160	0.055	847	400	0.3	21.3	23.1	8.3	270	360	71	5.97	0.000156	0.00038
median	113	<0.010	411	156	0.12	1.7	2.7	7.44	56	247	<1	0.51	0.0000320	0.000031
mean [a]	109	0.015	423	180	0.14	5.7	5.6	7.60	75	230	7	2.22	0.0000411	0.000060
standard deviation (SD) [a]	37	0.016	248	79	0.09	7.0	6.6	0.48	54	81	15	2.61	0.0000371	0.000083
max detection limit	-	0.01	-	-	-	-	-	-	-	-	1	-	-	0.0002
# < detection limit	-	9	-	-	-	-	-	-	-	-	11	-	-	1
% < detection limit	-	39%	-	-	-	-	-	-	-	-	44%	-	-	4%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	8%	9%	73%	46%	30%	11%	8%	0%	100%	60%	12%	40%	9%	19%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	6%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	0	1	1	1	0	1	0	1	1	0	0	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00023	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	2	1	0	-
% > current water quality criterion	-	0%	-	-	0%	11%	8%	0%	0%	-	8%	20%	0%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	6%	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.41: Water quality data and summary statistics for mine exposed station R4, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
23-Jan-08	79.2	0.000038		0.000129		0.0273	0.00077	1.62	< 0.000005	5.25	0.248	0.00255	0.0053	0.0047
20-Feb-08	78.4	0.000028	0.017	0.000036	16.2	0.023	0.00053	1.69	< 0.000005	5.72	0.258	0.00279	0.0031	0.0034
4-Mar-08	85	< 0.001	< 0.05			0.025	< 0.001	1.9	< 0.00025	7.38	0.31	0.0026	< 0.005	< 0.005
13-Mar-08	82.6		0.021	0.000057	17	0.0216	0.00055	1.73	< 0.000005	6.12	0.27		0.0065	0.0073
28-Apr-08	121	0.000667	0.064	0.000196	23.6	1.12	0.00442	2.38	< 0.000005	9.45	0.383	0.00307	0.0338	0.035
21-May-08	23.1	0.000197	0.808	0.000976	4.96	0.141	0.00212	1.34	< 0.000005	1.67	0.0785	0.000495	0.0209	
24-Jun-08	17.9	0.0014	1.27	0.00974	3.86	0.654	0.00375	0.78	0.000025		0.0702	0.000897	0.0443	0.0165
22-Jul-08	32.8	0.000242	0.14	0.000605	6.76	0.208	0.0014	0.8	< 0.000005	2.22	0.114	0.000874	0.0111	0.0098
29-Jul-08	41	0.000309	0.144	0.000446	8.3	0.316	0.00148	1.01	< 0.000005	3.66	0.151	0.00114	0.0136	0.013
19-Aug-08	40.6		0.23	< 0.001	9.72	0.37	0.002			3.28	0.16	0.0011	0.015	0.011
4-Sep-08	40.4	0.000341	0.154	0.00049	8.4	0.311	0.00163	1.01	< 0.000005	2.75	0.146	0.00105	0.014	0.0141
17-Sep-08		0.000336	0.162	0.00038	8.18	0.264	0.00149	1.05		2.72	0.146	0.00102		0.0138
8-Oct-08	42.2	0.000374	0.15	0.000302	8.88	0.34	0.0015	0.53	< 0.000005	2.69	0.153	< 0.000002	< 0.0001	0.0199
10-Dec-08	56.4	0.000072	0.07	0.000181	12			1.33	< 0.000005	3.62	0.191	0.00195	0.0169	0.0183
22-Jan-09	69.8	0.000038	0.041	0.000212	13.3	0.0418	0.00078	1.48	< 0.000005	5.11	0.228	0.00232	0.01	
24-Feb-09	45.1		0.226	0.000497	10.3	0.028	0.00036	1.2	< 0.000005	1.87	0.136		0.0035	0.0049
26-Mar-09		0.000034	0.026	0.000025	16	0.023	0.00069	1.65	< 0.000005	5.11	0.253	0.00267	0.005	0.0051
20-May-09	38.6	0.000575		0.0029	7.89	0.41	0.00247	1.3	0.00001	2.46	0.132	0.00099	0.0289	0.022
23-Jun-09	39.3	0.000454	0.162	0.000568	8.38	0.374	0.00169	0.94	< 0.000005	2.84	0.14	0.00102	0.0166	0.0157
30-Jul-09	63.2	0.000285	0.107	0.000135	13.4	0.366	0.00146	1.55		4.25		0.00161		0.0114
25-Aug-09	44.8	0.000562	0.217		10.8	0.46	0.00198	1.15	< 0.000005	3.48	0.164	0.00113	0.0187	0.0163
30-Sep-09	35.1	0.000156	0.158	0.000428	7.9	0.171	0.00119	0.87	< 0.000005	2.38	0.13	0.00119	0.0157	0.0124
28-Oct-09	68.6	0.000793	0.147	0.00022	14.2	0.739	0.00238	1.49	< 0.000005	4.35	0.23	0.00164	0.0362	
24-Nov-09	54.4	0.000038	0.045	0.000114	11.4	0.0567	0.00086	1.25	< 0.000005	3.56	0.183	0.00187	0.0123	0.0114
19-May-11		0.00364		0.0109	4.6	2.01	0.0067	1.8	0.000031	1.8	0.0749	0.000581	0.066	0.0227
29-May-12	23.2	0.000606			4.51	0.361	0.00186	1.01	0.0000122	1.32	0.0884	0.000609	0.0118	0.0133
29-Aug-12	51.6	0.00158	0.283		11.5	0.961	0.00234	1.23	< 0.000005	3.13	0.18	0.00117	0.0157	0.0139
23-Oct-12														
n	24	24	23	23	25	26	26	26	23	26	26	25	25	24
minimum	17.9	0.000028	0.017	0.000025	3.86	0.0216	0.00036	0.53	<0.000005	1.32	0.0702	<0.000002	<0.0001	0.0034
maximum	121	0.00364	1.27	0.0109	23.6	2.01	0.0067	2.38	0.000031	9.45	0.383	0.00307	0.066	0.035
median	45.0	0.000339	0.15	0.00038	9.7	0.314	0.0015	1.28	<0.000005	3.38	0.157	0.00114	0.014	0.013
mean [a]	53.1	0.000553	0.20	0.00131	10.5	0.378	0.0018	1.31	0.000005	3.78	0.178	0.00145	0.017	0.013
standard deviation (SD) [a]	24.1	0.000769	0.28	0.00291	4.6	0.442	0.0014	0.41	0.000008	1.90	0.076	0.000817	0.015	0.007
max detection limit	-	0.001	0.05	0.001	-	-	0.001	-	0.000005	-	-	0.000002	0.005	0.005
# < detection limit	-	1	1	1	-	-	1	-	19	-	-	1	2	1
% < detection limit	-	4%	4%	4%	-	-	4%	-	83%	-	-	4%	8%	4%
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	46%	63%	9%	13%	40%	77%	69%	38%	9%	58%	42%	20%	48%	21%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.3	0.13	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	1	1	2	-	1	0	0	0	-	-	0	4	-
% > current water quality criterion	-	4%	4%	9%	-	4%	0%	0%	0%	-	-	0%	16%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics

Suspect value, excluded from summary statistics

Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.42: Water quality data and summary statistics for mine exposed station A1, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
23-Jan-08	130	< 0.005	381	180	0.25	1	1	7.35	60.6	220	< 1		0.000006	
20-Feb-08	150	< 0.005	402	186	0.24	1.3	1.7	7.7	55	220	< 1		0.000011	< 0.000005
13-Mar-08	140	< 0.005	58.1	189	0.25	1.4		6.44	53.4	250	1		0.00001	
28-Apr-08	130	< 0.005	447	224	0.17	1.1	1.8	7.34	88	290	8		0.000045	0.000061
21-May-08	43	< 0.005	144.5	70.5	0.03	14.6	15.1	7.47	18	7.8	130		0.00012	
24-Jun-08	51	< 0.005	150.1	68.3	0.03	7.7	8.3	7.45	19	110	87		0.00017	0.000058
29-Jul-08	92	0.009		117	0.08	4.2			32	140	4		0.000025	0.000026
17-Sep-08	91			119	0.06	5.2	5.1		34	170	11		0.000037	0.000013
8-Oct-08	100	< 0.005	280	127	0.08	3.6	3.1		34	170	3		0.000022	0.000022
10-Dec-08	140	0.008	250		0.17	0.8	1.2	7.36			3		0.000017	0.000013
22-Jan-09	140			167	0.18				47	180	3			0.000011
24-Feb-09	150	0.007		188	0.27				50	200	39		0.000084	0.000016
26-Mar-09		0.027	372	180	0.27				58	230	< 1		0.00002	0.00002
20-May-09	79	< 0.005	643	113	0.06			7.42	43	180	29		0.000088	
23-Jun-09	91		596	112	0.04			8.25	30	140	19		0.000028	0.000319
30-Jul-09	120	< 0.005	300	165	< 0.02			8.42	42		2		0.000025	0.000031
25-Aug-09	96	< 0.005	250	123	0.04			8.32	30	140	8		0.000031	0.000021
30-Sep-09	110	< 0.005	185.1	134	0.08			8	31	160	9			0.000017
28-Oct-09	120	0.008		184					71	220			0.000038	0.000029
24-Nov-09	140		10.45	166	0.16			8.1	43	220	2			0.000016
21-Jan-10		0.009	199.1	181	0.24				44	230	1		0.000008	< 0.000005
26-Feb-10	150	< 0.005	208.2	177	0.24			8.21	56	220	< 1		0.000011	0.000006
30-Mar-10	150	< 0.005	231	206	0.25			8.36	81	240	1		0.00002	0.000033
19-May-10	75	0.009	146	118	0.06			7.81	45	160	93		0.000173	
3-Aug-10	130	< 0.005	236	148	< 0.02			8.29	40	170	1		0.000033	
4-Nov-10	120	0.015		157	0.15			8.11	41	180	8		0.000023	0.000008
19-May-11	39	0.039		22.8	0.05	24.4	23.2		15	86	180	18.4	0.00007	0.000053
29-May-12	54	0.049			0.0457		10.4		17.9	110	27.4	13.9	0.0000803	0.0000246
29-Aug-12													0.000068	0.000022
23-Oct-12	140				0.125		3.92		43.5	228	1.7	1.17		
n	27	24	20	26	28	11	11	18	28	27	28	3	26	23
minimum	39	<0.005	10.45	22.8	<0.02	0.8	1	6.44	15	7.8	<1	1.17	0.000006	<0.000005
maximum	150	0.049	643	224	0.27	24.4	23.2	8.42	88	290	180	18.4	0.000173	0.000319
median	120	<0.005	243	161	0.10	3.6	3.9	7.91	43	180	4	13.9	0.0000295	0.000021
mean [a]	110	0.009	274	147	0.13	5.9	6.8	7.80	44	180	24	11.2	0.0000486	0.000036
standard deviation (SD) [a]	35	0.012	161	47	0.09	7.4	7.0	0.52	18	59	44	8.9	0.0000465	0.000064
max detection limit	-	0.005	-	-	0.02	-	-	-	-	-	1	-	-	0.000005
# < detection limit	-	14	-	-	2	-	-	-	-	-	4	-	-	2
% < detection limit	-	58%	-	-	7%	-	-	-	-	-	14%	-	-	9%
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	0%	35%	50%	29%	9%	18%	6%	86%	44%	25%	67%	12%	4%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	-	-	-	-	-	-
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	6%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	0	1	1	1	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00024	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	7	2	0	-
% > current water quality criterion	-	0%	-	-	0%	9%	9%	0%	0%	-	25%	67%	0%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	6%	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.42: Water quality data and summary statistics for mine exposed station A1, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
23-Jan-08	53.2	0.000022	0.02	0.000033	11.5	0.00414	0.00035	1.46	< 0.000005	3.39	0.177	0.00249	0.0013	0.0035
20-Feb-08	55.2	0.00002	0.018	0.000033	11.7	0.00435		1.57	< 0.000005	3.78	0.177	0.00251	0.0012	0.0017
13-Mar-08	56.2	0.000023		0.00008	11.8	0.00746	0.00033	1.56	< 0.000005	3.8	0.18	0.00256	0.0046	0.0055
28-Apr-08	68		0.164	0.000341	13.1	0.0464		1.86	< 0.000005	4.24	0.214	0.00252	0.0073	0.0063
21-May-08	20.4	0.000857	1.07	0.00313	4.756	0.346	0.00419	1.52	0.00002	1.35	0.066	0.000691	0.0229	0.0091
24-Jun-08	19.8	0.00103	1.13	0.00468	4.59		0.00398	0.86	0.000026	1.39	0.0694	0.000866	0.0238	0.0057
29-Jul-08	34.5	0.000106	0.121	0.000268	7.45		0.00099		< 0.000005	2.85	0.115	0.00126	0.0064	0.0043
17-Sep-08	35.1	0.000234	0.274	0.000394	7.71	0.0902	0.00168	1.12	< 0.000005	2.17	0.12	0.00121	0.0061	0.0036
8-Oct-08	37.5	0.00016	0.162	0.000262	8.23	0.102		0.59	0.000005	2.22	0.12		0.0001	0.0052
10-Dec-08	48	0.000034	0.047	0.000191	10.5	0.00587	0.00061	1.42		2.77	0.154	0.00217	0.0048	0.0032
22-Jan-09	49.9	0.000045	0.082		10.4	0.0136	0.0005	1.4	< 0.000005	3.9	0.159	0.00234	0.0038	0.0041
24-Feb-09	56.1	0.000414	0.551	0.00167	11.7	0.123	0.00158	1.63	< 0.000005	3.18	0.181	0.0023	0.0099	0.0026
26-Mar-09	53.5		0.074	0.00012		0.00891		1.51	< 0.000005	3.25	0.178	0.00258	0.0017	0.0015
20-May-09	33.6		0.559	0.00145	7.2	0.139	0.00269		0.00001	1.97	0.11	0.00129	0.0114	0.0063
23-Jun-09	32.7	0.000241		0.000632		0.0703	0.00161	1.06	0.000005	2.17	0.105	0.00122	0.0067	0.0069
30-Jul-09		0.000063	0.066	0.000095	10.6	0.0317	0.00071	1.49	< 0.000005	2.98	0.155	0.00178	0.002	0.0024
25-Aug-09	35.7	0.000141	0.184	0.000433	8.32	0.0719		1.09	< 0.000005	2.45	0.122	0.00132	0.0048	0.0024
30-Sep-09	39.1	0.000109	0.161		8.83	0.073	0.00102	1.11	< 0.000005	2.36	0.13	0.00159	0.0058	0.0049
28-Oct-09		0.000232	0.157	0.000582	11.6	0.2	0.00117	1.41	< 0.000005	3.28	0.175	0.00187	0.0089	0.0068
24-Nov-09	48.8	0.000044	0.039	0.000104	10.6	0.00941	0.00071	1.44	< 0.000005	3.11	0.157	0.00203	0.0034	0.0036
21-Jan-10	53.6	0.000029	0.041	0.000086	11.4	0.0102	0.00049	1.49	< 0.000005	3.34	0.172	0.00238	0.0021	0.0025
26-Feb-10	52.7	0.000026	0.035	0.000034	11	0.00625	0.00039	1.41	< 0.000005			0.00249	0.0015	0.0017
30-Mar-10	60.6	0.00005	0.057	0.000198	13.2	0.0145	0.00053	1.61	< 0.000005	4.22	0.195	0.00279	0.0036	0.0018
19-May-10	34.1	0.00164	2.08	0.00402	7.9	0.524	0.00653	1.47	< 0.000005	2.1	0.11	0.00133	0.0324	
3-Aug-10	43.2	0.000078	0.069	0.000167	9.72	0.0365	0.00087	1.35	< 0.000005	2.71		0.00161	0.0027	
4-Nov-10	45.5	0.000144	0.152	0.000472	10.6	0.0468	0.00091				0.157		0.0048	0.0013
19-May-11	5.8	0.00098		0.00062	2	0.081	0.0023	1	0.000018	0.8	0.0325	0.00175	0.007	0.009
29-May-12	20.4	0.000583	0.68		4.24	0.217	0.00273	1.17	0.000018	1.14	0.0729	0.000684	0.0086	0.00352
29-Aug-12	42.5	0.000651	0.631	0.00072	9.73	0.31	0.00243	1.3	0.000005	2.4	0.136	0.00139	0.00886	0.00324
23-Oct-12														
n	27	26	26	26	27	27	24	26	27	27	27	27	29	27
minimum	5.8	0.00002	0.018	0.000033	2	0.00414	0.00033	0.59	<0.000005	0.8	0.0325	0.000684	0.0001	0.0013
maximum	68	0.00164	2.08	0.00468	13.2	0.524	0.00653	1.86	0.000026	4.24	0.214	0.00279	0.0324	0.0091
median	43.2	0.000125	0.15	0.000305	10.4	0.0468	0.0010	1.42	<0.000005	2.77	0.154	0.00178	0.0048	0.0036
mean [a]	42.1	0.000306	0.33	0.000801	9.3	0.0961	0.0016	1.34	0.000006	2.72	0.139	0.00182	0.0072	0.0042
standard deviation (SD) [a]	14.4	0.000411	0.48	0.00124	2.8	0.126	0.0015	0.27	0.000007	0.92	0.044	0.000635	0.0074	0.0022
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	19	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	70%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	44%	27%	27%	12%	33%	56%	46%	62%	4%	41%	30%	19%	10%	0%
lower background (BG) benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.3	0.14	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	3	0	-	0	0	0	0	-	-	0	1	-
% > current water quality criterion	-	0%	12%	0%	-	0%	0%	0%	0%	-	-	0%	3%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, retained in summary statistics
Suspect value, excluded from summary statistics
Value reported as below detection limit (DL) but DL was above water quality guideline, value was excluded from summary statistics
Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.43: Water quality data and summary statistics for Pelly River station P1, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
24-Jan-08	130	< 0.005	411	211	0.1	1.2	1.8	7.5	66		< 1		0.00013	0.000126
20-Feb-08	160	< 0.005	465	211	0.11	2	1.9		66.1	240	< 1			0.000125
12-Mar-08	150		375	216		1.9	1.9	6.4	66.3		< 1		0.000108	0.000102
28-Apr-08	130	< 0.005		206	0.04	1.1	1.1		63	240	2		0.000159	0.000101
21-May-08	58	0.013	144.5	107	< 0.02	11.3	11.6	7.47			210		0.0011	0.000265
24-Jun-08	82	< 0.005	231	143	0.02	3.1	3.1	7.89	42	150	120		0.000442	0.000064
29-Jul-08	100	< 0.005	299	154	< 0.02		4	8.46		160	8			
17-Sep-08	92	< 0.005		144	< 0.02	5.5	5.5	7.7	54	200	14		0.000214	
8-Oct-08	96	< 0.005	324	148	< 0.02	3.3	3.6		47	86	9			0.000155
10-Dec-08	130	< 0.005	650	204	0.09	2.5	2.4	7.6	61	210	2		0.000183	0.000178
22-Jan-09	150	< 0.005			0.06					250	7		0.000082	0.000076
24-Feb-09	160	< 0.005		217	0.05				63	250	3		0.000188	
26-Mar-09	150	0.014	396	198					68				0.000073	0.00007
20-May-09	86	< 0.005	558	121	0.02			7.79	36	210	22		0.000251	0.000146
23-Jun-09	89	< 0.005	604	121	0.02			7.92	38	150	31		0.000201	0.000274
30-Jul-09	110	0.014	331	179	0.06			8.15	65	190	4		0.000101	0.000093
25-Aug-09	100	< 0.005	302	161	< 0.02			8.2	55	170	15		0.000137	0.00006
30-Sep-09	94	< 0.005	305		< 0.02			8		180	14		0.000221	0.000111
28-Oct-09	120	< 0.005		174	0.03				62	220	4		0.000152	
24-Nov-09	160	< 0.005	4	208	0.05			8.05	62	260	< 1		0.000169	0.000069
19-May-11	72	0.023		112	< 0.02	16.7	18.2	7.97	30	140	160	17.1		0.000176
29-May-12	64	0.018		98.5	0.0246		9.42		32.8		116		0.000885	0.000148
29-Aug-12				178									0.000148	0.000102
23-Oct-12	145	0.019			0.0295		3.04		77.1	288	6.9	1.42		
n	23	22	14	21	21	10	13	14	19	18	22	2	19	19
minimum	58	<0.005	144.5	98.5	<0.02	1.1	1.1	6.4	30	86	<1	1.42	0.000073	0.00006
maximum	160	0.023	650	217	0.11	16.7	18.2	8.46	77.1	288	210	17.1	0.0011	0.000274
median	110	<0.005	353	174	0.02	2.8	3.1	7.91	62	205	7.5	9.26	0.000169	0.000111
mean [a]	114	0.006	385	167	0.04	4.9	5.2	7.79	55.5	200	34	9.26	0.000260	0.000128
standard deviation (SD) [a]	33	0.007	143	40	0.03	5.1	5.0	0.49	13.7	51	60	11.1	0.000273	0.000062
max detection limit	-	0.005	-	-	0.02	-	-	-	-	-	1	-	-	-
# < detection limit	-	16	-	-	7	-	-	-	-	-	4	-	-	-
% < detection limit	-	73%	-	-	33%	-	-	-	-	-	18%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	13%	0%	86%	57%	0%	0%	8%	7%	100%	61%	27%	50%	84%	89%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	0	1	1	0	1	1	1	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00025	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	0	0	0	0	-	5	1	4	-
% > current water quality criterion	-	0%	-	-	0%	0%	0%	0%	0%	-	23%	50%	21%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	7%	-	-	-	-	-	-

Suspect value, excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.43: Water quality data and summary statistics for Pelly River station P1, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
24-Jan-08	54.4	0.000019	0.04	0.000022	18.4	0.0106	0.00317	0.83	< 0.000005	2.43	0.22	0.00189		0.0183
20-Feb-08	54.8	0.000018	0.024	0.000019	18	0.0103	0.00252	0.83	< 0.000005	2.5	0.222	0.00204	0.0161	0.0159
12-Mar-08	56	0.000024	0.032	0.000026	18.5	0.0129	0.0025	0.83	< 0.000005	2.46	0.23	0.00212		0.0184
28-Apr-08	54.3	0.000059	0.095	0.000144	17.2		0.00247	0.87	< 0.000005	2.25	0.224	0.00218	0.0165	0.0141
21-May-08	27.8	0.00232	3.11	0.00378	9.04	0.266	0.0151	1.12	0.000105	1.23		0.001		0.0134
24-Jun-08	37.4		1.44	0.00241	12	0.1	0.00606	0.67	0.000039	1.04	0.146	0.00132	0.0347	0.0038
29-Jul-08	40.3	0.000157	0.232	0.000339	12.9	0.0181	0.00355	0.62		2.25	0.172	0.00145	0.0103	0.0058
17-Sep-08	37.4	0.000253	0.32		12.4	0.0287	0.00572	0.62	0.000005	1.51	0.162		0.0202	0.0105
8-Oct-08	38		0.251	0.00026	13		0.00627	1.09	0.000005	1.56	0.159	0.0004	0.0001	0.0136
10-Dec-08	52.5	0.000042	0.069	0.000158	17.6	0.0131	0.00493	0.81	< 0.000005	2.2	0.212	0.0019	0.0261	0.0256
22-Jan-09		0.000076	0.247	0.000214	16.4	0.0377	0.00099	0.63	< 0.000005		0.211	0.00217	0.0054	
24-Feb-09	60.1	0.000035	0.052	0.000078	16.3	0.0427	0.00252		< 0.000005	1.73	0.241		0.0113	0.0126
26-Mar-09		0.000028	0.006	0.000014	15.2	0.011	0.00089	0.78	< 0.000005	1.74	0.221	0.00119	0.0035	0.0037
20-May-09	31.4	0.000282	0.469	0.000522	10.3	0.0425	0.00512	0.91	0.000009	1.51	0.131	0.00113	0.0155	0.0077
23-Jun-09	31.9	0.000369	0.489	0.000724	10.2	0.039	0.00481	0.6	< 0.000005	1.37		0.0011	0.0189	
30-Jul-09	47.2	0.000046	0.071	0.000118	14.9	0.0127		0.86	< 0.000005	1.8	0.191	0.00165	0.0042	0.0042
25-Aug-09	41.1	0.000179		0.000343	14.3	0.0241	0.00337	0.7	0.000005	1.58	0.181	0.00154	0.0103	0.0032
30-Sep-09	37.5	0.000253	0.297	0.000308	12.7	0.0372	0.00592	0.59	< 0.000005	1.36	0.165	0.0014		0.0087
28-Oct-09	45.1		0.111	0.000112	14.9	0.0135	0.0043		0.000013	1.82	0.187	0.00174	0.0122	0.011
24-Nov-09	55.1	0.000244	0.299	0.000561	17.1	0.0349	0.00252	0.9	< 0.000005	2.03	0.221	0.00223	0.0146	0.0071
19-May-11	28.6	0.00238	4.74	0.00366	9.8	0.294	0.0215		0.000086	1.3	0.124	0.00122	0.076	0.0099
29-May-12	25.9	0.00154	1.82	0.00185	8.18	0.166	0.0114	0.835	0.0000638	0.978	0.117	0.000973	0.0679	0.00871
29-Aug-12		0.0001	0.153	0.000124	15	0.0137	0.00362	0.742	< 0.000005	1.78	0.191	0.00165	0.00786	0.00507
23-Oct-12														
n	20	20	22	22	23	21	22	20	22	22	21	21	19	21
minimum	25.9	0.000018	0.006	0.000014	8.18	0.0103	0.00089	0.59	<0.000005	0.978	0.117	0.0004	0.0001	0.0032
maximum	60.1	0.00238	4.74	0.00378	18.5	0.294	0.0215	1.12	0.000105	2.5	0.241	0.00223	0.076	0.0256
median	40.7	0.000129	0.24	0.000237	14.9	0.0287	0.0040	0.82	<0.000005	1.74	0.191	0.00154	0.015	0.0099
mean [a]	42.8	0.000421	0.65	0.000718	14.1	0.0585	0.0054	0.79	0.000017	1.75	0.187	0.00154	0.020	0.0105
standard deviation (SD) [a]	10.8	0.000738	1.18	0.00114	3.1	0.0821	0.0048	0.15	0.000030	0.46	0.0373	0.000488	0.020	0.0058
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	13	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	59%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	40%	35%	27%	14%	78%	33%	91%	0%	18%	0%	62%	0%	53%	14%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	0	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.4	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	4	0	-	0	0	0	1	-	-	0	3	-
% > current water quality criterion	-	0%	18%	0%	-	0%	0%	0%	5%	-	-	0%	16%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.44: Water quality data and summary statistics for Pelly River station P2, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
24-Jan-08	140	< 0.005	412	217	0.1	1.7	1.7	7.7	65.7	230	< 1		0.000127	0.00012
20-Feb-08	160	< 0.005	470	225	0.1	2	2.3	7.5	69.8	250	< 1		0.000128	0.000125
12-Mar-08	150	< 0.005		218	0.11	2.3		6.4	66.6	280	< 1		0.000103	0.000113
28-Apr-08	140	< 0.005	414	209	0.03	0.9	0.9	7.8	61	250	< 1		0.000097	0.000095
21-May-08	57	< 0.005	173.9	95.1	< 0.02	11.3		7.78	31	120	48		0.000452	0.000181
24-Jun-08	82	< 0.005	229	145	0.02		3.7		43	170	150		0.000505	0.000069
29-Jul-08	100	< 0.005	299	143	< 0.02	4	3.8	8.46	52	190	8		0.000124	0.000076
17-Sep-08	94	0.007	300	147	< 0.02	5.5	5.1		50	210	13		0.000209	0.000141
8-Oct-08	97	< 0.005	322	146	< 0.02	4.2	3.5		44	190	7		0.000209	0.000175
10-Dec-08	140	0.029	870	202	< 0.02	1.3	1.3	7.83	50	210	12		0.000171	0.000056
22-Jan-09	150	0.008		202	0.08				66	230	2		0.000146	0.000141
24-Feb-09		< 0.005		221	0.09				63	320	< 1			0.000051
26-Mar-09	150	0.027	326	202	0.11				72	250	< 1		0.000111	0.00013
20-May-09	87	< 0.005		118	0.03			7.74	49	180	27		0.000246	0.000139
23-Jun-09	91	0.015	687	121	0.03			8.22	37	140	30		0.000226	0.000162
30-Jul-09	120	0.006	341	180	< 0.02			8.2	52	190	3		0.000087	
25-Aug-09	120	0.013	339	191	0.02			8.24	53	200			0.000124	0.00013
n	16	17	13	17	17	9	8	11	17	17	16	0	16	16
minimum	57	<0.005	173.9	95.1	<0.02	0.9	0.9	6.4	31	120	<1	-	0.000087	0.000051
maximum	160	0.029	870	225	0.11	11.3	5.1	8.46	72	320	150	-	0.000505	0.000181
median	120	<0.005	339	191	0.03	2.3	2.9	7.80	52	210	5	-	0.000137	0.000128
mean [a]	117	0.008	399	175	0.05	3.7	2.8	7.81	54	212	19	-	0.000192	0.000119
standard deviation (SD) [a]	31	0.009	189	42	0.04	3.2	1.5	0.55	12	50	38	-	0.000122	0.000040
max detection limit	-	0.005	-	-	0.02	-	-	-	-	-	1	-	-	-
# < detection limit	-	10	-	-	6	-	-	-	-	-	6	-	-	-
% < detection limit	-	59%	-	-	35%	-	-	-	-	-	38%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	6%	0%	85%	59%	0%	0%	0%	9%	100%	76%	25%	-	81%	88%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	0	1	1	0	0	1	1	1	1	1	-	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00025	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	0	0	0	0	-	4	-	2	-
% > current water quality criterion	-	0%	-	-	0%	0%	0%	0%	0%	-	25%	-	13%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	9%	-	-	-	-	-	-

Table C.44: Water quality data and summary statistics for Pelly River station P2, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
24-Jan-08	56.7	0.000021	0.045	0.00001	18.3	0.0131	0.00302	0.85	< 0.000005	2.38	0.229	0.00188	0.0173	0.0178
20-Feb-08		0.000022	0.026	0.000012	19	0.0156	0.00266	0.87	< 0.000005	2.64	0.231	0.00213	0.0159	0.0164
12-Mar-08	56.5	0.00002	0.03	0.000056	18.8	0.0141	0.00264	0.84	< 0.000005	2.49	0.23	0.00212	0.0181	0.018
28-Apr-08	55.2	0.000039	0.052	0.000072	17.2	0.0285	0.00226	0.84	< 0.000005	2.21	0.221	0.00209	0.0136	0.0129
21-May-08	24.9	0.000771	1.17	0.00134	7.99	0.097	0.00819	1.27	0.000042	1.21	0.0999	0.000749	0.0348	0.0122
24-Jun-08	38.2	0.00141	1.97	0.00276	12.2	0.108	0.00735	0.69		1.04	0.148	0.00135	0.0401	0.0039
29-Jul-08	37.5	0.00012	0.16	0.000234	12	0.0167	0.00308	0.57	< 0.000005	2.14	0.168	0.00142	0.0116	0.0056
17-Sep-08	38.2	0.00024	0.299	0.000297	12.6	0.0279	0.00559	0.64	< 0.000005	1.8	0.161	0.0012	0.0229	0.01
8-Oct-08	37.5	0.00016	0.21	0.000236	12.7	0.0218	0.00583	1.18	0.000004	1.54	0.159	0.0003	0.0001	0.0148
10-Dec-08	55.1	0.000247	0.251	0.000224	15.8	0.347	0.00208	0.79	< 0.000005	1.71	0.211	0.000731	0.0079	0.0054
22-Jan-09	53	0.000024	0.043	0.000172	16.9	0.0115	0.00299	0.78	< 0.000005	3.22	0.22	0.00201	0.0207	0.0222
24-Feb-09	59.1		0.033	0.000052		0.0149		0.72	< 0.000005	2.06	0.232	0.00182	0.0027	0.0026
26-Mar-09	52.4	0.00002	0.03		17.4	0.0102	0.00254	0.79	< 0.000005	2.23	0.23	0.00214	0.0152	0.0152
20-May-09	30.7	0.000256	0.469	0.000523	10.1	0.0411	0.00488	0.86	0.000005	1.45	0.131	0.00112	0.0153	
23-Jun-09	31.6	0.000335	0.466	0.000908	10.2	0.0377	0.00474	0.59	0.000007	1.39	0.138	0.00113	0.0166	0.0073
30-Jul-09	47.4		0.07	0.000089		0.0119	0.00204	0.8	< 0.000005	1.82	0.191	0.00165	0.0037	0.0027
25-Aug-09	50	0.000089	0.128	0.000203	16.1	0.0133	0.0026	0.81	< 0.000005	2.05	0.207	0.00167	0.0067	0.0044
n	16	15	17	16	15	17	16	17	16	17	17	17	17	16
minimum	24.9	0.00002	0.026	0.00001	7.99	0.0102	0.00204	0.57	0.000004	1.04	0.0999	0.0003	0.0001	0.0026
maximum	59.1	0.00141	1.97	0.00276	19	0.347	0.00819	1.27	0.000042	3.22	0.232	0.00214	0.0401	0.0222
median	48.7	0.000120	0.13	0.0002135	15.8	0.0167	0.0030	0.80	<0.000005	2.05	0.207	0.00165	0.015	0.011
mean [a]	45.3	0.000252	0.32	0.000449	14.5	0.0488	0.0039	0.82	0.000006	1.96	0.189	0.00150	0.015	0.011
standard deviation (SD) [a]	11.0	0.000376	0.51	0.000713	3.6	0.0821	0.0019	0.18	0.000010	0.56	0.0426	0.000564	0.011	0.0063
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	12	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	75%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	56%	27%	24%	6%	80%	24%	100%	0%	6%	6%	59%	0%	59%	19%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	0	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.4	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	2	0	-	0	0	0	0	-	-	0	2	-
% > current water quality criterion	-	0%	12%	0%	-	0%	0%	0%	0%	-	-	0%	12%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table C.45: Water quality data and summary statistics for Pelly River station P3, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
23-Jan-08	130	< 0.005	369	174	0.25	2.1	1.1	6.74	49.2	220	< 1		0.000034	0.000037
20-Feb-08	150	< 0.005	414	193	0.24	1.1	1.2	7.6	53.3	220	< 1		0.000039	0.000034
13-Mar-08	150	< 0.005	289	208	0.14	1.9	1.9	6.44	60.6	280	< 1		0.00008	0.000092
28-Apr-08	140	< 0.005	390	196	0.09	< 0.5	0.5	7.33	60	220	< 1		0.000058	0.000091
21-May-08	61	< 0.005	171.4	107	< 0.02	11.8	12.3		27	130	140		0.00083	0.000216
24-Jun-08	82	< 0.005	230	127	< 0.02	2.5	2.6	7.79	43	150	74		0.000279	0.000061
29-Jul-08	110	0.006	305	150	0.03	3.6	3.7	7.85	49	190	7		0.000108	0.000058
17-Sep-08	96	< 0.005	301		< 0.02	5.8	5.2	7.58	50	210	11		0.000187	0.000074
8-Oct-08	110	< 0.005		159	0.05	3.3	3.9		40	210	11		0.000226	0.000103
10-Dec-08	130	< 0.005	540	204	0.06	2.3	2.4	7.4	58	230	2		0.000159	0.000145
22-Jan-09	140	< 0.005							46	200	7		0.000058	0.000073
24-Feb-09	140	< 0.005		178	0.21				47	200	42		0.000049	0.000045
26-Mar-09	140	0.032	325	175	0.25				53	240	< 1		0.00004	0.000045
20-May-09	100	< 0.005	748	130	0.05			7.33	60		18		0.000199	0.000119
23-Jun-09	94	< 0.005	675	129	0.05					160	43		0.000223	0.000094
30-Jul-09	120	< 0.005	343	185	< 0.02			7.84	48	230	2		0.000062	
25-Aug-09	120		328	167	0.03			7.98	51	190	4		0.000082	0.000058
n	17	16	14	15	16	10	10	11	16	16	17	0	17	16
minimum	61	<0.005	171.4	107	<0.02	<0.5	0.5	6.44	27	130	<1	-	0.000034	0.000034
maximum	150	0.032	748	208	0.25	11.8	12.3	7.98	60.6	280	140	-	0.00083	0.000216
median	120	<0.005	336	174	0.05	2.4	2.5	7.58	49.6	210	7	-	0.000082	0.000074
mean [a]	118	0.005	388	165	0.09	3.5	3.5	7.44	49.7	205	21	-	0.000160	0.000084
standard deviation (SD) [a]	25	0.007	162	31	0.09	3.3	3.4	0.48	8.6	37	37	-	0.000190	0.000047
max detection limit	-	0.005	-	-	0.02	0.5	-	-	-	-	1	-	-	-
# < detection limit	-	14	-	-	4	1	-	-	-	-	5	-	-	-
% < detection limit	-	88%	-	-	25%	10%	-	-	-	-	29%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	0%	0%	79%	60%	25%	0%	0%	0%	100%	81%	24%	-	47%	56%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	0	1	1	1	0	1	0	1	1	1	-	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	-	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00025	-
source [b]	-	CCME	-	-	CCME	-	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	-	0	0	0	-	4	-	2	-
% > current water quality criterion	-	0%	-	-	0%	-	0%	0%	0%	-	24%	-	12%	-
# < current water quality criterion	-	-	-	-	-	-	1	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	10%	9%	-	-	-	-	-	-

Suspect value, excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.45: Water quality data and summary statistics for Pelly River station P3, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
23-Jan-08	51.5	0.000016	0.008	0.000043	11.1	0.00044	0.00051	1.33	< 0.000005	2.98	0.167		0.0014	0.0019
20-Feb-08	56.9	0.000015	0.005	0.000008	12.3	0.0014	0.00059	1.44	< 0.000005	3.4	0.174	0.00245	0.0028	0.0027
13-Mar-08	56.3		0.021	0.000051	16.3	0.00939	0.00165	1.07	< 0.000005	2.92	0.213	0.00211	0.0123	0.0134
28-Apr-08	55.6	0.000026	0.035	0.000074	13.8	0.00882	0.00135	1.17	< 0.000005	3.21	0.198	0.00202	0.0055	0.0106
21-May-08	28.1	0.00168	2.39	0.00324	8.96	0.195	0.0126	1.16	0.000094	1.28	0.11	0.00101	0.0569	0.0106
24-Jun-08	33.3	0.000628	0.78	0.00166	10.6	0.0729	0.00438	0.6	0.000022	1.06	0.138	0.00117	0.0223	0.0043
29-Jul-08	40.3	0.000124	0.169	0.000309	12.1	0.0176	0.00274	0.71	0.000006	2.45	0.167	0.00148	0.0104	0.0042
17-Sep-08	37.7	0.000246	0.344	0.000325	12	0.0309	0.00503	0.67	0.000006	1.56	0.165	0.00125	0.018	0.0083
8-Oct-08	43.7	0.000317	0.363	0.000604	12.2	0.0456	0.00469	0.82	0.000005	2.04	0.161	0.0006	0.0001	0.0086
10-Dec-08	52.2	0.000073	0.084	0.000256	17.8	0.0176	0.00464	0.83	< 0.000005	2.26	0.212	0.00191	0.0212	0.0202
22-Jan-09		0.000038	0.044	0.000147	11.2	0.00595	0.00098	1.29			0.17	0.00183	0.0064	0.0123
24-Feb-09	53.4	0.000071	0.109	0.000148	10.9	0.00868	0.00065	1.38	< 0.000005	2.78	0.169		0.0032	0.003
26-Mar-09	51	0.000016	0.009	0.000008	11.5		0.00064	1.27	< 0.000005	2.77	0.173	0.00236	0.0022	0.0019
20-May-09	35.4	0.000255	0.434	0.000495	10.2	0.0358	0.00417	0.99	0.000006	1.74	0.137	0.00132	0.012	0.0064
23-Jun-09	33.9	0.000451	0.597	0.00101	10.8	0.0523	0.00481	0.66		1.52		0.00119		0.0052
30-Jul-09	50	0.000049	0.054	0.000092	14.6	0.0103			< 0.000005	2.2	0.187	0.00174	0.0029	0.0025
25-Aug-09	45.2	0.000072	0.083		13	0.0104	0.00177	0.99	< 0.000005	2.26	0.175	0.00168	0.0045	0.0021
n	16	16	17	16	17	16	16	16	15	16	16	15	16	17
minimum	28.1	0.000015	0.005	0.000008	8.96	0.00044	0.00051	0.6	<0.000005	1.06	0.11	0.0006	0.0001	0.0019
maximum	56.9	0.00168	2.39	0.00324	17.8	0.195	0.0126	1.44	0.000094	3.4	0.213	0.00245	0.0569	0.0202
median	47.6	0.0000725	0.084	0.000202	12.0	0.0140	0.0023	1.03	<0.000005	2.26	0.170	0.00168	0.0060	0.0052
mean [a]	45.3	0.000255	0.33	0.000529	12.3	0.0327	0.0032	1.02	0.000011	2.28	0.170	0.00161	0.011	0.0070
standard deviation (SD) [a]	9.4	0.000420	0.58	0.00085	2.2	0.0479	0.0031	0.28	0.000024	0.71	0.0265	0.000523	0.014	0.0051
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	9	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	60%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	50%	31%	18%	6%	71%	25%	69%	6%	13%	13%	31%	0%	25%	6%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	0	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.4	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	0	1	0	-	0	0	0	0	-	-	0	1	-
% > current water quality criterion	-	0%	6%	0%	-	0%	0%	0%	0%	-	-	0%	6%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.46: Water quality data and summary statistics for Pelly River station P4, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	mg/L	mg/L	µS/cm	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
23-Jan-08		< 0.005	425		0.23	1.9	1.7	7.22	62.2	260	< 1		0.000118	0.000111
20-Feb-08	160	< 0.005	379	214	0.1	1.9	2.2	7.7	67.3	250	< 1			0.000101
13-Mar-08			399	216	0.1	1.9	1.9	6.44	64.1	340	< 1		0.000094	0.000099
28-Apr-08	130	0.046	397	200	0.04	1.1	1.3	6.94	61	230	1		0.000092	0.000083
21-May-08		< 0.005	179.4	104		11.8	12.2	7.68	29	140			0.000634	0.000322
24-Jun-08	72	< 0.005	195	117	0.02	4.1	4.8	7.73	37	140	110		0.000302	0.000064
29-Jul-08		< 0.005		136	0.09	4.1	3.8		44	160	7		0.000074	0.000043
17-Sep-08	91	< 0.005		136	< 0.02	5.1	5.3		40	170	15		0.00015	0.000101
8-Oct-08	110	< 0.005	330	153	< 0.02	2.7	4.9		50	210	6		0.000165	0.000097
10-Dec-08	130	< 0.005	600	200	0.07	2.6	2.6	7.32	58	270	120		0.000224	0.000168
22-Jan-09	160	0.01		182	0.04				35	190	17		0.00009	0.000036
24-Feb-09		< 0.005		196	0.03				36	210	< 1		0.000033	0.000032
26-Mar-09	150	0.034	418	199	0.11				69	260	< 1		0.000099	0.000101
20-May-09	84	< 0.005	628	121				7.35	48	170			0.000212	0.000111
23-Jun-09	91	0.005			0.02			8.3		140	42		0.000226	0.000467
30-Jul-09	140	0.006	349	191	< 0.02			8.2	44	180	1		0.000094	
25-Aug-09	100	< 0.005	289	154				8.27	47	180			0.000065	0.000045
30-Sep-09	100	< 0.005		145	0.03			8.04	48	180	6		0.000132	0.000068
28-Oct-09		< 0.005		181	0.03				61	220	2			0.000092
24-Nov-09	130	0.005	5.9	173	0.1					150	160		0.000605	0.000039
19-May-11	52	0.029		90.8	0.23	19.8	24	7.9	27	110	190	20.4	0.000635	0.000114
29-May-12	64.7	0.022			0.0234		9.14		30.1	132			0.00103	0.000114
29-Aug-12													0.000088	0.000058
23-Oct-12	147	0.02			0.0377		3.27		67.9	292	1.9	1.11		
n	17	22	12	19	20	11	13	13	21	23	19	2	21	22
minimum	52	<0.005	179.4	90.8	<0.02	1.1	1.3	6.44	27	110	<1	1.11	0.000033	0.000032
maximum	160	0.046	628	216	0.23	19.8	24	8.3	69	340	190	20.4	0.00103	0.000467
median	110	<0.005	388	173	0.04	2.7	3.8	7.70	48	180	6	10.76	0.000132	0.000098
mean [a]	112	0.010	382	164	0.07	5.2	5.9	7.62	49	199	36	10.76	0.000246	0.000112
standard deviation (SD) [a]	34	0.012	135	38	0.07	5.7	6.3	0.55	14	58	61	13.64	0.000259	0.000100
max detection limit	-	0.005	-	-	0.02	-	-	-	-	-	1	-	-	-
# < detection limit	-	13	-	-	3	-	-	-	-	-	5	-	-	-
% < detection limit	-	59%	-	-	15%	-	-	-	-	-	26%	-	-	-
upper background (BG) benchmark	150.0	0.054	292	159	0.20	19.0	15.0	8.4	21.5	180	20	2.23	0.000107	0.000067
% samples > upper BG benchmark	12%	0%	75%	53%	10%	9%	8%	0%	100%	48%	26%	50%	57%	68%
lower background (BG) benchmark	10.0	-	-	-	-	0.8	0.7	6.6	21.5	180	20	2.23	0.000107	0.000067
% samples < lower BG benchmark	0%	-	-	-	-	0%	0%	0%	-	-	-	-	-	-
background median	40.1	0.01	110	48.0	0.04	2.4	2.3	7.73	7.4	64	<1	0.53	0.000012	0.000014
station median > BG median	1	0	1	1	1	1	1	0	1	1	1	1	1	1
current water quality criterion [b]	-	0.20	-	-	3.0	0.6 - 19.3	0.6 - 19.3	6.5 - 9.0	309	-	25	4.23	0.00025	-
source [b]	-	CCME	-	-	CCME	BCMOE	BCMOE	CCME	BCMOE	-	CCME	CCME	CCME	-
# > current water quality criterion	-	0	-	-	0	1	1	0	0	-	5	1	5	-
% > current water quality criterion	-	0%	-	-	0%	9%	8%	0%	0%	-	26%	50%	24%	-
# < current water quality criterion	-	-	-	-	-	0	0	1	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	0%	0%	8%	-	-	-	-	-	-

Suspect value, excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.46: Water quality data and summary statistics for Pelly River station P4, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
23-Jan-08	54.3	0.000041	0.043	0.000143	18.5	0.029	0.00283	0.96	< 0.000005	2.59	0.234	0.002	0.0152	0.0167
20-Feb-08	55.6	0.00003	0.028	0.000017	18.4	0.021		0.88	< 0.000005	2.76	0.228	0.00207	0.0128	0.0138
13-Mar-08	55.9	0.000028	0.038	0.000042	18.5	0.0174	0.00241	0.82	< 0.000005	2.51		0.00209	0.0156	0.0225
28-Apr-08	52.8	0.000044	0.065			0.0201	0.00217	0.82	< 0.000005	2.21	0.213	0.002	0.0116	0.0112
21-May-08	27.2	0.00134	1.8	0.00248	8.69	0.157	0.0106	1.11	0.00009	1.27	0.107	0.0009		0.0132
24-Jun-08	31.2	0.000879	1.14	0.00289		0.157	0.00495	0.7	0.000022	1.17	0.126	0.00115	0.0267	0.0041
29-Jul-08	37.1	0.000117	0.164	0.000326	10.4	0.0304	0.00225	0.75	0.000006	2.4	0.153		0.0076	0.0043
17-Sep-08	36.8		0.313	0.000377		0.0489	0.00402	0.79	< 0.000005	1.72	0.139	0.00116	0.0142	
8-Oct-08	39.9	0.000134		0.000254	12.9	0.0189	0.00489	1.02	0.000004	1.74	0.164	0.0003	0.0001	0.0079
10-Dec-08	51.5	0.000282	0.388	0.000648	17.4	0.0369	0.00544	0.8	0.006	2.13	0.209	0.00189	0.026	0.0213
22-Jan-09	51	0.000116	0.186	0.000391	13.3	0.0277	0.00091	1.49	< 0.000005	4.4		0.00139	0.0073	0.0055
24-Feb-09	53.8		0.01	0.000029				1.68	< 0.000005	4.15	0.227	0.00142	0.0022	0.003
26-Mar-09	51.9	0.000022	0.034	0.000041	16.9	0.0134	0.00198	0.87	< 0.000005	2.27	0.217	0.00205	0.0113	
20-May-09		0.000382	0.567	0.000962	9.51	0.0773	0.00479	1.11	0.000011	1.69	0.126	0.00119	0.0148	0.0061
23-Jun-09	33.6	0.000591	0.759	0.00113	10.3	0.0686	0.00483	0.72		1.56	0.134		0.0189	0.0073
30-Jul-09	51.2	0.000039	0.038	0.000064	15.3		0.00168	1.25	< 0.000005	2.96	0.203	0.00179	0.0029	0.0027
25-Aug-09	40.8	0.000088	0.14	0.00026	12.6	0.022	0.00186	0.9	< 0.000005	2.08	0.166	0.00154	0.0041	0.0022
30-Sep-09	38.7	0.000155	0.219	0.000239	11.8	0.0353	0.00389	0.73	< 0.000005			0.00145	0.0125	
28-Oct-09	47.1	0.000058	0.09	0.000137	15.4	0.0134		0.71	< 0.000005	1.9	0.194	0.00181	0.0086	0.0067
24-Nov-09	47.9	0.000959	1.15	0.00217	13	0.199	0.00485	1.27	0.000009	2.32		0.00122	0.0333	0.0042
19-May-11	23.7	0.00427	6.22	0.00858	7.7	1.34	0.0164	1.9	0.000096	1.3	0.0971	0.00113	0.077	0.0084
29-May-12	28.9	0.00215	2.97		8.37	0.246	0.0134	0.925	0.0000937	1	0.121	0.00106	0.0798	0.00722
29-Aug-12	45.2	0.000263		0.000259	13.9	0.113	0.00288	0.922	0.000005	2.13	0.182	0.0015	0.00631	0.00235
23-Oct-12														
n	22	21	21	21	19	21	20	23	21	22	19	21	22	20
minimum	23.7	0.000022	0.01	0.000017	7.7	0.0134	0.00091	0.7	0.000004	1	0.0971	0.0003	0.0001	0.0022
maximum	55.9	0.00427	6.22	0.00858	18.5	1.34	0.0164	1.9	0.000096	4.4	0.234	0.00209	0.0798	0.0225
median	46.2	0.000134	0.19	0.00026	13.0	0.0353	0.0040	0.9	<0.000005	2.13	0.166	0.00145	0.013	0.0070
mean [a]	43.5	0.000571	0.78	0.00102	13.3	0.128	0.0049	1.0	0.00002	2.19	0.171	0.00148	0.019	0.0085
standard deviation (SD) [a]	10.1	0.00101	1.45	0.00193	3.6	0.286	0.0041	0.3	0.0000	0.85	0.0449	0.000467	0.021	0.0061
max detection limit	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-
# < detection limit	-	-	-	-	-	-	-	-	12	-	-	-	-	-
% < detection limit	-	-	-	-	-	-	-	-	57%	-	-	-	-	-
upper background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples > upper BG benchmark	50%	43%	33%	19%	68%	43%	95%	13%	19%	9%	47%	0%	41%	10%
lower background (BG) benchmark	45.7	0.000248	0.46	0.00203	11.0	0.0378	0.0011	1.39	0.000020	3.08	0.175	0.00251	0.014	0.017
% samples < lower BG benchmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-
background median	14.9	0.0000300	0.082	0.000215	2.52	0.00609	0.00034	0.55	<0.000005	1.84	0.0681	0.000683	0.0021	0.0031
station median > BG median	1	1	1	1	1	1	1	1	0	1	1	1	1	1
current water quality criterion [b]	-	0.0025	1	0.007	-	1.4	0.15	373	0.0001	-	-	0.015	0.03	-
source [b]	-	CCME	BCMOE	CCME	-	BCMOE	CCME	BCMOE	CCME	-	-	CCME	CCME	-
# > current water quality criterion	-	1	5	1	-	0	0	0	0	-	-	0	3	-
% > current water quality criterion	-	5%	24%	5%	-	0%	0%	0%	0%	-	-	0%	14%	-
# < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Suspect value, excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Tables 6H-1 and 6H-2 for information regarding the source, selection, and derivation of water quality criteria.

Table C.47: Water quality data and summary statistics for drinking water station GCULV, Faro Mine, Yukon.

	Non-metals												Metals	
Date	**Alkalinity, Total**	**Ammonia-N**	**Conductivity, Field**	**Hardness, Total ($CaCO_3$)**	**Nitrate-N**	**Organic carbon, Dissolved**	**Organic carbon, Total**	**pH, Field**	**Sulfate**	**Total dissolved solids**	**Total suspended solids**	**Turbidity, Lab**	**Cadmium, Total**	**Cadmium, Dissolved**
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
7-Jan-08	42.1	0.02						8.3	6.15		< 1	0.25	< 0.0002	< 0.0002
18-Feb-08	54.4	0.01		52				7.8	5.23		< 1	0.45	< 0.0002	< 0.0002
17-Mar-08	60.2	0.01		55				7.9	5.98		< 1	0.32	< 0.0002	< 0.0002
14-Apr-08	55.4	0.03		54				8	6.38		< 1	0.26	< 0.0002	< 0.0002
14-May-08	18.8	< 0.01		23				8.5	8.43		4	1.5	< 0.0002	< 0.0002
16-Jun-08	12.9	< 0.01		19				8.4	3.38		1	0.45	< 0.0002	< 0.0002
14-Jul-08		< 0.01		15				8.1	3.95		2	1.7	< 0.0002	< 0.0002
11-Aug-08	26	0.01		22				8.5			< 1	0.47	< 0.0002	< 0.0002
15-Sep-08	21.2	0.02		19				8.3	5.43		< 1	0.5	< 0.0002	< 0.0002
15-Oct-08	25.9	< 0.01		23				7.9			< 1	0.32	< 0.0002	< 0.0002
3-Nov-08	25.1	0.02		30				8	6.06		< 1	0.3	0.0003	0.0003
1-Dec-08	31.2	< 0.01		40				8.4	6.4		< 1	0.35	< 0.0002	< 0.0002
3-Nov-10	30	0.011	40.9	31.8	0.04			7.66	7	54	< 4		< 0.000005	< 0.000005
18-May-11	14	0.097		21.9	0.03	24	25	6.99	< 0.5	34	13	2.08	0.000077	0.00004
29-May-12	16	0.012			0.0213		7.2		1.99	30	6	2.32	0.000021	0.0000133
28-Aug-12				23.5									0.000011	< 0.000005
24-Oct-12	28.2				0.0326		2.47		7.69	64	< 1	0.18		
n	15	15	1	14	4	1	3	14	14	4	16	15	16	16
minimum	12.9	<0.01	-	15	0.0213	24	2.47	6.99	<0.5	30	<1	0.18	<0.000005	<0.000005
maximum	60.2	0.097	-	55	0.04	24	25	8.5	8.43	64	13	2.32	0.0003	0.0003
median	26.0	<0.01	-	23	0.03	24	7.2	8.1	6.0	44	<1	0.45	<0.0002	<0.0002
mean [a]	30.8	0.018	-	31	0.03	24	11.6	8.1	5.3	46	2	0.76	0.000094	0.00009
standard deviation (SD) [a]	15.4	0.023	-	14	0.01	-	11.9	0.4	2.2	16	3	0.74	0.000065	0.00007
max detection limit	-	0.01	-	-	-	-	-	-	0.5	-	4	-	0.0002	0.0002
# < detection limit	-	5	-	-	-	-	-	-	1	-	11	-	12	13
% < detection limit	-	33%	-	-	-	-	-	-	7%	-	69%	-	75%	81%
current drinking water quality criterion [b]	30 - 500	-	-	-	10	5	4	6.5 - 8.5	500	500	-	0.1 - 1.0	0.005	-
source [b]	OMOE	-	-	-	Health Canada	OMOE	BCMOE	Health Canada	Health Canada	Health Canada	-	Health Canada	Health Canada	-
# > current drinking water quality criterion	0	-	-	-	0	1	2	0	0	0	-	4	0	-
% > current drinking water quality criterion	0%	-	-	-	0%	100%	67%	0%	0%	0%	-	27%	0%	-
# < current drinking water quality criterion	9	-	-	-	-	-	-	0	-	-	-	0	-	-
% < current drinking water quality criterion	60%	-	-	-	-	-	-	0%	-	-	-	0%	-	-

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Table 6H-3 for information regarding the source of drinking water quality guidelines

Table C.47: Water quality data and summary statistics for drinking water station GCULV, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
7-Jan-08	13.6	< 0.001	0.06	< 0.001	2.55	0.006	< 0.001	0.5	< 0.00025	2.05	0.071	0.001	0.011	< 0.005
18-Feb-08	15.9	< 0.001	0.08	< 0.001	2.9	0.004	< 0.001	0.4	< 0.00025	2.65	0.086	0.0009	< 0.005	< 0.005
17-Mar-08	16.1	< 0.001	0.06	< 0.001	3.48	0.001	< 0.001	0.6	< 0.00025	2.87	0.082	0.0017	< 0.005	< 0.005
14-Apr-08	16.4	< 0.001	0.06	< 0.001	3.27	0.001	< 0.001	0.6	< 0.00025	2.82	0.093	0.0018	0.005	< 0.005
14-May-08	7.46	< 0.001	0.44	< 0.001	1.12	0.039	< 0.001	0.8	< 0.00025	1.75	0.048	< 0.0005	< 0.005	< 0.005
16-Jun-08	5.95	< 0.001	0.13	< 0.001	0.94	0.009	< 0.001	0.5	< 0.00025	1.52	0.035	< 0.0005	0.005	0.007
14-Jul-08	4.75	< 0.001	< 0.05	< 0.001	0.74	< 0.001	< 0.001	0.2	< 0.00025	1.01	0.029	< 0.0005	< 0.005	< 0.005
11-Aug-08	6.69		0.1	< 0.001	1.28	0.007	< 0.001	0.3		1.51	0.04	< 0.0005	< 0.005	< 0.005
15-Sep-08	6.19	< 0.001	0.11	< 0.001	0.97	0.007	< 0.001			1.32	0.046	0.0005	< 0.005	< 0.005
15-Oct-08		< 0.001	< 0.05	< 0.001	1.03	0.004	< 0.001	0.3	< 0.00025		0.043	< 0.0005	< 0.005	< 0.005
3-Nov-08	9.36	< 0.001	0.08	< 0.001	1.67	0.008	< 0.001	0.4	0.0005	1.98	0.053	0.0006		< 0.005
1-Dec-08	13		< 0.05	< 0.001	1.87	0.005	< 0.001		< 0.00025	2.1	0.062		0.008	< 0.005
3-Nov-10	9.93	0.000021	0.07	0.00003	1.71	0.00759	0.00014	0.32	< 0.000005	1.87	0.0629	0.000546	0.001	0.0007
18-May-11	6.63	0.000269	0.645	0.00136	1.31	0.12	0.00081	2.35	0.000012	0.73	0.037	0.000828	0.0104	0.0076
29-May-12	6.13	0.0000939	0.39		0.976	0.0437	0.000394	0.837	0.0000051	1.11	0.0397	0.000647	0.00184	0.00831
28-Aug-12	7.31	0.00008		0.000117	1.27	0.0334	0.000303	0.257	< 0.000005	1.45	0.0442	0.000503	0.00115	0.00109
24-Oct-12														
n	15	4	15	15	16	16	4	14	14	15	16	15	15	16
minimum	4.75	0.000021	<0.05	0.00003	0.74	<0.001	0.00014	0.2	<0.000005	0.73	0.029	<0.0005	0.001	0.0007
maximum	16.4	0.000269	0.645	0.00136	3.48	0.12	0.00081	2.35	0.0005	2.87	0.093	0.0018	0.011	0.00831
median	7.46	0.000087	0.08	<0.001	1.30	0.0070	0.0003	0.5	<0.00025	1.75	0.047	0.00055	<0.005	<0.005
mean [a]	9.7	0.00012	0.15	0.00050	1.69	0.019	0.0004	0.6	0.000118	1.78	0.054	0.00068	0.004	0.003
standard deviation (SD) [a]	4.2	0.00011	0.18	0.00028	0.88	0.030	0.0003	0.5	0.000123	0.65	0.020	0.00050	0.003	0.002
max detection limit	-	-	0.05	0.001	-	0.001	-	-	0.00025	-	-	0.001	0.005	0.005
# < detection limit	-	-	3	12	-	1	-	-	11	-	-	5	7	11
% < detection limit	-	-	20%	80%	-	6%	-	-	79%	-	-	33%	47%	69%
current drinking water quality criterion [b]	-	-	0.3	0.01	100	0.05	-	-	-	200	-	0.02	5	-
source [b]	-	-	Health Canada	Health Canada	BCMOE	Health Canada	-	-	-	Health Canada	-	Health Canada	Health Canada	-
# > current drinking water quality criterion	-	-	3	0	0	1	-	-	-	0	-	0	0	-
% > current drinking water quality criterion	-	-	20%	0%	0%	6%	-	-	-	0%	-	0%	0%	-
# < current drinking water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current drinking water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Table 6H-3 for information regarding the source of drinking water quality guidelines

Table C.48: Water quality data and summary statistics for drinking water station K8, Faro Mine, Yukon.

Date	Non-metals												Metals	
	Alkalinity, Total	Ammonia-N	Conductivity, Field	Hardness, Total ($CaCO_3$)	Nitrate-N	Organic carbon, Dissolved	Organic carbon, Total	pH, Field	Sulfate	Total dissolved solids	Total suspended solids	Turbidity, Lab	Cadmium, Total	Cadmium, Dissolved
Units	**mg/L**	**mg/L**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**pH units**	**mg/L**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**mg/L**
7-Jan-08	55.7	0.01		59				8.1	12.4		< 1	0.11		< 0.0002
18-Feb-08	71.9	0.01		65				7.8	12		< 1	0.13	< 0.0002	< 0.0002
17-Mar-08	< 0.5	0.02		76				7.8	13.5		< 1	0.11	< 0.0002	< 0.0002
14-Apr-08	70.1	0.02		86				8	13.8		< 1	0.19	< 0.0002	< 0.0002
14-May-08	44.3	< 0.01		69				8.4	19.8		< 1	0.41	< 0.0002	< 0.0002
16-Jun-08	17.8	< 0.01		18				8.4	2.43		< 1	0.25	< 0.0002	< 0.0002
14-Jul-08		0.01		23				8	4.14		3	0.62	< 0.0002	< 0.0002
11-Aug-08	48.5			43				8.2	8.2		< 1	0.6	< 0.0002	< 0.0002
15-Sep-08	33.8	0.03		33				8.2	7.68				< 0.0002	< 0.0002
15-Oct-08	47.5	< 0.01		47				7.8	10.3		< 1	0.17	< 0.0002	< 0.0002
3-Nov-08	47.7	0.02		62				7.9	12.1		< 1	0.17	0.0003	0.0003
1-Dec-08	52.3	< 0.01		78				8.4	13.1		< 1			< 0.0002
12-Jan-09	70.4	0.03		77				7.9	15		< 1	0.12		< 0.0002
2-Feb-09		< 0.01		77				8.4	15.2		< 1	0.13	< 0.0002	< 0.0002
19-Jul-09	44	< 0.01		49		1.9	2.1		8.8	78	< 1		0.00003	0.00002
3-Nov-10	53	0.041	59.7	56.6	0.05			7.91	11	74	< 4		0.000006	< 0.000005
18-May-11	30	0.02		42.8	0.12	17.7	15.7	7.4	14	88	8	2.23	0.00007	0.000071
28-May-12	33.4	0.025					8.29		8.64	62	< 1	0.63	0.0000262	0.0000242
28-Aug-12				34.4									0.000006	< 0.000005
24-Oct-12	46.9	0.013			0.0649				11.5	86	< 1			
n	17	18	1	18	3	2	3	16	19	5	18	14	16	19
minimum	<0.5	<0.01	-	18	0.05	1.9	2.1	7.4	2.43	62	<1	0.11	0.000006	<0.000005
maximum	71.9	0.041	-	86	0.12	17.7	15.7	8.4	19.8	88	8	2.23	0.0003	0.0003
median	47.5	0.012	-	58	0.06	9.8	8.3	8.0	12.0	78	<1	0.18	<0.0002	<0.0002
mean [a]	45.2	0.016	-	55	0.08	9.8	8.7	8.0	11.2	78	1	0.42	0.000090	0.00009
standard deviation (SD) [a]	18.5	0.011	-	20	0.04	11.2	6.8	0.3	4.0	10	2	0.56	0.000067	0.00006
max detection limit	0.5	0.01	-	-	-	-	-	-	-	-	4	-	0.0002	0.0002
# < detection limit	1	6	-	-	-	-	-	-	-	-	16	-	10	15
% < detection limit	6%	33%	-	-	-	-	-	-	-	-	89%	-	63%	79%
current drinking water quality criterion [b]	30 - 500	-	-	-	10	5	4	6.5 - 8.5	500	500	-	0.1 - 1.0	0.005	-
source [b]	OMOE	-	-	-	Health Canada	OMOE	BCMOE	Health Canada	Health Canada	Health Canada	-	Health Canada	Health Canada	-
# > current drinking water quality criterion	0	-	-	-	0	1	2	0	0	0	-	1	0	-
% > current drinking water quality criterion	0%	-	-	-	0%	50%	67%	0%	0%	0%	-	7%	0%	-
# < current drinking water quality criterion	2	-	-	-	-	-	-	0	-	-	-	0	-	-
% < current drinking water quality criterion	12%	-	-	-	-	-	-	0%	-	-	-	0%	-	-

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Table 6H-3 for information regarding the source of drinking water quality guidelines

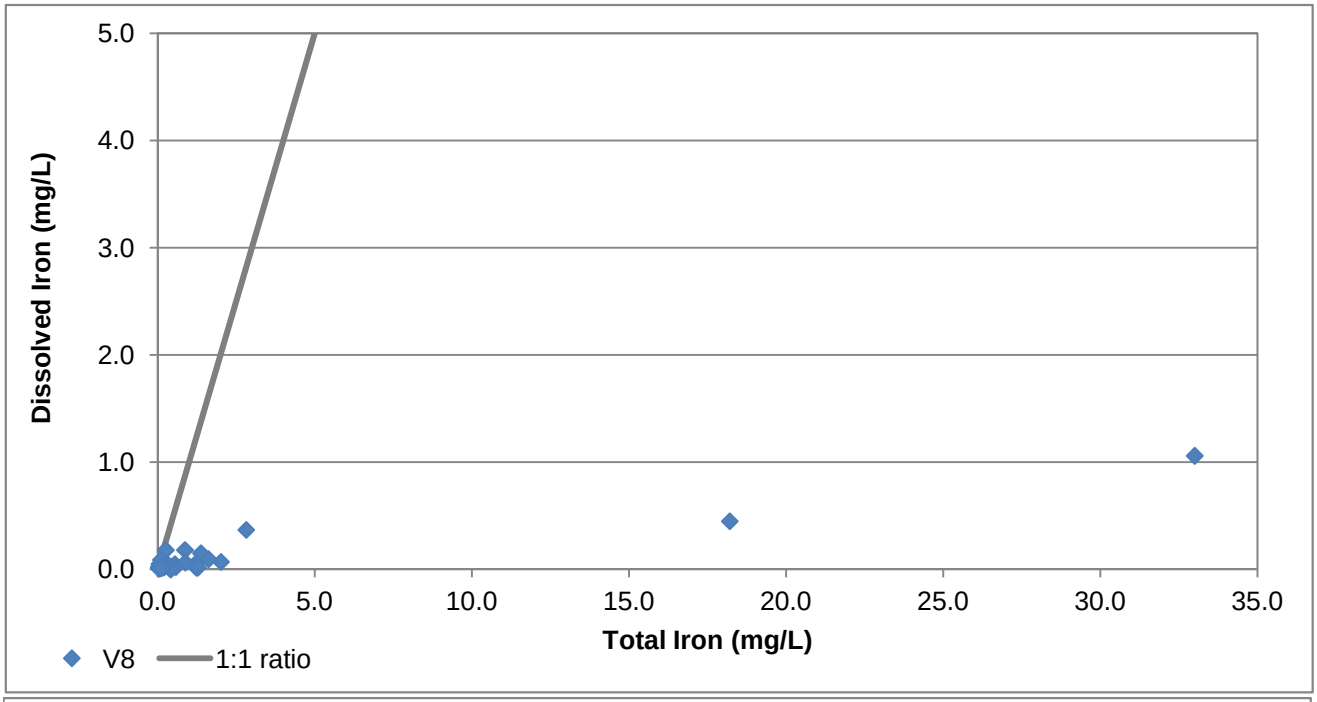
Table C.48: Water quality data and summary statistics for drinking water station K8, Faro Mine, Yukon.

Date	Metals													
	Calcium, Total	Cobalt, Total	Iron, Total	Lead, Total	Magnesium, Total	Manganese, Total	Nickel, Total	Potassium, Total	Silver, Total	Sodium, Total	Strontium, Total	Uranium, Total	Zinc, Total	Zinc, Dissolved
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
7-Jan-08	19.3	< 0.001	< 0.05	< 0.001	2.52		< 0.001	0.5	< 0.00025	1.91	0.12	0.0026	< 0.005	< 0.005
18-Feb-08	21.2	< 0.001	< 0.05	< 0.001	2.85	< 0.001	< 0.001	0.4	< 0.00025	2.37	0.13	0.0024	< 0.005	< 0.005
17-Mar-08	24	< 0.001	< 0.05	< 0.001	3.94	< 0.001		0.7	< 0.00025	2.8	0.14	0.0044	< 0.005	< 0.005
14-Apr-08	27.6	< 0.001	< 0.05	< 0.001	4.16	< 0.001	< 0.001	0.7	< 0.00025	3.06	0.18	0.0053	< 0.005	< 0.005
14-May-08	22.5	< 0.001	0.09	0.001	3.08	0.002	0.001	1.2	< 0.00025	1.74	0.13	0.0024	0.005	< 0.005
16-Jun-08	5.77	< 0.001	< 0.05	< 0.001	0.79	0.001	< 0.001	0.4	< 0.00025	1.28	0.032	< 0.0005	0.006	0.006
14-Jul-08	7.42	< 0.001	0.08	< 0.001	1.01	< 0.001	< 0.001	0.3	< 0.00025	1.38	0.044	< 0.0005	0.017	< 0.005
11-Aug-08	14	< 0.001		< 0.001	1.89	< 0.001	< 0.001	0.4	< 0.00025	1.77	0.08	0.0009	< 0.005	< 0.005
15-Sep-08	10.9	< 0.001	< 0.05	< 0.001	1.47	0.001	< 0.001	0.3	< 0.00025	1.66	0.08	0.0012	< 0.005	
15-Oct-08	15.6	< 0.001		< 0.001	1.88	< 0.001	< 0.001	0.4	< 0.00025	1.68	0.094	0.0015	< 0.005	< 0.005
3-Nov-08	20.1	< 0.001	< 0.05	< 0.001	2.88		< 0.001	0.6	0.0003	2.37	0.12	0.0025	< 0.005	< 0.005
1-Dec-08	25.6	< 0.001	< 0.05	< 0.001	3.3	< 0.001	< 0.001		< 0.00025	2.48	0.14	0.0032	< 0.005	< 0.005
12-Jan-09	25.4	< 0.001	< 0.05	< 0.001		< 0.001	< 0.001	0.6	< 0.00025	2.25	0.16	0.0047	< 0.005	< 0.005
2-Feb-09	25.3	< 0.001	0.05	< 0.001	3.44	< 0.001	< 0.001	0.6	< 0.00025	2.35	0.17	0.0046	< 0.005	< 0.005
19-Jul-09	15.7	< 0.0005	0.015	0.0007		0.002	< 0.001	0.54	< 0.00002	1.89	0.1	0.0012	< 0.005	< 0.005
3-Nov-10	18.4	0.000014	0.006	0.000052	2.58	0.00023		0.45	< 0.000005	2.01	0.122	0.00214	0.0006	0.0014
18-May-11	12.9	0.00047	0.553	0.00543	2.6	0.0166	0.0022	2.1	0.00002	1.2	0.0783	0.00103	0.017	0.0092
28-May-12	10.7	0.0000358		0.000486	1.62	0.00199	0.000549	1.27	0.0000079	1.13	0.0765	0.000954	0.00282	0.00819
28-Aug-12	11.3	0.000019	0.035	0.000119	1.51	0.000863	0.000243	0.376	< 0.000005	1.77	0.0646	0.000695	0.00085	0.00084
24-Oct-12														
n	19	4	16	19	17	17	17	18	19	19	19	19	19	18
minimum	5.77	0.000014	0.006	0.000052	0.79	0.00023	0.000243	0.3	<0.000005	1.13	0.032	<0.0005	0.0006	0.00084
maximum	27.6	0.00047	0.553	0.00543	4.16	0.0166	0.0022	2.1	0.0003	3.06	0.18	0.0053	0.017	0.0092
median	18.4	0.000027	<0.05	<0.001	2.58	<0.001	<0.001	0.5	<0.00025	1.89	0.120	0.00214	<0.005	<0.005
mean [a]	17.6	0.00013	0.07	0.00075	2.44	0.0018	0.0006	0.7	0.000104	1.95	0.108	0.00222	0.004	0.003
standard deviation (SD) [a]	6.6	0.00022	0.13	0.0011	0.99	0.0039	0.0004	0.5	0.000071	0.53	0.041	0.00158	0.005	0.002
max detection limit	-	-	0.05	0.001	-	0.001	0.001	-	0.00025	-	-	0.001	0.005	0.005
# < detection limit	-	-	9	13	-	9	13	-	16	-	-	2	12	13
% < detection limit	-	-	56%	68%	-	53%	76%	-	84%	-	-	11%	63%	72%
current drinking water quality criterion [b]	-	-	0.3	0.01	100	0.05	-	-	-	200	-	0.02	5	-
source [b]	-	-	Health Canada	Health Canada	BCMOE	Health Canada	-	-	-	Health Canada	-	Health Canada	Health Canada	-
# > current drinking water quality criterion	-	-	1	0	0	0	-	-	-	0	-	0	0	-
% > current drinking water quality criterion	-	-	6%	0%	0%	0%	-	-	-	0%	-	0%	0%	-
# < current drinking water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% < current drinking water quality criterion	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Value was reported as below detection limit (DL) but the DL was the maximum reported station value; therefore, the value was excluded from summary statistics

[a] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

[b] Refer to Table 6H-3 for information regarding the source of drinking water quality guidelines



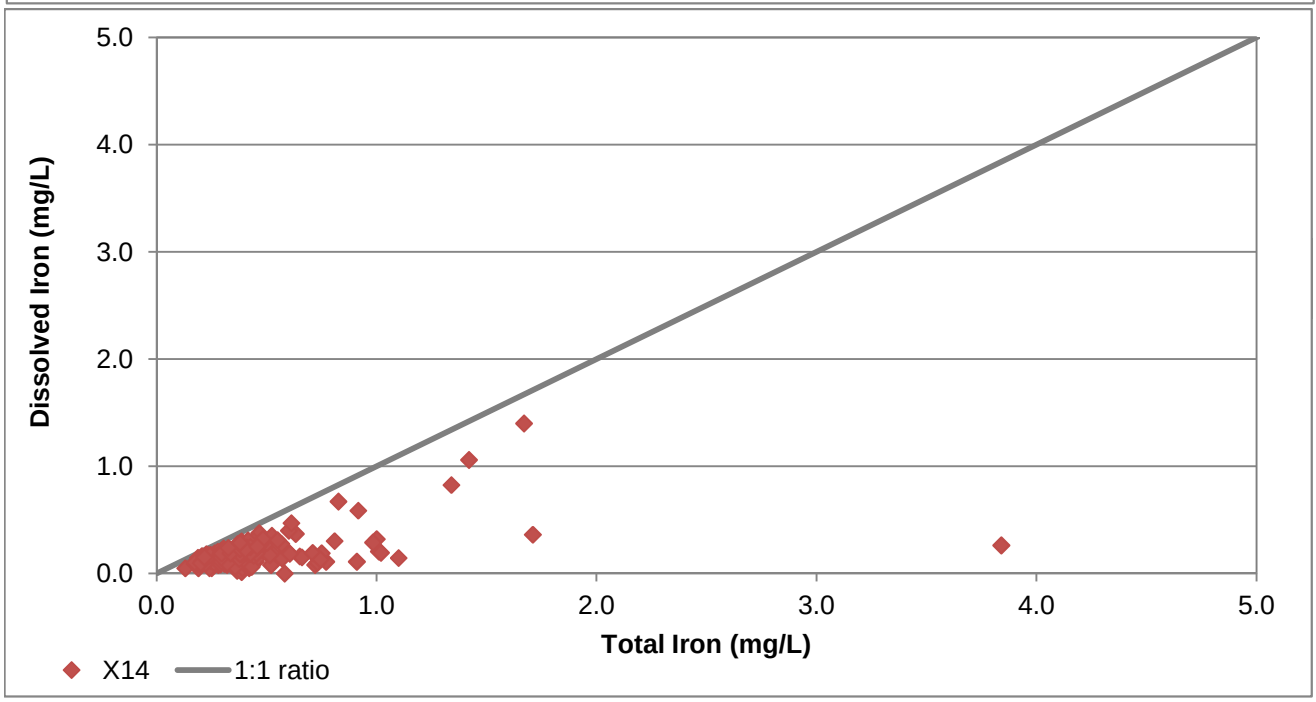


Figure C.1: Total versus dissolved iron at mine-exposed stations V8 and X14, 2008-2012.

ATTACHMENT D

SEDIMENT DATA

Table D.1: Rose-Anvil sediment chemistry data, mean values (n=3/area, unless otherwise noted) by year (1996 to 2008) for the 0.15mm fraction. Highlighted values exceeded Canadian Sediment Quality Guidelines.

Station	Year	Source	Metal (mg/kg)														
			Aluminum	Antimony	Arsenic	Barium	Berylium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese
		CSQG			17				3.5				197		91.3		
R1	1973	Hoos and Holman 1973 (n=1)[a]							23				64.0	34,000	280		700
	1983	Godin and Ostler 1985	15,900		15.4	297	0.54		0.81	6,580	35.7	13.6	25.6	25,542	161	5,915	1,122
	1996	Laberge 1997 (n=1)	10,900	2.0	6.0	195	0.90		0.60	5,300	27.0	9.0	21.0	20,900	74	4,500	1,419
	2004	Laberge 2004	11,533	0.3	12.1	175	1.00	1.00	0.73	4,463	31.7	12.0	18.3	20,667	125	4,947	1,590
	2006	Laberge 2006	7,997	10.0	10.0	98	1.00	1.00	0.50	2,513	17.0	9.3	10.0	14,700	23	3,567	1,123
	2008	Laberge 2009	19,100	1.6	33.5	369	1.17		2.83	7,160	48.3	24.2	51.5	46,067	357	8,410	3,030
R2	1973	Hoos and Holman 1973 (n=1)[a]							<15				24.0	29,000	83		460
	1983	Godin and Ostler 1985	15,450		85.5	3,320	0.48		1.21	8,445	51.4	31.1	116.0	59,725	665	7,060	1,053
	1996	Laberge 1997 (n=1)	12,100	3.0	32.0	399	1.00		1.60	7,900	50.0	16.0	60.0	33,800	310	7,200	2,808
	1999	YG unpublished? (n=6)	22,733	13.8	35.1	1,471	0.93	2.00	1.87	11,730	75.6	41.5	122.6	50,117	476	11,328	16,430
	2004	Laberge 2004	13,233	1.3	19.6	463	1.00	1.33	1.30	7,977	36.0	17.0	58.3	27,500	207	6,407	2,577
	2006	Laberge 2006	19,733	10.0	23.7	437	1.00	1.00	1.23	9,290	51.3	25.0	60.7	27,067	179	7,080	4,797
	2008	Minnow 2009 (n=1)	18,000	2.0	20.2	404	0.80		0.86		53.0	29.4	45.0	43,400	134	10,300	9,620
	2008	Laberge 2009	12,533	1.5	18.4	353	0.53		0.76	6,923	34.0	15.5	47.3	29,900	160	6,727	2,137
R3	1973	Hoos and Holman 1973 (n=1)[a]							<15				44.0	34,000	280		490
	1983	Godin and Ostler 1985	14,200		103.5	2,915	0.46		1.125	7,295	43.0	34.9	116.5	67,058	682	6,020	1,550
	1996	Laberge 1997 (n=1)	10,500	2.0	31.0	263	0.90		1.00	6,500	39.0	17.0	59.0	29,500	244	5,900	4,665
	1999	YG unpublished (n=6)	21,550	8.8	33.0	2,335	0.85	2.00	1.63	8,270	55.6	31.7	85.5	39,800	261	8,050	10,340
	2004	Laberge 2004	10,823	1.7	15.6	280	1.00	1.00	0.77	6,340	27.0	17.0	46.7	24,133	165	5,170	4,151
	2006	Laberge 2006	13,800	10.0	15.0	303	1.00	1.00	0.80	4,953	35.0	20.3	46.3	20,633	143	5,273	5,040
	2008	Laberge 2009	11,767	1.4	16.8	410	0.57		0.68	6,240	28.7	16.7	49.2	27,600	202	5,803	4,553
R4	1983	Godin and Ostler 1985	14,950		51.1	4,825	0.63		1.14	6,265	40.6	20.7	172.0	37,450	737	5,830	1,723
	1996	Laberge 1997 (n=1)	12,000	2.0	32.0	600	1.20		2.10	6,800	46.0	24.0	78.0	32,400	267	7,000	11,466
	2004	Laberge 2004	9,887	1.3	14.2	267	1.00	1.00	0.70	4,823	29.0	11.7	38.7	20,467	154	4,983	2,483
	2005	Access et al. 2006	14,000	<1	14.0	560	0.69	<1	1.20	6,600	45.0	20.0	48.0	30,000	170	7,300	6,100
	2006	Laberge 2006	15,027	10.0	14.0	419	1.00	1.00	0.97	5,887	46.0	22.7	47.0	21,400	120	6,127	5,927
	2008	Laberge 2009	9,530	0.9	10.6	295	0.30		0.37	4,823	30.7	10.4	26.4	19,233	64	6,247	1,557
R5	1973	Hoos and Holman 1973 (n=1)[a]							<15				93.0	45,000	650		590
	1996	Laberge 1997 (n=1)	13,600	3.0	14.0	308	0.90		0.80	6,500	45.0	13.0	35.0	26,500	20	7,300	1,855
	2004	Laberge 2004	10,057	0.9	11.4	253	1.00	1.00	0.90	5,450	35.0	11.0	42.3	20,267	69	4,810	1,518
	2005	Access et al. 2006	11,000	1.0	32.0	350	0.61		1.40	6,000	39.0	18.0	78.0	37,000	290	5,900	4,100
	2006	Laberge 2006	19,200	10.0	12.0	258	1.00	1.00	0.97	6,363	41.3	15.7	38.3	21,667	25	7,320	1,014
	2008	Laberge 2009	14,100	1.8	10.9	203	0.60		0.83	5,733	33.0	12.7	34.1	26,633	19	7,477	457
R6	1983	Godin and Ostler 1985	13,350		70.9	3,880	0.40		1.05	6,205	36.4	23.6	117.5	52,400	507	5,605	901
	1996	Laberge 1997 (n=1)	14,200	<2	9.0	238	0.90		1.00	6,900	45.0	13.0	34.0	26,500	11	7,600	1,222
	2004	Laberge 2004	8,817	0.9	12.2	142	1.00	1.00	0.63	4,690	21.3	8.7	20.0	18,700	11	4,293	890
	2005	Access et al. 2006	17,000	<1	15.0	360	0.86	<1	1.60	9,800	48.0	16.0	31.0	36,000	16	8,300	2,600
	2006	Laberge 2006	17,033	10.0	11.3	176	1.00	1.00	0.83	6,070	41.7	14.7	33.0	20,967	15	6,933	634
	2008	Laberge 2009	13,367	0.8	6.7	178	0.47		0.57	7,390	33.0	10.8	23.7	20,100	10	7,067	635
R7	1996	Laberge 1997 (n=1)	8,600	<2	10.0	173	0.70		0.40	4,000	20.0	4.0	14.0	18,400	18	3,500	887
	2004	Laberge 2004	10,703	0.6	11.9	162	1.00	1.00	0.53	4,410	21.3	9.0	17.3	19,367	15	4,287	809
	2006	Laberge 2006	14,093	10.0	11.3	165	1.00	1.00	0.57	4,127	24.7	10.7	17.3	18,233	15	4,387	745
	2008	Minnow 2009 (n=1)	10,400	0.6	8.6	192	0.40		0.23		19.0	8.0	13.0	22,400	13	3,690	576
	2008	Laberge 2009	8,900	0.4	5.2	116	0.47		0.23	3,817	16.0	6.3	12.8	15,867	10	3,507	319
R8	1973	Hoos and Holman 1973 (n=1)[a]							<15				68.0	71,000	830		500
	2006	Laberge 2006	20,600	10.0	12.7	209	1.00	1.00	1.07	6,490	44.7	17.3	47.0	23,300	17	7,767	773
A4	2004	Access et al. 2005[b]	10,500	1.0	11.5	453	0.42	0.50	0.71	5,020	50.7	13.5	24.0	25,300	98	5,640	3,580
	2005	Access et al. 2006	16,000	<1	14.0	760	0.78	<1	1.10	7,500	45.0	20.0	42.0	32,000	150	7,700	5,800
	2006	Access and Laberge 2007	16,367	1.4	16.4	512	0.67		0.83	6,043	38.3	13.6	42.6	30,067	66	7,673	1,937
A3	2004	Access et al. 2005[b]	11,100	1.4	13.0	326	0.47	0.80	0.73	6,170	42.1	10.8	26.8	24,500	62	6,360	1,020
	2005	Access et al. 2006	20,000	<1	12.0	380	1.00	<1	1.80	9,800	56.0	19.0	58.0	32,000	99	9,800	1,100
	2006	Access and Laberge 2007	16,000	0.8	15.7	493	0.68		0.77	8,350	49.1	12.2	122.6	26,667	44	8,840	2,140
A2	2004	Access et al. 2005[b]	12,200	1.0	13.6	500	0.52	0.60	0.78	6,800	55.1	10.7	27.5	25,600	53	7,080	862
	2005	Access et al. 2006	17,000	<1	12.0	580	0.92	<1	1.40	11,000	50.0	17.0	44.0	30,000	61	8,800	3,100
	2006	Access and Laberge 2007	14,900	0.7	14.8	551	0.64		0.79	8,890	44.0	10.6	92.4	25,733	35	7,863	1,455
A1	1973	Hoos and Holman 1973 (n=1)[a]							<15				100.0	27,000	175		500
	1983	Godin and Ostler 1985	13,900		14.7	1,395	0.28		1.5	15,750	69.2	13.4	29.8	25,400	50	8,780	745
	2004	Access et al. 2005[b]	9,840	1.3	11.0	287	0.37		0.46	7,210	29.5	7.5	18.0	21,200	19	6,130	381
	2006	Access and Laberge 2007	14,100	<0.5	12.3	482	0.55		0.61	11,327	42.3	9.5	82.7	24,233	20	8,107	872

[a] Analysis completed on bulk sample, not a fraction.

[b] Samples sieved using 2 mm mesh.

Table D.1: Rose-Anvil sediment chemistry data, mean values (n=3/area, unless otherwise noted) by year (1996 to 2008) for the 0.15mm fraction. Highlighted values exceeded Canadian Sediment Quality Guidelines.

Station	Year	Source	Metal (mg/kg)													
			Mercury	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silver	Sodium	Strontium	Thallium	Tin	Titanium	Vanadium	Zinc
		CSQG	0.486													315
R1	1973	Hoos and Holman 1973 (n=1)[a]														270
	1983	Godin and Ostler 1985	0.34	3.85	27.1	1,041	1,800		0.38	502	63.8		3.2	676	38.6	260
	1996	Laberge 1997 (n=1)	0.05	1.00	25.0	1,167	849	0.42	0.10	500	55.0			500	27.0	221
	2004	Laberge 2004	0.09	1.07	27.7	2,087	1,080	0.60	0.17	208	41.0	0.23	5.0	282	24.3	203
	2006	Laberge 2006	0.01	4.00	19.7	447	619	0.23	2.00	135	34.7		5.0	132	15.7	131
	2008	Laberge 2009	0.27	2.40	59.0	968	2,273	1.23	0.81	286	52.1	0.42	1.5	516	46.7	920
R2	1973	Hoos and Holman 1973 (n=1)[a]														180
	1983	Godin and Ostler 1985	1.05	8.44	38.9	1,012	2,300		1.16	442	63.7		<2	712	46.4	918
	1996	Laberge 1997 (n=1)	0.28	1.00	49.0	1,162	2,577	0.81	0.60	500	51.0			500	34.0	617
	1999	YG unpublished (n=6)	0.37	2.33	214.7	1,100	3,633	0.78	0.73	462	81.1		8.0	922	66.5	1,060
	2004	Laberge 2004	0.18	1.23	43.7	2,177	1,363	0.87	0.37	196	42.0	0.40	8.0	346	30.3	482
	2006	Laberge 2006	0.18	4.00	54.3	876	1,677	0.80	2.00	295	54.3		5.0	431	34.3	694
	2008	Minnow 2009 (n=1)	0.07	2.7	63.5	793	1,640	<0.5	0.28	329	57.8	0.34	3.8	361	39.0	546
	2008	Laberge 2009	0.15	1.5	38.3	1,062	986	<0.5	0.46	231	43.1	0.25	0.7	288	32.7	369
R3	1973	Hoos and Holman 1973 (n=1)[a]														440
	1983	Godin and Ostler 1985	1.06	9.30	32.3	1,025	1,925		1.42	416	57.8		<2	706	42.6	996
	1996	Laberge 1997 (n=1)	0.17	1.00	42.0	1,183	2,374	0.77	0.40	500	45.0			400	29.0	581
	1999	YG unpublished (n=6)	0.23	2.00	113.3	1,008	3,698	0.97	0.78	520	71.3		8.0	1,037	62.5	890
	2004	Laberge 2004	0.12	1.37	35.3	4,293	996	0.67	0.37	159	33.7	0.33	5.0	269	26.3	376
	2006	Laberge 2006	0.10	4.00	39.0	763	1,101	0.47	2.00	220	38.3		5.0	319	26.0	464
	2008	Laberge 2009	0.17	1.33	33.9	991	1,050	<0.5	0.49	239	42.3	0.30	0.8	318	29.7	424
R4	1983	Godin and Ostler 1985	1.03	7.79	32.5	1,060	2,260		1.12	469	63.6		4.0	753	45.4	885
	1996	Laberge 1997	0.11	2.00	66.0	1,043	1,048	0.61	0.90	700	57.0			500	35.0	908
	2004	Laberge 2004	0.11	1.30	31.3	2,887	855	0.57	0.33	169	31.3	0.27	5.0	293	26.3	294
	2005	Access et al. 2006	0.18	2.20	52.0	930	1,300	0.50	0.30	340	52.0	1.00	1.9	410	38.0	560
	2006	Laberge 2006	0.09	4.00	51.0	797	1,156	0.70	0.30	226	41.7		5.0	345	30.7	470
	2008	Laberge 2009	0.06	1.10	31.2	977	754	<0.5	0.22	181	30.7	0.15	0.5	250	31.7	184
R5	1973	Hoos and Holman 1973 (n=1)[a]														1,100
	1996	Laberge 1997 (n=1)	0.11	1.00	41.0	1,413	1,089	0.73	0.10	400	39.0			700	53.0	161
	2004	Laberge 2004	0.03	1.93	33.0	3,040	996	0.87	0.13	137	27.7	0.20	16.7	397	36.0	212
	2005	Access et al. 2006	0.34	2.20	44.0	1,200	990	0.50	0.40	270	45.0	0.84	3.6	380	39.0	470
	2006	Laberge 2006	0.04	4.00	43.3	1,173	1,247	0.73	2.00	236	36.7		5.0	490	55.0	149
	2008	Laberge 2009	<0.05	2.20	38.7	1,180	987	<0.5	0.29	178	32.0	0.20	0.6	377	60.3	154
R6	1983	Godin and Ostler 1985	0.95	8.70	24.7	1,012	1,750		1.32	399	28.8		<2	732	43.4	878
	1996	Laberge 1997 (n=1)	0.02	1.00	40.0	1,349	1,079	0.59	0.10	400	40.0			700	54.0	125
	2004	Laberge 2004	0.01	1.67	25.7	2,803	821	0.57	0.10	124	24.7	0.10	5.0	198	36.3	66
	2005	Access et al. 2006	0.05	1.50	48.0	1,400	1,600	0.50	0.30	360	56.0	<0.5	3.9	530	67.0	140
	2006	Laberge 2006	0.02	4.00	41.0	1,197	1,164	0.63	0.30	185	32.7		5.0	392	51.3	109
	2008	Laberge 2009	<0.05	1.00	33.3	1,107	1,137	<0.5	0.13	274	40.6	0.15	0.6	360	41.0	80
R7	1996	Laberge 1997 (n=1)	0.05	1.00	17.0	1,109	2,056	0.60	0.10	100	31.0			500	24.0	82
	2004	Laberge 2004	0.02	0.97	23.3	2,993	1,126	0.60	0.10	115	26.7	0.13	5.0	322	31.0	78
	2006	Laberge 2006	0.02	4.00	22.0	768	1,431	0.60	0.30	155	31.0		5.0	407	27.0	81
	2008	Minnow 2009 (n=1)	<0.05	0.80	17.9	741	1,360	0.5	0.10	148	29.2	0.15	0.7	396		63
	2008	Laberge 2009	<0.05	0.53	13.9	902	1,047	<0.5	0.09	141	28.4	0.14	0.6	301	23.0	56
R8	1973	Hoos and Holman 1973 (n=1)[a]														2,000
	2006	Laberge 2006	0.03	4.00	48.7	1,107	1,343	0.73	0.30	215	36.3		5.0	502	64.0	142
A4	2004	Access et al. 2005[b]	0.05	1.75	47.6	851	1,500	0.20	0.18	370	36.6	0.40	0.5	429	34.7	274
	2005	Access et al. 2006	0.14	2.20	52.0	1,100	1,500	0.20	0.18	370	57.0	1.00	1.0	480	50.0	430
	2006	Access and Laberge 2007	0.08	1.93	42.0	1,103	1,637	<0.3	0.33	327	41.3	<0.3	1.2	449	60.6	313
A3	2004	Access et al. 2005[b]	0.06	1.12	40.4	952	2,300	0.20	0.11	340	34.8	<0.2	0.5	453	39.6	184
	2005	Access et al. 2006	0.13	1.80	66.0	1,100	2,300	0.20	0.11	340	59.0	0.52	0.7	500	66.0	400
	2006	Access and Laberge 2007	0.07	1.53	55.5	949	2,247	<0.3	0.27	311	50.1	<0.3	9.2	447	52.6	221
A2	2004	Access et al. 2005[b]	0.06	1.08	45.5	933	2,300	0.20	0.16	300	41.5	<0.2	0.7	516	44.7	167
	2005	Access et al. 2006	0.04	1.30	59.0	1,000	2,300	0.20	0.16	300	62.0	1.20	0.7	460	58.0	300
	2006	Access and Laberge 2007	0.07	1.30	44.6	1,074	2,103	<0.3	0.23	300	48.6	<0.3	3.4	421	54.0	195
A1	1973	Hoos and Holman 1973 (n=1)[a]														275
	1983	Godin and Ostler 1985	0.13	4.50	43.4	1,335	2,020		0.83	425	70.3		8.0	1,020	61.4	145
	2004	Access et al. 2005[b]	0.04	0.77	30.8	765		<0.2	<0.05		37.1	<0.2	0.5	452	35.1	90
	2006	Access and Laberge 2007	0.05	1.06	38.4	1,110	2,013	<0.3	0.20	359	55.0	<0.3	1.4	466	49.1	133

[a] Analysis completed on bulk sample, not a fraction.

[b] Samples sieved using 2 mm mesh.

Table D.2: Vangorda sediment chemistry data, mean values (n=3/area, unless otherwise noted) by year (1995 to 2007) for the 0.15mm fraction. Highlighted values exceeded Canadian Sediment Quality Guidelines.

Station	Year	Source	Metal (mg/kg)										
			Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
		CSQG		17		3.5				197		91.3	
V-1	1995	Laberge 1996	14,333	30.3	232	0.8	5,000	40.3	12.0	33.3	30,767	43	5,500
	1997	Laberge 1998	14,000	25.7	240	0.6	3,900	27.7	12.3	53.0	27,333	58	4,800
	1999	Laberge 2000	17,237	28.1	284	0.7	5,304	59.5	20.0	39.2	40,230	45	7,187
	2001	Laberge 2002	12,949	11.9	107	0.5	3,995	30.1	10.0	18.9	23,863	18	5,684
	2003	Laberge 2003	14,884	20.5	149	1.0	5,311	30.6	12.1	26.0	24,864	37	4,547
	2005	Laberge 2005	9,947	10.0	67	0.5	1,757	17.0	9.7	17.0	15,533	19	4,007
	2007	Minnow 2009 (n=1)	16,100	16.2	130	0.5		26.0	17.2	28.4	34,100	25	
	2007	Laberge 2007	11,350	18.6	157	0.4	4,950	30.7	16.7	37.0	26,400	62	6,597
V-27	1995	Laberge 1996	7,150	109.0	144	1.3	7,350	43.0	21.5	65.0	29,200	2,707	6,350
	1997	Laberge 1998	11,167	104.7	266	1.4	6,533	48.0	26.7	87.7	37,867	1,492	7,900
	1999	Laberge 2000	11,089	152.4	366	2.3	6,448	43.3	21.6	128.9	42,859	2,069	8,700
	2001	Laberge 2002	11,817	108.8	105	1.9	9,040	52.9	23.9	101.5	39,031	2,801	10,118
	2003	Laberge 2003	12,461	86.6	194	2.2	6,948	43.3	24.3	74.4	30,375	1,384	8,908
	2005	Laberge 2005	12,967	24.3	106	1.0	9,003	40.3	15.3	36.3	20,033	188	8,277
	2007	Minnow 2009	14,100	44.8	271	2.4		44	23.7	55.1	35,067	342	
	2007	Laberge 2007	11,140	35.5	241	1.3	8,357	41	18.7	45.0	27,833	269	10,807
V-5	1995	Laberge 1996	6,100	34.3	181	1.0	14,667	36.3	9.7	36.3	18,233	52	9,000
	1997	Laberge 1998	8,700	21.7	347	0.3	20,133	44.0	11.7	35.7	20,900	35	11,000
	1999	Laberge 2000	7,030	14.5	269	0.2	16,484	34.8	9.9	24.9	18,142	30	8,611
	2001	Laberge 2002	8,040	12.2	209	0.9	15,185	44.9	9.3	28.3	19,332	32	9,504
	2003	Laberge 2003	7,425	12.2	138	0.5	14,382	52.5	11.8	22.5	16,710	25	11,142
	2005	Laberge 2005	10,020	10.3	138	0.9	19,433	51.3	13.7	25.0	16,667	21	11,767
	2007	Laberge 2007	8,013	12.2	290	0.7	19,200	52.7	14.0	31.0	20,967	25	12,733
V-8	1995	Laberge 1996	7,567	44.0	217	1.2	9,400	33.0	12.7	48.3	21,733	218	7,133
	1997	Laberge 1998	10,333	25.0	378	0.8	8,333	41.7	13.0	36.3	23,233	114	8,267
	1999	Laberge 2000	7,940	18.0	250	0.3	10,526	33.4	10.7	29.0	20,012	89	7,588
	2001	Laberge 2002	8,968	16.7	260	0.9	10,109	44.2	10.0	34.3	21,686	110	8,864
	2003	Laberge 2003	7,861	13.1	172	0.9	10,992	41.1	11.6	29.4	16,842	74	8,882
	2005	Laberge 2005	11,300	14.0	133	0.9	10,667	50.3	14.3	34.7	19,033	75	9,730
	2007	Laberge 2007	9,770	13.3	279	0.9	14,000	42.0	13.7	34.0	22,100	51	10,043

Table D.2: Vangorda sediment chemistry data, mean values (n=3/area, unless otherwise noted) by year (1995 to 2007) for the 0.15mm fraction. Highlighted values exceeded Canadian Sediment Quality Guidelines.

Station	Year	Source	Metal (mg/kg)										
			Manganese	Molybdenum	Nickel	Phosphorus	Potassium	Silver	Sodium	Strontium	Titanium	Vandium	Zinc
		CSQG											315
V-1	1995	Laberge 1996	753	2.3	40.3	1,077	1,339	0.30	200	43	733	28	177
	1997	Laberge 1998	966	1.3	26.7	969	1,200	0.17	400	35	500	27	132
	1999	Laberge 2000	1,508	3.0	49.1	1,110	1,756	0.10	329	44	708	36	141
	2001	Laberge 2002	396	1.1	27.6	702	1,013	0.11	285	30	390	25	88
	2003	Laberge 2003	759	1.2	23.6	1,082	1,992	0.11	260	39	506	29	132
	2005	Laberge 2005	335	4.0	18.7	394	734		87	13	138	16	60
	2007	Minnow 2009 (n=1)	736	0.8	32.7			0.14		21	247	25	108
	2007	Laberge 2007	668	0.5	37.7	698	885	0.20	130	29	215	26	131
V-27	1995	Laberge 1996	403	1.0	51.5	1,282	673	1.55	100	42	450	23	547
	1997	Laberge 1998	666	3.0	49.3	1,369	700	1.70	267	40	500	30	652
	1999	Laberge 2000	657	5.7	56.0	1,315	671	3.41	258	51	342	26	921
	2001	Laberge 2002	616	2.5	58.1	917	607	2.43	264	46	340	30	868
	2003	Laberge 2003	640	1.9	35.2	776	937	1.53	214	40	428	29	951
	2005	Laberge 2005	697	4.0	38.7	611	447		85	34	129	22	288
	2007	Minnow 2009	2,300	1.9	54.3			0.68		51	167	27	749
	2007	Laberge 2007	1,634	1.3	46.0	557	514	0.43	94	33	143	23	564
V-5	1995	Laberge 1996	402	2.0	55.3	1,291	630	0.40	100	61	300	21	133
	1997	Laberge 1998	487	2.0	53.7	1,483	800	0.10	300	82	400	30	100
	1999	Laberge 2000	384	2.1	44.6	1,119	606	0.10	250	64	363	25	81
	2001	Laberge 2002	469	2.0	57.2	1,118	635	0.12	401	63	311	28	116
	2003	Laberge 2003	422	1.2	43.8	954	665	0.10	305	66	402	29	80
	2005	Laberge 2005	452	4.0	70.3	885	442		114	60	139	26	86
	2007	Laberge 2007	466	1.7	73.0	1,019	676	0.17	111	61	164	29	113
V-8	1995	Laberge 1996	505	1.3	51.7	1,093	698	2.10	100	50	267	21	391
	1997	Laberge 1998	459	2.0	44.0	1,358	833	0.40	333	46	433	31	221
	1999	Laberge 2000	439	1.9	41.0	989	646	0.16	253	48	372	26	148
	2001	Laberge 2002	399	1.7	50.2	1,076	682	0.17	313	48	363	29	248
	2003	Laberge 2003	411	1.1	36.6	859	805	0.14	280	52	347	26	243
	2005	Laberge 2005	566	4.0	52.7	695	525		84	38	146	25	192
	2007	Laberge 2007	683	1.4	57.3	861	825	0.20	117	50	160	29	187

Table D.3: Sediment chemistry data from Pelly River Aquatic Effects Studies, 2004 and 2005 (Access et al. 2005, 2006).

Analyte	2004				2005											
	Anvil Creek A1	Anvil Creek A2	Anvil Creek A3	Anvil Creek A4	Anvil Creek A3		Anvil Creek A2		Anvil Creek A4		Anvil Creek R6		Anvil Creek R5		Rose Creek R4	
	10 mesh	10 mesh	10 mesh	10 mesh	10 mesh	100 mesh	10 mesh	100 mesh	10 mesh	100 mesh	10 mesh	100 mesh	10 mesh	100 mesh	10 mesh	100 mesh
	13-Aug-04	13-Aug-04	13-Aug-04	13-Aug-04	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05	5-Aug-05
pH	8.1	8.3	8	8	7.2	7.3	7.6	7.7	7.3	7.3	7.4	7.6	6.9	7.2	7	7.6
Aluminum	9,840	12,200	11,100	10,500	17,000	20,000	16,000	17,000	10,000	16,000	12,000	17,000	11,000	11,000	10,000	14,000
Antimony	1.3	1	1.4	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Arsenic	11	13.6	13	11.5	11	12	13	12	10	14	11	15	14	32	8.7	14
Barium	287	500	326	453	380	380	500	580	600	760	180	360	460	350	280	560
Beryllium	0.37	0.52	0.47	0.42	0.83	1	0.9	0.92	0.6	0.78	0.53	0.86	0.54	0.61	0.52	0.69
Bismuth	0.7	0.6	0.8	0.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	0.46	0.78	0.73	0.71	1.2	1.8	1.4	1.4	0.8	1.1	0.84	1.6	0.79	1.4	0.72	1.2
Calcium	7,210	6,800	6,170	5,020	7,700	9,800	11,000	11,000	5,000	7,500	5,400	9,800	4,200	6,000	3,700	6,600
Chromium	29.5	55.1	42.1	50.7	61	56	49	50	30	45	32	48	64	39	28	45
Cobalt	7.48	10.7	10.8	13.5	16	19	17	17	20	20	12	16	17	18	15	20
Copper	18	27.5	26.8	24	42	58	42	44	40	42	20	31	37	78	32	48
Iron	21,200	25,600	24,500	25,300	29,000	32,000	30,000	30,000	30,000	32,000	27,000	36,000	29,000	37,000	24,000	30,000
Lead	19.4	52.9	62	98	86	99	59	61	200	150	11	16	220	290	140	170
Lithium					33	37	31	32	20	29	21	29	22	20	19	26
Magnesium	6,130	7,080	6,360	5,640	9,800	9,800	9,000	8,800	7,000	7,700	6,300	8,300	7,200	5,900	5,700	7,300
Manganese	381	862	1,020	3,580	1,200	1,100	2,800	3,100	4,000	5,800	1,400	2,600	4,200	4,100	4,100	6,100
Mercury	0.04	0.06	0.06	0.05	0.087	0.13	0.084	0.044	0.1	0.14	0.017	0.047	0.064	0.34	0.051	0.18
Molybdenum	0.77	1.08	1.12	1.75	1.8	1.8	1.4	1.3	2	2.2	1.6	1.5	1.8	2.2	1.8	2.2
Nickel	30.8	45.5	40.4	47.6	59	66	63	59	40	52	37	48	47	44	41	52
Phosphorus	765	933	952	851	960	1,100	1,000	1,000	800	1,100	1,200	1,400	950	1,200	640	930
Potassium					1,900	2,300	2,200	2,300	1,000	1,500	940	1,600	910	990	950	1,300
Selenium	<0.2	<0.2	<0.2	<0.2	<0.50	<0.50	<0.50	<0.50	<0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Silicon	2,430	2,620	2,540	2,010	580	340	470	600	400	450	290	740	200	440	200	630
Silver	<0.05	0.16	0.11	0.18	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.5	<0.3	<0.3
Sodium					350	340	300	300	300	370	230	360	190	270	220	340
Strontium	37.1	41.5	34.8	36.6	50	59	62	62	40	57	37	56	37	45	39	52
Thallium	<0.2	<0.2	<0.2	0.4	0.61	0.52	0.9	1.2	1	1	<0.5	<0.5	0.6	0.84	<0.5	1
Tin	0.5	0.7	0.5	0.5	<0.5	0.66	<0.5	0.69	<0.5	1	<0.5	3.9	<0.5	3.6	<0.5	1.9
Titanium	452	516	453	429	430	500	450	460	400	480	240	530	230	380	210	410
Vanadium	35.1	44.7	39.6	34.7	54	66	56	58	40	50	52	67	32	39	29	38
Zinc	89.7	167	184	274	300	400	290	300	300	430	91	140	390	470	370	560
Zirconium	2.22	2.31	2.27	2.1	6.4	7.8	6.6	6.9	4	5	4.4	6.2	4.2	4.4	4.2	4.7

10 mesh = 2 mm seive size

100 mesh = 0.15 mm seive size

ATTACHMENT E

PERIPHYTON DATA

Table E.1: Raw periphyton data (# cells/sample) for communities sampled in 2009. Data from de Graff (2013).

FES Sample Number			090505	090506	090507	090508	090509	090510	090511	090512	090513	090514	090515	090516
Label Number			RD-Site 1	RD-Site 2	RD-Site 3	RD-Site 4	RD-Site 5	NF1-Site 1	NF1-Site 2	NF2-Site 1	NF2-Site 2	NF3-Site 1	NF3-Site 2	NF3-Site 3
Sampling Date			Aug. 30	Aug. 30	Aug. 29	Aug. 29	Aug. 28	Aug. 27	Aug. 29	Aug. 25	Aug. 25	Aug. 26	Aug. 27	Aug. 27
Area Sampled (cm^2)			400.5	400.5	400.5	400.5	400.5	400.5	320.4	240.3	320.4	400.5	400.5	400.5
# discs			5	5	5	5	5	5	4	3	4	5	5	5
Phylum	Order	Genera and Species												
Bacillariophyceae	Centrales	*Cyclotella sp.*				<60.0	<90.8	<39.7						
		Melosira spp.	588.0	268.8	1,596.4	360.0	1,271.2	555.8	1,818.0	2,262.4	1,680.0	166.2		<7.1
	Pennales	*Achnanthes flexella*	7,604.0	1,737.5	40,315.0	23,293.4	21,658.4	158.8	<101.0	141.4	<56.0	<13.9	<8.8	7.1
		Achnanthes lanceolata	1,140.6	347.5		465.6	1,407.0	615.2	202.0	1,095.8	434.4	27.7	52.8	14.2
		Achnanthes leavis	2,661.4	2,085.0	12,827.5	8,959.0	21,658.4	9,469.6	4,700.4	7,670.6	868.4		68.4	<7.1
		Achnanthes linearis	11,704.0	16,048.8	10,995.0	2,328.0	24,365.7	8,285.9	2,350.2	5,479.0	434.4	3,310.4	136.8	<7.1
		Achnanthes minutissima	392,084.0	393,195.6	469,120.0	401,363.2	768,873.2	262,781.4	1,024,998	354,202.8	230,708.4	96,001.6	31,034.0	494.1
		Achnanthes spp.	4,389.0	9,361.8	21,990.0	14,334.4	8,121.9	4,734.8	6,029.4	12,650.1	3,343.6	5,379.4	1,315.0	54.9
		Amphipleura pellucida	490.0	537.6	8,571.6	3,724.8	2,814.0	238.2	202.0	141.4	224.0	27.7	17.6	
		Amphora spp.	<49.0	<44.8	61.4	240.0	726.4	39.7	101.0	<141.4	<56.0		<8.8	
		Anomoeoneis spp.	1,901.0	1,390.0	95,290.0	89,590.0	37,902.2		<101.0					<7.1
		Caloneis spp.	2,281.2	448.0	9,524.0	480.0	3,517.5	317.6	202.0	282.8	224.0	138.5	<8.8	<7.1
		Ceratoneis arcus	7,315.0	695.0	2,857.2	931.2	3,517.5	2,153.2	10,184.2	6,574.8	16,718.0	1,505.0	6,575.0	3,380.8
		Cocconies placentula	490.0	44.8	368.4	360.0	726.4	1,538.0	6,267.2	7,670.6	2,172.0	537.5	342.0	71.0
		Cymatopleura elliptica				<60.0	90.8	<39.7		<141.4				
		Cymatopluera solea	<49.0		<61.4	60.0	<90.8	<39.7	<101.0	<141.4	<56.0			
		Cymbella cestaii	90.8	179.2	245.6	720.0	1,407.0							
		Cymbella cistula	98.0	89.6	736.8	840.0	2,905.6	<39.7	<101.0	<141.4	<56.0		<8.8	
		Cymbella lanceolata	<49.0	<44.8	<61.4	<60.0	<90.8	<39.7		<141.4			<8.8	
		Cymbella mexicana		<44.8	<61.4	<60.0	<90.8							
		Cymbella minuta	81,928.0	28,085.4	98,955.0	78,839.2	124,535.8	63,919.8	217,058.4	151,801.2	106,995.2	19,034.8	33,664.0	3,169.5
		Cymbella sinuata	1,140.6	268.8	2,857.2	360.0	2,110.5	922.8	3,133.6	5,497.0	868.8	83.1	<8.8	109.8
		Cymbella spp.	4,182.2	2,085.0	18,325.0	19,709.8	13,536.5	<39.7	<101.0	<141.4	168.0	110.8	17.6	
		Denticula sp.	1,140.6	1,042.5	1,904.8	4,190.4	703.5							
		Diatoma elongatum	58,520.0	16,048.8	29,320.0	35,836.0	75,804.4	158.8	3,917.0		868.8	27.7		<7.1
		Diatoma hiemale					<90.8				<56.0	<13.9	<8.8	
		Diatoma mesodon	196.0	<44.8	122.8	120.0	181.6	238.2	606.0	<141.4	<56.0	55.4	<8.8	<7.1
		Diatoma sp.	49.0	<44.8	<61.4				<101.0					
		Diatomella sp.					<90.8							
		Didymosphenia geminata	294.0	179.2	245.6	600.0	544.8	158.8	1,010.0	565.6	358.4	193.9	2,464.0	<7.1
		Diploneis spp.	196.0	89.6	368.4	480.0	1,089.6	<39.7	<101.0	<141.4	<56.0	<13.9		<7.1
		Epithemia turgida	49.0	<44.8	<61.4	<60.0	90.8	79.4	101.0	<141.4	<56.0	27.8	<8.8	
		Epithemia sp.						<39.7	<101.0					
		Eunotia spp.	588.0	448.0	491.2	<60.0	908.0	158.8	808.0	<141.4	<56.0	55.4	<8.8	<7.1
		Fragilaria capucina	147.0	<44.8	<61.4	1,680.0	2,179.2	79.4	303.0	1,131.2	784.0	387.8	140.8	35.5
		Fragilaria construens	3,041.6	1,737.5	11,905.0	15,830.4	15,477.0	11,837.0	18,801.6	25,300.2	21,733.4	2,896.6	342.0	42.6
		Fragilaria crotonensis			2,381.0	600.0	1,407.0							
		Fragilaria leptostauron	392.0	695.0	2,381.0	480.0	908.0	158.8	202.0	282.8	336.0	83.1	17.6	
		Fragilaria pinnata	1,520.8	3,822.5	11,905.0	12,571.2	9,145.5	2,153.2	3,133.6	5,479.0	2,172.0	1,655.2		
		Fragilaria vaucheria	19,019.0	1,042.5	5,497.5	10,750.8	27,073.0	44,980.6	120,588.0	126,501.0	110,338.8	2,896.6	4,734.0	1,482.3
		Fragilaria spp.	57,057.0	22,735.8	14,660.0	30,460.6	40,609.5	40,245.8	355,734.6	371,069.6	117,026.0	16,552.0	9,205.0	1,043.1
		Frustulia sp.	49.0	<44.8	122.8	<60.0	181.6	79.4	1,818.0	1,696.8	224.0	97.3	<8.8	
		Gomphonema acuminata	<49.0	<44.8	61.4									<7.1
		Gomphonema angustatum/parvulum	1,140.6	347.5	4,285.8	465.6	3,517.5	2,460.8	16,451.4	4,383.2	3,909.6	537.5	205.2	219.6
		Gomphonema brebissonii	588.0	358.4	368.4	240.0	90.8	238.2	606.0	282.8	224.0	138.5	35.2	<7.1
		Gomphonema olivaceum	1,901.0	<44.8	476.2	<60.0	1,407.0	922.8	3,133.6	1,095.8	1,303.2	322.5	205.2	274.5
		Gomphonema truncatum		<44.8										
		Gomphonema spp.	1,520.8	8,024.4	3,333.4	1,862.4	3,517.5	1,538.0	6,267.2	3,287.4	868.8	752.5	273.6	329.4
		Gyrosigma sp.			<61.4	<60.0	<90.8							
		Meridion circulare	686.0	<44.8	736.8	600.0	2,110.5	1,230.4	2,350.2	2,262.4	1,737.6	304.7	52.8	21.3
		Navicula aurora		<44.8	<61.4	<60.0			<101.0	<141.4	<56.0	<13.9		
		Navicula cryptonella	3,041.6	347.5	1,904.8	3,259.2	21,658.4	3,998.8	4,700.4	4,382.8	11,702.6	1,182.5	342.0	42.6
		Navicula cuspidata			<61.4	<60.0				<141.4	<56.0			
		Navicula radiosa	490.0	268.8	1,719.2	1,440.0	7,990.4	1,349.8	5,656.0	2,828.0	5,600.0	415.5	334.4	7.1
		Navicula spp.	5,703.0	1,390.0	18,325.0	12,542.6	75,804.4	5,918.5	19,585.0	21,083.5	10,030.8	1,827.5	136.8	42.6
		Neidium spp.							<101.0	<141.4				
		Nitzschia acicularis						307.6		<141.4			<8.8	
		Nitzschia dissipata	1,463.0		952.4	2,328.0	5,414.6	7,102.2	5,483.8	4,383.2	6,687.2	1,655.2	478.8	164.7
		Nitzschia palea	760.4	695.0	10,995.0	8,959.0	16,243.8	8,285.9	9,400.8	8,766.4	10,030.8	2,482.8	136.8	109.8
		Nitzschia spp.	70,224.0	14,711.4	67,802.5	39,419.6	89,340.9	35,511.0	13,317.8	67,467.2	66,872.0	21,517.6	3,156.0	988.2
		Pinnularia spp.	588.0	179.2	368.4	240.0	2,110.5	238.2	606.0	848.4	224.0	55.4	<8.8	<7.1
		Rhoicosphenia curvata	<49.0					79.4	202.0	141.4	56.0	<13.9		
		Rhopalodia gibba	<49.0	<44.8	245.6	60.0	90.8					<13.9		
		Stauroneis sp.	<49.0	<44.8	<61.4	<60.0	<90.8	<39.7	<101.0	<141.4	<56.0	<13.9		<7.1
		Surirella spp.	49.0	89.6	184.2	240.0	363.2	39.7	101.0	<141.4	56.0	<13.9		
		Synedra ulna	14,630.0	7,645.0	23,822.5	16,126.2	35,194.9	7,960.0	21,102.9	37,950.3	30,092.4	4,138.0	4,997.0	494.1
		Synedra spp.	49,742.0	6,687.0	45,812.5	35,836.0	119,121.2	47,348.0	42,205.8	59,033.8	76,902.8	7,448.4	2,630.0	1,427.4
		Tabellaria fenestrata	98.0	358.4	61.4	360.0	726.4	<39.7	<101.0	<141.4	<56.0	<13.9		
		Tabellaria flocculosa	392.0	268.8	614.0	720.0	363.2	79.4	<101.0	<141.4	112.0	<13.9		<7.1
		UID girdle view												54.9
Chlorophyta	Chaetophorales	*Stigeoclonium sp.*					<90.8					249.3	1,504.8	227.2
		UID Chaetophorales							<101.0		<56.0		2,599.2	113.6
	Chlorococcales	*Ankistrodesmus spp.*	<49.0		1,428.6	4,190.4	1,407.0	1,538.0	783.4		1,303.2	430.0	615.6	164.7
		Selanastrum spp.				240.0		158.8	<101.0		112.0	55.4		<7.1
		Scenedesmus spp	<49.0	89.6	<61.4	300.0	1,089.6	<39.7						
		Tetraedron minimum						<39.7						
	Oedogoniales	*Oedogonium spp.*	441.0	224.0	245.6	480.0	363.2		<101.0			<13.9		
	Ulothricales	*Geminella sp.?*										<13.9		
		Microspora sp.			<61.4	1,440.0	908.0	1,349.8	35,253.0	70,131.2	16,128.0	<13.9	44.0	
		Ulothrix zonata					<90.8		<101.0		2,016.0	110.8	2,358.4	63.9
		Ulothrix spp.						<39.7			<56.0	166.2	668.8	<7.1
		Ulothrix sp. ?					<90.8							
	Zygnematales	*Closterium spp*	196.0	268.8	614.0	840.0	1,089.6	635.2	4,444.0	1,979.6	3,136.0	720.2	193.6	<7.1
		Cosmarium spp.	49.0	44.8	184.2	720.0	544.8	<39.7	<101.0	<141.4	<56.0	<13.9	<8.8	
		Euastrum sp.									<56.0			
		Hyalotheca sp.				<60.0						<13.9		
		Mougeotia spp.	98.0	358.4	4,762.0	8,846.4	4,221.0	39.7			<56.0	55.4	<8.8	<7.1
		Spirogyra sp									<56.0			
		Staurastrum spp.	98.0	44.8	122.8	120.0	<90.8	79.4	606.0	1,414.0	560.0	13.9	8.8	<7.1
		Teilingia granulata				<60.0	<90.8							
Chlorophyta		UID Chlorophyta colonial						238.2		<141.4	<56.0	<13.9	1,573.2	1,866.6
		UID Chlorophyta flagellate					703.5	615.2		1,095.8	434.4	83.1	52.8	7.1
		UID Chlorophyta unicellular	380.2	347.5		465.6	1,407.0	2,153.2	<101.0		868.8	430.0	615.6	219.6

Table E.1: Raw periphyton data (# cells/sample) for communities sampled in 2009. Data from de Graff (2013).

FES Sample Number			090505	090506	090507	090508	090509	090510	090511	090512	090513	090514	090515	090516
Label Number			RD-Site 1	RD-Site 2	RD-Site 3	RD-Site 4	RD-Site 5	NF1-Site 1	NF1-Site 2	NF2-Site 1	NF2-Site 2	NF3-Site 1	NF3-Site 2	NF3-Site 3
Sampling Date			Aug. 30	Aug. 30	Aug. 29	Aug. 29	Aug. 28	Aug. 27	Aug. 29	Aug. 25	Aug. 25	Aug. 26	Aug. 27	Aug. 27
Area Sampled (cm^2)			400.5	400.5	400.5	400.5	400.5	400.5	320.4	240.3	320.4	400.5	400.5	400.5
# discs			5	5	5	5	5	5	4	3	4	5	5	5
Phylum	Order	Genera and Species												
Chrysophyta	Chromulinales	*Chrysococcus sp.*			122.8	465.6								<7.1
	Mischococcales	*Ophiocytium sp.*							<101.0					
	Ochromonadales	*Pseudokephyrion sp.*		<44.8		600.0	181.6							
		Hyalobryon sp.					90.8							
		UID Chrysophyte colonial			491.2							860.0		84,027.5
		UID Chrysophyte cyst	7,315.0	1,390.0	2,381.0	4,190.4	3,517.5	4,306.4	5,483.8	7,670.6	3,475.2	322.5		<7.1
		UID Chrysophyte unicellular				120.0	703.5		202.0					
Cryptophyta	Cryptomonadales	UID Cryptomonadales				60.0	363.2	<39.7						
Cyanophyta	Chamaesiphonales	*Chamaesiphon spp.*	14,630.0	26,748.0	9,162.5	7,449.6		15,388.1	45,220.5	4,216.7	35,107.8	48,000.8	81,530.0	352,640.0
		Clastidium setigerum										413.8	13,676.0	31,682.5
	Chroococcales	*Aphanocapsa sp.*			<61.4	<60.0		<39.7						
		Aphanothece sp.		4,170.0		2,880.0		<39.7						
		Chroococcus sp. ?				<60.0	4,221.0							
		Gloeothece sp.				<60.0								
		Gomphosphaeria sp.				2,880.0	<90.8							
		Merismopedia sp.	<49.0	<44.8	<61.4	360.0	726.4				<56.0			
		Microcystis sp.		<44.8										
		UID Chrooccocales		5,349.6	1,904.8	5,375.4							<8.8	
	Nostocales	*Anabaena / Nostoc sp.*									<56.0	<13.9		
		Calothrix / Rivularia sp.		<44.8	<61.4	1,080.0	2,179.2							<7.1
		Nostoc sp.			<61.4			<39.7				<13.9		
		Tolypothrix sp.		<44.8										
		UID Nostocales	<49.0		<61.4									<7.1
	Oscillatoriales	*Homoeothrix varians*		5,560.0		<60.0	11,256.0	21,839.6	49,354.2		38,661.6	147,312.8	911,032.0	1,997,375
		Lyngbya spp.										4,192.5		
		Oscillatoria spp.												2,196.0
		Phormidium sp.	13,307.0					5,844.4	2,828.0			29,379.8	9,028.8	7,576.2
		Pseudanabaena spp.		7,645.0	16,667.0	670,133.2	341,119.8	22,762.4		848.4	7,819.2	4,945.0	9,468.0	384.3
		UID Oscillatoriales	7,223.8	1,612.8	13,809.8	3,000.0	31,657.5	3,691.2	<101.0	1,696.8	10,860.0	12,414.0	9,205.0	2,031.3
Euglenophyta	Euglenales	UID Euglenales					<90.8							
Rhodophyta	Nemalionales	*Audouinella sp.*				<60.0	51,438.7	<39.7	28,202.4	4,524.8	13,552.0	858.7	23,144.0	1,098.0
		Batrachospermum sp.		<44.8	614.0	<60.0	544.8		808.0					
		Lemanea sp.	286,290.6	112,242.5	7,143.0	3,724.8	726.4	2,858.4	409,999.2	21,775.6	5,040.0	50,632.5	<8.8	<7.1
UID colonial				<44.8		480.0	<90.8		<101.0		<56.0			
UID filamentous						<60.0								
UID flagellate						465.6								
UID unicellular			380.2	1,337.4	3,665.0	12,542.6	10,829.2	4,734.8	12,058.8	16,866.8	6,687.2	827.6	1,315.0	633.9

UID = unidentified due to lack of size and / or missing morphological characters.

? = possibly for genus

Synonyms:

Diatoma mesodon = Diatoma hiemale var. mesodon

Table E.2: Quantitative periphyton data converted to cells per cm^2. Data from de Graff (2013).

Phylum	Order	Genera and Species	RD-1	RD-2	RD-3	RD-4	RD-5	NF1-1	NF1-2	NF2-1	NF2-2	NF3-1	NF3-2	NF3-3
Bacillariophyceae	Centrales	Cyclotella sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Melosira spp.	1.47	0.67	3.99	0.90	3.17	1.39	5.67	9.41	5.24	0.41	0.00	0.00
	Pennales	Achnanthes flexella	18.99	4.34	100.66	58.16	54.08	0.40	0.00	0.59	0.00	0.00	0.00	0.02
		Achnanthes lanceolata	2.85	0.87	0.00	1.16	3.51	1.54	0.63	4.56	1.36	0.07	0.13	0.04
		Achnanthes leavis	6.65	5.21	32.03	22.37	54.08	23.64	14.67	31.92	2.71	0.00	0.17	0.00
		Achnanthes linearis	29.22	40.07	27.45	5.81	60.84	20.69	7.34	22.80	1.36	8.27	0.34	0.00
		Achnanthes minutissima	978.99	981.76	1171.34	1002.16	1919.78	656.13	3199.12	1474.00	720.06	239.70	77.49	1.23
		Achnanthes spp.	10.96	23.38	54.91	35.79	20.28	11.82	18.82	52.64	10.44	13.43	3.28	0.14
		Amphipleura pellucida	1.22	1.34	21.40	9.30	7.03	0.59	0.63	0.59	0.70	0.07	0.04	0.00
		Amphora spp.	0.00	0.00	0.15	0.60	1.81	0.10	0.32	0.00	0.00	0.00	0.00	0.00
		Anomoeoneis spp.	4.75	3.47	237.93	223.70	94.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Caloneis spp.	5.70	1.12	23.78	1.20	8.78	0.79	0.63	1.18	0.70	0.35	0.00	0.00
		Ceratoneis arcus	18.26	1.74	7.13	2.33	8.78	5.38	31.79	27.36	52.18	3.76	16.42	8.44
		Cocconies placentula	1.22	0.11	0.92	0.90	1.81	3.84	19.56	31.92	6.78	1.34	0.85	0.18
		Cymatopleura elliptica	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymatopluera solea	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella cestaii	0.23	0.45	0.61	1.80	3.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella cistula	0.24	0.22	1.84	2.10	7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella lanceolata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella mexicana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella minuta	204.56	70.13	247.08	196.85	310.95	159.60	677.46	631.72	333.94	47.53	84.05	7.91
		Cymbella sinuata	2.85	0.67	7.13	0.90	5.27	2.30	9.78	22.88	2.71	0.21	0.00	0.27
		Cymbella spp.	10.44	5.21	45.76	49.21	33.80	0.00	0.00	0.00	0.52	0.28	0.04	0.00
		Denticula sp.	2.85	2.60	4.76	10.46	1.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Diatoma elongatum	146.12	40.07	73.21	89.48	189.27	0.40	12.23	0.00	2.71	0.07	0.00	0.00
		Diatoma hiemale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Diatoma mesodon	0.49	0.00	0.31	0.30	0.45	0.59	1.89	0.00	0.00	0.14	0.00	0.00
		Diatoma sp.	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Diatomella sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Didymosphenia geminata	0.73	0.45	0.61	1.50	1.36	0.40	3.15	2.35	1.12	0.48	6.15	0.00
		Diploneis spp.	0.49	0.22	0.92	1.20	2.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Epithemia turgida	0.12	0.00	0.00	0.00	0.23	0.20	0.32	0.00	0.00	0.07	0.00	0.00
		Epithemia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Eunotia spp.	1.47	1.12	1.23	0.00	2.27	0.40	2.52	0.00	0.00	0.14	0.00	0.00
		Fragilaria capucina	0.37	0.00	0.00	4.19	5.44	0.20	0.95	4.71	2.45	0.97	0.35	0.09
		Fragilaria construens	7.59	4.34	29.73	39.53	38.64	29.56	58.68	105.29	67.83	7.23	0.85	0.11
		Fragilaria crotonensis	0.00	0.00	5.95	1.50	3.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Fragilaria leptostauron	0.98	1.74	5.95	1.20	2.27	0.40	0.63	1.18	1.05	0.21	0.04	0.00
		Fragilaria pinnata	3.80	9.54	29.73	31.39	22.84	5.38	9.78	22.80	6.78	4.13	0.00	0.00
		Fragilaria vaucheria	47.49	2.60	13.73	26.84	67.60	112.31	376.37	526.43	344.38	7.23	11.82	3.70
		Fragilaria spp.	142.46	56.77	36.60	76.06	101.40	100.49	1110.28	1544.19	365.25	41.33	22.98	2.60
		Frustulia sp.	0.12	0.00	0.31	0.00	0.45	0.20	5.67	7.06	0.70	0.24	0.00	0.00
		Gomphonema acuminata	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gomphonema angustatum/parvulum	2.85	0.87	10.70	1.16	8.78	6.14	51.35	18.24	12.20	1.34	0.51	0.55
		Gomphonema brebissonii	1.47	0.89	0.92	0.60	0.23	0.59	1.89	1.18	0.70	0.35	0.09	0.00
		Gomphonema olivaceum	4.75	0.00	1.19	0.00	3.51	2.30	9.78	4.56	4.07	0.81	0.51	0.69
		Gomphonema truncatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gomphonema spp.	3.80	20.04	8.32	4.65	8.78	3.84	19.56	13.68	2.71	1.88	0.68	0.82
		Gyrosigma sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Meridion circulare	1.71	0.00	1.84	1.50	5.27	3.07	7.34	9.41	5.42	0.76	0.13	0.05
		Navicula aurora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Navicula cryptonella	7.59	0.87	4.76	8.14	54.08	9.98	14.67	18.24	36.52	2.95	0.85	0.11
		Navicula cuspidata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Navicula radiosa	1.22	0.67	4.29	3.60	19.95	3.37	17.65	11.77	17.48	1.04	0.83	0.02
		Navicula spp.	14.24	3.47	45.76	31.32	189.27	14.78	61.13	87.74	31.31	4.56	0.34	0.11
		Neidium spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Nitzschia acicularis	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.00	0.00	0.00	0.00
		Nitzschia dissipata	3.65	0.00	2.38	5.81	13.52	17.73	17.12	18.24	20.87	4.13	1.20	0.41
		Nitzschia palea	1.90	1.74	27.45	22.37	40.56	20.69	29.34	36.48	31.31	6.20	0.34	0.27
		Nitzschia spp.	175.34	36.73	169.29	98.43	223.07	88.67	41.57	280.76	208.71	53.73	7.88	2.47
		Pinnularia spp.	1.47	0.45	0.92	0.60	5.27	0.59	1.89	3.53	0.70	0.14	0.00	0.00
		Rhoicosphenia curvata	0.00	0.00	0.00	0.00	0.00	0.20	0.63	0.59	0.17	0.00	0.00	0.00
		Rhopalodia gibba	0.00	0.00	0.61	0.15	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Stauroneis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Surirella spp.	0.12	0.22	0.46	0.60	0.91	0.10	0.32	0.00	0.17	0.00	0.00	0.00
		Synedra ulna	36.53	19.09	59.48	40.27	87.88	19.88	65.86	157.93	93.92	10.33	12.48	1.23
		Synedra spp.	124.20	16.70	114.39	89.48	297.43	118.22	131.73	245.67	240.02	18.60	6.57	3.56
		Tabellaria fenestrata	0.24	0.89	0.15	0.90	1.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Tabellaria flocculosa	0.98	0.67	1.53	1.80	0.91	0.20	0.00	0.00	0.35	0.00	0.00	0.00
		UID girdle view	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Chlorophyta	Chaetophorales	Stigeoclonium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	3.76	0.57
		UID Chaetophorales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.49	0.28
	Chlorococcales	Ankistrodesmus spp.	0.00	0.00	3.57	10.46	3.51	3.84	2.45	0.00	4.07	1.07	1.54	0.41
		Selanastrum spp.	0.00	0.00	0.00	0.60	0.00	0.40	0.00	0.00	0.35	0.14	0.00	0.00
		Scenedesmus spp	0.00	0.22	0.00	0.75	2.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Tetraedron minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oedogoniales	Oedogonium spp.	1.10	0.56	0.61	1.20	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ulothricales	Geminella sp.?	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Microspora sp.	0.00	0.00	0.00	3.60	2.27	3.37	110.03	291.85	50.34	0.00	0.11	0.00
		Ulothrix zonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.29	0.28	5.89	0.16
		Ulothrix spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	1.67	0.00
		Ulothrix sp. ?	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Zygnematales	Closterium spp	0.49	0.67	1.53	2.10	2.72	1.59	13.87	8.24	9.79	1.80	0.48	0.00
		Cosmarium spp.	0.12	0.11	0.46	1.80	1.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Euastrum sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Hyalotheca sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Mougeotia spp.	0.24	0.89	11.89	22.09	10.54	0.10	0.00	0.00	0.00	0.14	0.00	0.00
		Spirogyra sp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Staurastrum spp.	0.24	0.11	0.31	0.30	0.00	0.20	1.89	5.88	1.75	0.03	0.02	0.00
		Teilingia granulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Unknown	UID Chlorophyta colonial	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	3.93	4.66
		UID Chlorophyta flagellate	0.00	0.00	0.00	0.00	1.76	1.54	0.00	4.56	1.36	0.21	0.13	0.02
		UID Chlorophyta unicellular	0.95	0.87	0.00	1.16	3.51	5.38	0.00	0.00	2.71	1.07	1.54	0.55
Chrysophyta	Chromulinales	Chrysococcus sp.	0.00	0.00	0.31	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mischococcales	Ophiocytium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ochromonadales	Pseudokephyrion sp.	0.00	0.00	0.00	1.50	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Hyalobryon sp.	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		UID Chrysophyte colonial	0.00	0.00	1.23	0.00	0.00	0.00	0.00	0.00	0.00	2.15	0.00	209.81
		UID Chrysophyte cyst	18.26	3.47	5.95	10.46	8.78	10.75	17.12	31.92	10.85	0.81	0.00	0.00
		UID Chrysophyte unicellular	0.00	0.00	0.00	0.30	1.76	0.00	0.63	0.00	0.00	0.00	0.00	0.00
Cryptophyta	Cryptomonadales	UID Cryptomonadales	0.00	0.00	0.00	0.15	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyanophyta	Chamaesiphonales	Chamaesiphon spp.	36.53	66.79	22.88	18.60	0.00	38.42	141.14	17.55	109.57	119.85	203.57	880.50
		Clastidium setigerum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	34.15	79.11
	Chroococcales	Aphanocapsa sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Aphanothece sp.	0.00	10.41	0.00	7.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Chroococcus sp. ?	0.00	0.00	0.00	0.00	10.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gloeothece sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gomphosphaeria sp.	0.00	0.00	0.00	7.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Merismopedia sp.	0.00	0.00	0.00	0.90	1.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Microcystis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		UID Chrooccocales	0.00	13.36	4.76	13.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Nostocales	Anabaena / Nostoc sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Calothrix / Rivularia sp.	0.00	0.00	0.00	2.70	5.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Nostoc sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Tolypothrix sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		UID Nostocales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oscillatoriales	Homoeothrix varians	0.00	13.88	0.00	0.00	28.10	54.53	154.04	0.00	120.67	367.82	2274.74	4987.20
		Lyngbya spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.47	0.00	0.00
		Oscillatoria spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.48
		Phormidium sp.	33.23	0.00	0.00	0.00	0.00	14.59	8.83	0.00	0.00	73.36	22.54	18.92
		Pseudanabaena spp.	0.00	19.09	41.62	1673.24	851.73	56.83	0.00	3.53	24.40	12.35	23.64	0.96
		UID Oscillatoriales	18.04	4.03	34.48	7.49	79.04	9.22	0.00	7.06	33.90	31.00	22.98	5.07
Euglenophyta	Euglenales	UID Euglenales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhodophyta	Nemalionales	Audouinella sp.	0.00	0.00	0.00	0.00	128.44	0.00	88.02	18.83	42.30	2.14	57.79	2.74
		Batrachospermum sp.	0.00	0.00	1.53	0.00	1.36	0.00	2.52	0.00	0.00	0.00	0.00	0.00
		Lemanea sp.	714.83	280.26	17.84	9.30	1.81	7.14	1279.65	90.62	15.73	126.42	0.00	0.00
UID colonial			0.00	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UID filamentous			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UID flagellate			0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UID unicellular			0.95	3.34	9.15	31.32	27.04	11.82	37.64	70.19	20.87	2.07	3.28	1.58
Cell Density			**2861**	**1782**	**2800**	**4042**	**5178**	**1670**	**7899**	**5984**	**3093**	**1240**	**2926**	**6233**

Table E.3: Periphyton data from de Graff (2013) converted to proportional (percentage) abundance.

Phylum	Order	Genera and Species	RD-1	RD-2	RD-3	RD-4	RD-5	NF1-1	NF1-2	NF2-1	NF2-2	NF3-1	NF3-2	NF3-3
Bacillariophyceae	Centrales	Cyclotella sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Melosira spp.	0.05	0.04	0.14	0.02	0.06	0.08	0.07	0.16	0.17	0.03	0.00	0.00
	Pennales	Achnanthes flexella	0.66	0.24	3.60	1.44	1.04	0.02	0.00	0.01	0.00	0.00	0.00	0.00
		Achnanthes lanceolata	0.10	0.05	0.00	0.03	0.07	0.09	0.01	0.08	0.04	0.01	0.00	0.00
		Achnanthes leavis	0.23	0.29	1.14	0.55	1.04	1.42	0.19	0.53	0.09	0.00	0.01	0.00
		Achnanthes linearis	1.02	2.25	0.98	0.14	1.17	1.24	0.09	0.38	0.04	0.67	0.01	0.00
		Achnanthes minutissima	34.22	55.11	41.84	24.80	37.08	39.29	40.50	24.63	23.28	19.34	2.65	0.02
		Achnanthes spp.	0.38	1.31	1.96	0.89	0.39	0.71	0.24	0.88	0.34	1.08	0.11	0.00
		Amphipleura pellucida	0.04	0.08	0.76	0.23	0.14	0.04	0.01	0.01	0.02	0.01	0.00	0.00
		Amphora spp.	0.00	0.00	0.01	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
		Anomoeoneis spp.	0.17	0.19	8.50	5.53	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Caloneis spp.	0.20	0.06	0.85	0.03	0.17	0.05	0.01	0.02	0.02	0.03	0.00	0.00
		Ceratoneis arcus	0.64	0.10	0.25	0.06	0.17	0.32	0.40	0.46	1.69	0.30	0.56	0.14
		Cocconies placentula	0.04	0.01	0.03	0.02	0.04	0.23	0.25	0.53	0.22	0.11	0.03	0.00
		Cymatopleura elliptica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymatopluera solea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella cestaii	0.01	0.03	0.02	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella cistula	0.01	0.01	0.07	0.05	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella lanceolata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella mexicana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Cymbella minuta	7.15	3.94	8.82	4.87	6.01	9.56	8.58	10.56	10.80	3.83	2.87	0.13
		Cymbella sinuata	0.10	0.04	0.25	0.02	0.10	0.14	0.12	0.38	0.09	0.02	0.00	0.00
		Cymbella spp.	0.36	0.29	1.63	1.22	0.65	0.00	0.00	0.00	0.02	0.02	0.00	0.00
		Denticula sp.	0.10	0.15	0.17	0.26	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Diatoma elongatum	5.11	2.25	2.61	2.21	3.66	0.02	0.15	0.00	0.09	0.01	0.00	0.00
		Diatoma hiemale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Diatoma mesodon	0.02	0.00	0.01	0.01	0.01	0.04	0.02	0.00	0.00	0.01	0.00	0.00
		Diatoma sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Diatomella sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Didymosphenia geminata	0.03	0.03	0.02	0.04	0.03	0.02	0.04	0.04	0.04	0.04	0.21	0.00
		Diploneis spp.	0.02	0.01	0.03	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Epithemia turgida	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
		Epithemia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Eunotia spp.	0.05	0.06	0.04	0.00	0.04	0.02	0.03	0.00	0.00	0.01	0.00	0.00
		Fragilaria capucina	0.01	0.00	0.00	0.10	0.11	0.01	0.01	0.08	0.08	0.08	0.01	0.00
		Fragilaria construens	0.27	0.24	1.06	0.98	0.75	1.77	0.74	1.76	2.19	0.58	0.03	0.00
		Fragilaria crotonensis	0.00	0.00	0.21	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Fragilaria leptostauron	0.03	0.10	0.21	0.03	0.04	0.02	0.01	0.02	0.03	0.02	0.00	0.00
		Fragilaria pinnata	0.13	0.54	1.06	0.78	0.44	0.32	0.12	0.38	0.22	0.33	0.00	0.00
		Fragilaria vaucheria	1.66	0.15	0.49	0.66	1.31	6.72	4.77	8.80	11.14	0.58	0.40	0.06
		Fragilaria spp.	4.98	3.19	1.31	1.88	1.96	6.02	14.06	25.81	11.81	3.33	0.79	0.04
		Frustulia sp.	0.00	0.00	0.01	0.00	0.01	0.01	0.07	0.12	0.02	0.02	0.00	0.00
		Gomphonema acuminata	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gomphonema angustatum/parvulum	0.10	0.05	0.38	0.03	0.17	0.37	0.65	0.30	0.39	0.11	0.02	0.01
		Gomphonema brebissonii	0.05	0.05	0.03	0.01	0.00	0.04	0.02	0.02	0.02	0.03	0.00	0.00
		Gomphonema olivaceum	0.17	0.00	0.04	0.00	0.07	0.14	0.12	0.08	0.13	0.06	0.02	0.01
		Gomphonema truncatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gomphonema spp.	0.13	1.12	0.30	0.12	0.17	0.23	0.25	0.23	0.09	0.15	0.02	0.01
		Gyrosigma sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Meridion circulare	0.06	0.00	0.07	0.04	0.10	0.18	0.09	0.16	0.18	0.06	0.00	0.00
		Navicula aurora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Navicula cryptonella	0.27	0.05	0.17	0.20	1.04	0.60	0.19	0.30	1.18	0.24	0.03	0.00
		Navicula cuspidata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Navicula radiosa	0.04	0.04	0.15	0.09	0.39	0.20	0.22	0.20	0.57	0.08	0.03	0.00
		Navicula spp.	0.50	0.19	1.63	0.77	3.66	0.88	0.77	1.47	1.01	0.37	0.01	0.00
		Neidium spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Nitzschia acicularis	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
		Nitzschia dissipata	0.13	0.00	0.08	0.14	0.26	1.06	0.22	0.30	0.67	0.33	0.04	0.01
		Nitzschia palea	0.07	0.10	0.98	0.55	0.78	1.24	0.37	0.61	1.01	0.50	0.01	0.00
		Nitzschia spp.	6.13	2.06	6.05	2.44	4.31	5.31	0.53	4.69	6.75	4.33	0.27	0.04
		Pinnularia spp.	0.05	0.03	0.03	0.01	0.10	0.04	0.02	0.06	0.02	0.01	0.00	0.00
		Rhoicosphenia curvata	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00
		Rhopalodia gibba	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Stauroneis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Surirella spp.	0.00	0.01	0.02	0.01	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00
		Synedra ulna	1.28	1.07	2.12	1.00	1.70	1.19	0.83	2.64	3.04	0.83	0.43	0.02
		Synedra spp.	4.34	0.94	4.09	2.21	5.74	7.08	1.67	4.11	7.76	1.50	0.22	0.06
		Tabellaria fenestrata	0.01	0.05	0.01	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Tabellaria flocculosa	0.03	0.04	0.05	0.04	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00
		UID girdle view	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorophyta	Chaetophorales	Stigeoclonium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.13	0.01
		UID Chaetophorales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00
	Chlorococcales	Ankistrodesmus spp.	0.00	0.00	0.13	0.26	0.07	0.23	0.03	0.00	0.13	0.09	0.05	0.01
		Selanastrum spp.	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.01	0.00	0.00
		Scenedesmus spp	0.00	0.01	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Tetraedron minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oedogoniales	Oedogonium spp.	0.04	0.03	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ulothricales	Geminella sp.?	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Microspora sp.	0.00	0.00	0.00	0.09	0.04	0.20	1.39	4.88	1.63	0.00	0.00	0.00
		Ulothrix zonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.02	0.20	0.00
		Ulothrix spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.00
		Ulothrix sp. ?	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Zygnematales	Closterium spp	0.02	0.04	0.05	0.05	0.05	0.09	0.18	0.14	0.32	0.15	0.02	0.00
		Cosmarium spp.	0.00	0.01	0.02	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Euastrum sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Hyalotheca sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Mougeotia spp.	0.01	0.05	0.42	0.55	0.20	0.01	0.00	0.00	0.00	0.01	0.00	0.00
		Spirogyra sp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Staurastrum spp.	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.10	0.06	0.00	0.00	0.00
		Teilingia granulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		UID Chlorophyta colonial	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.13	0.07
		UID Chlorophyta flagellate	0.00	0.00	0.00	0.00	0.03	0.09	0.00	0.08	0.04	0.02	0.00	0.00
		UID Chlorophyta unicellular	0.03	0.05	0.00	0.03	0.07	0.32	0.00	0.00	0.09	0.09	0.05	0.01
Chrysophyta	Chromulinales	Chrysococcus sp.	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mischococcales	Ophiocytium sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ochromonadales	Pseudokephyrion sp.	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Hyalobryon sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		UID Chrysophyte colonial	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	3.37
		UID Chrysophyte cyst	0.64	0.19	0.21	0.26	0.17	0.64	0.22	0.53	0.35	0.06	0.00	0.00
		UID Chrysophyte unicellular	0.00	0.00	0.00	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Cryptophyta	Cryptomonadales	UID Cryptomonadales	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyanophyta	Chamaesiphonales	Chamaesiphon spp.	1.28	3.75	0.82	0.46	0.00	2.30	1.79	0.29	3.54	9.67	6.96	14.13
		Clastidium setigerum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	1.17	1.27
	Chroococcales	Aphanocapsa sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Aphanothece sp.	0.00	0.58	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Chroococcus sp. ?	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gloeothece sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gomphosphaeria sp.	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Merismopedia sp.	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Microcystis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		UID Chrooccocales	0.00	0.75	0.17	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Nostocales	Anabaena / Nostoc sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Calothrix / Rivularia sp.	0.00	0.00	0.00	0.07	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Nostoc sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Tolypothrix sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		UID Nostocales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oscillatoriales	Homoeothrix varians	0.00	0.78	0.00	0.00	0.54	3.26	1.95	0.00	3.90	29.67	77.75	80.01
		Lyngbya spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00
		Oscillatoria spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
		Phormidium sp.	1.16	0.00	0.00	0.00	0.00	0.87	0.11	0.00	0.00	5.92	0.77	0.30
		Pseudanabaena spp.	0.00	1.07	1.49	41.40	16.45	3.40	0.00	0.06	0.79	1.00	0.81	0.02
		UID Oscillatoriales	0.63	0.23	1.23	0.19	1.53	0.55	0.00	0.12	1.10	2.50	0.79	0.08
Euglenophyta	Euglenales	UID Euglenales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhodophyta	Nemalionales	Audouinella sp.	0.00	0.00	0.00	0.00	2.48	0.00	1.11	0.31	1.37	0.17	1.98	0.04
		Batrachospermum sp.	0.00	0.00	0.05	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00
		Lemanea sp.	24.99	15.73	0.64	0.23	0.04	0.43	16.20	1.51	0.51	10.20	0.00	0.00
UID colonial			0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UID filamentous			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UID flagellate			0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UID unicellular			0.03	0.19	0.33	0.77	0.52	0.71	0.48	1.17	0.67	0.17	0.11	0.03

Table E.4: Qualitative and quantitative richness values and Simpson's evenness for the seven Phyla identified in Rose Creek, 2009.

Phylum	Site ID	NF3-3	NF3-2	NF3-1	NF2-2	NF2-1	NF1-2	NF1-1	RD-5	RD-4	RD-3	RD-2	RD-1
Bacillariophyceae (Diatoms)	Qualitative Richness[a]	39	42	48	52	54	54	54	60	60	59	56	56
	Quantitative Richness[b]	24	29	38	39	36	41	44	52	48	49	41	49
	Simpson's Evenness[c]	0.29	0.16	0.09	0.18	0.15	0.07	0.09	0.08	0.09	0.09	0.05	0.08
Chlorophyta	Qualitative Richness[a]	12	13	16	15	6	10	13	14	12	8	7	8
	Quantitative Richness[b]	7	11	10	8	4	4	9	9	10	6	7	6
	Simpson's Evenness[c]	0.28	0.52	0.53	0.27	0.28	0.33	0.53	0.59	0.31	0.36	0.71	0.67
Chrysophyta	Qualitative Richness[a]	3	0	2	1	1	3	1	4	4	3	2	1
	Quantitative Richness[b]	1	0	2	1	1	2	1	4	4	3	1	1
	Simpson's Evenness[c]	n/a	n/a	0.83	n/a	n/a	0.54	n/a	0.39	0.40	0.50	n/a	n/a
Cryptophyta	Qualitative Richness[a]	0	0	0	0	0	0	1	1	1	0	0	0
	Quantitative Richness[b]	0	0	0	0	0	0	0	1	1	0	0	0
	Simpson's Evenness[c]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cyanophyta	Qualitative Richness[a]	9	7	9	6	3	4	8	7	12	9	10	5
	Quantitative Richness[b]	7	6	7	4	3	3	5	6	8	4	6	3
	Simpson's Evenness[c]	0.20	0.21	0.35	0.74	0.71	0.70	0.76	0.22	0.13	0.78	0.51	0.93
Euglenophyta	Qualitative Richness[a]	0	0	0	0	0	0	0	1	0	0	0	0
	Quantitative Richness[b]	0	0	0	0	0	0	0	0	0	0	0	0
	Simpson's Evenness[c]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rhodophyta	Qualitative Richness[a]	2	2	2	2	2	3	2	3	3	2	2	1
	Quantitative Richness[b]	1	1	2	2	2	3	1	3	1	2	1	1
	Simpson's Evenness[c]	n/a	n/a	0.52	0.83	0.70	0.38	n/a	0.35	n/a	0.59	n/a	n/a
Total	Qualitative Richness[a]	66	65	78	78	67	76	80	92	96	82	79	72
	Quantitative Richness[b]	61	57	65	75	76	61	54	47	55	60	48	41
	Simpson's Evenness[c]	0.08	0.05	0.08	0.06	0.07	0.09	0.08	0.14	0.17	0.11	0.03	0.04

[a] Qualitiative value is derived from a 'quick scan' of periphyton sample.

[b] Quantitative value is derived from actual cell counts from grided sample tray.

[c] Simpson's evenness is calculated on quantitative data only and is a value between 0 and 1, where 1 is an evenly dispersed population.

ATTACHMENT F

BENTHIC INVERTEBRATE DATA

Table F.1: Community metrics derived from analysis of collected benthic samples at the Rose Creek study sites during August 2009 (from de Graff 2013).

Parameter	Reference Sites Mean	RD1	RD2	RD3	RD4	RD5	NF1-1	NF1-2	NF2-1	NF2-2	NF3-1	NF3-2	NF3-3
Total Number of Taxa Present	12.4	14	12	15	12	16	9	10	16	12	19	15	18
Shannon Weiner Diversity	1.47	0.87	0.71	1.34	1.29	1.60	0.43	0.42	0.79	0.43	1.95	1.56	2.20
EPT Taxa (number)	5.7	8	7	7	6	8	2	4	9	5	12	10	12
% of Dominant Taxa	50.2	81.0	85.2	63.8	60.7	58.0	90.0	92.4	84.4	92.7	38.8	54.8	24.1
% of 2 Dominant Taxa	69.8	87.1	90.7	77.8	78.6	67.8	97.6	94.6	89.1	94.2	60.5	70.5	47.8

Table F.2: Absolute abundance data of benthic invertebrates identified to lowest possible level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	Order: Ephemeroptera	Family: Ameletidae	*Ameletus sp.*	Family: Baetidae	*Acentrella sp.*	*Baetis bicaudatus*	*Baetis tricaudatus*	*Baetis sp.*	*Fallceon sp.*	Family: Ephemerellidae	*Drunella sp.*	*Drunella spinifera*	*Drunella grandis*	*Serratella sp.*	*Ephemerella sp.*	*Drunella coloradensis*	*Drunella doddsi*	Family: Heptageniidae	*Rhithrogena sp.*	*Cinygmula sp.*	*Epeorus sp.*	Family: Leptophlebiidae	Order: Plecoptera	Family: Capniidae	Family: Chloroperlidae	*Alloperla sp.*	*Suwallia sp.*	*Sweltsa sp.*	Family: Leuctridae	Family: Nemouridae	*Podmosta sp.*	*Zapada cinctipes*	*Zapada columbiana*	*Zapada oregonensis/haysi*	*Zapada sp.*
2008	Reference	VR	0	0	0	55	0	18	0	10	0	22	0	0	0	0	0	0	0	15	0	3	5	0	8	114	24	0	1	3	0	0	0	0	0	0	26
		USFR	0	0	10	0	0	0	4	24	0	268	0	0	0	0	0	9	45	135	4	7	78	0	1	8	4	0	0	4	9	0	0	17	48	26	673
		NXT	4	0	30	4	0	0	1	0	0	136	0	0	0	0	0	4	4	335	0	11	32	0	0	61	0	0	28	16	2	0	0	18	2	62	144
		R7-1	1	0	4	0	4	0	0	0	0	96	1	0	0	0	1	0	17	32	0	0	2	0	8	50	0	0	55	1	4	0	0	15	0	22	37
		R7-2	1	0	19	1	0	1	0	4	0	113	0	0	0	0	4	1	25	52	0	26	1	0	0	239	0	0	20	1	0	0	0	21	0	48	72
		FC1	0	0	20	2	2	0	0	0	0	34	0	0	0	0	2	0	0	18	0	0	0	0	6	30	0	0	2	12	0	0	0	20	0	14	88
		BLC-1	0	0	1	1	3	0	2	1	0	6	0	0	0	0	0	0	3	26	33	3	2	0	1	55	0	0	2	2	0	0	0	0	0	1	4
		BLC-2	0	0	5	1	5	0	4	1	0	22	0	2	0	0	0	0	13	78	35	3	2	0	11	181	0	0	2	18	0	0	0	0	0	1	12
		BLC-3	0	0	0	7	6	0	6	0	0	23	2	10	0	0	0	0	2	29	16	2	2	0	3	120	0	0	0	8	0	0	0	0	0	2	27
		STC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	3	0	1	0	0	1	6	2	0	0	0	0	0	0	0	0	0	1
		BEC	0	0	0	0	0	0	14	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	1	0	1	0
		HOC	0	0	0	14	17	0	1	0	0	5	0	0	0	0	0	0	3	2	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	4
		GRC	0	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	9	0	0	0	0	0	0	0	0	0	0	9
		BTT	0	0	64	277	0	0	32	128	0	0	0	0	0	0	0	0	0	32	0	0	0	373	32	0	0	0	0	0	0	0	0	192	0	0	192
		BUC	0	0	0	355	0	0	10	0	0	40	0	0	0	0	5	0	40	460	5	10	5	0	10	15	10	0	0	10	5	0	0	30	0	0	380
		X2-1	0	0	1	2	26	4	0	5	0	69	0	0	0	0	0	5	11	111	0	10	9	0	4	200	0	0	5	3	1	0	0	7	0	13	33
		X2-2	0	0	0	0	8	16	0	4	0	20	0	0	0	0	0	0	8	4	0	0	0	0	0	64	0	0	0	0	0	0	0	8	0	8	40
		X2-3	0	0	0	8	8	8	0	0	0	24	0	0	0	0	0	8	0	8	0	0	0	0	8	48	0	0	0	0	0	0	0	48	0	32	56
		R2-1	0	0	0	93	6	0	1	3	0	32	0	0	0	1	0	0	11	85	0	1	3	0	15	36	18	0	11	0	0	0	0	1	0	2	8
		R2-2	0	0	0	92	4	0	2	2	0	5	0	0	0	0	0	0	8	91	0	0	3	0	10	59	1	0	14	1	0	0	0	0	0	2	6
		R2-3	0	0	0	77	13	0	13	6	0	26	0	0	0	0	0	0	15	103	0	2	11	0	7	76	0	0	11	0	0	0	0	0	0	8	18
2010	Reference	R6	13	0	0	0	25	0	0	1313	0	175	0	0	25	0	25	0	13	88	0	0	25	0	0	50	0	0	25	25	63	0	0	13	0	0	75
		R7	0	0	0	0	0	0	0	140	0	320	0	0	0	0	0	0	0	80	0	0	0	0	0	180	0	0	120	0	0	0	20	0	0	20	300
		FC	0	0	1050	0	0	0	0	300	0	350	0	0	0	0	0	0	0	100	0	0	50	0	0	50	0	0	0	150	0	0	0	250	50	0	2100
		VR	0	0	37	0	0	42	0	11	0	126	0	0	0	0	0	0	37	274	0	11	47	0	0	637	47	11	0	195	0	0	0	0	42	11	111
		USFR	0	0	45	0	0	64	0	973	0	236	0	0	0	0	45	0	18	82	0	9	55	0	0	9	0	0	0	36	0	0	0	18	64	27	418
		BLC	0	0	18	0	0	0	0	23	0	5	0	0	0	0	0	0	0	23	27	0	0	0	0	100	0	0	0	5	5	0	0	0	0	0	0
		BUC	0	0	0	0	0	0	0	340	0	60	0	0	10	0	0	0	0	200	0	0	0	0	0	10	0	0	0	0	10	0	0	0	0	20	610
		HOC	0	0	0	0	0	0	0	90	0	8	0	0	0	0	16	0	8	106	0	2	0	0	0	57	0	10	39	0	0	0	0	0	0	0	61
	Exposed	X2	0	0	0	0	40	0	0	1260	0	340	0	0	0	0	20	0	0	0	0	0	0	0	0	80	0	0	0	0	0	0	0	40	0	60	400
		R2	0	0	0	0	0	0	0	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	20	0	0	0	0	0	0	20	40
		R4	0	0	0	0	0	0	0	430	0	67	0	0	4	0	0	0	11	356	33	0	0	0	0	22	0	0	11	22	11	0	0	0	0	11	30
		VGMAIN	0	0	25	0	0	0	0	1238	0	38	0	0	0	0	0	0	0	163	38	0	0	0	13	375	0	38	38	0	88	0	0	13	0	75	888
		V5	0	0	0	0	0	13	0	217	0	0	0	0	0	0	0	0	4	78	0	0	4	0	0	52	0	13	74	0	0	0	4	4	26	74	122
		V8	0	0	6	0	0	0	0	118	0	2	0	0	0	0	3	0	3	67	0	0	0	0	0	58	0	3	5	5	16	0	0	2	1	11	74

Table F.2: Absolute abundance data of benthic invertebrates identified to lowest possible level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	Family: Perlodidae	*Isoperla sp.*	*Megarcys sp.*	*Skwala sp.*	*Kogotus sp.*	*Rickera sp.*	*Cultus sp.*	Family: Perlidae	Hesperoperla sp.	Family: Taeniopterygidae	*Taeniorema sp.*	Order: Trichoptera	**Family: Apataniidae**	*Apatania sp.*	Family: Brachycentridae	*Micrasema sp.*	*Brachycentrus sp.*	Family: Glossosomatidae	*Glossosoma sp.*	Family: Hydropsychidae	*Parapsyche sp.*	*Arctopsyche sp.*	Family: Limnephilidae	*Ecclisomyia sp.*	*Dicosmoecus sp.*	Family: Rhyacophilidae	*Rhyacophila sp.*	Family: Philopodamidae	*Wormaldia sp.*	Family: Uenoidae	*Oligophlebodes sp.*	Family: Hydroptilidae	*Hydroptila sp.*	*Stactobiella sp.*	*Oxyethira sp.*
2008	Reference	**VR**	2	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		USFR	5	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	36	24	15	0	0	0	0	0	6	0	0	0	0	0	0	0	0
		NXT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0	18	0	0	0	0	0	0	0	0
		R7-1	5	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	16	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0
		R7-2	1	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		FC1	2	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
		BLC-1	1	0	0	1	0	0	0	0	0	0	12	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
		BLC-2	1	0	0	1	0	0	0	0	0	0	12	4	0	0	0	0	0	0	0	2	0	0	2	0	0	0	6	0	0	0	2	0	0	0	0
		BLC-3	14	0	0	2	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	6	0	0	0	0	0	0	0	0
		STC	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		BEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	100	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		HOC	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
		GRC	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		BTT	0	0	0	0	0	0	0	543	32	0	0	64	0	0	0	96	0	0	0	0	0	0	596	0	0	0	0	0	0	0	0	0	0	0	0
		BUC	5	0	0	0	0	0	0	0	0	85	0	0	0	0	0	0	0	0	20	70	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Exposed	**X2-1**	0	0	0	1	0	0	0	0	0	0	6	1	0	0	0	0	0	0	13	0	2	0	0	0	0	0	10	0	0	0	0	0	0	0	0
		X2-2	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0
		X2-3	8	0	0	0	0	0	0	0	0	0	0	8	0	0	0	16	0	0	0	0	8	0	0	0	0	0	8	0	0	0	0	0	0	0	0
		R2-1	3	0	0	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		R2-2	3	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		R2-3	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
2010	Reference	**R6**	13	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		R7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		FC	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0
		VR	11	0	11	0	0	0	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
		USFR	0	9	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	27	27	0	0	0	0	0	18	0	0	0	0	0	0	0	0
		BLC	14	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
		BUC	0	0	0	0	0	0	0	0	0	70	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0
		HOC	4	0	0	0	0	0	0	0	0	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
	Exposed	**X2**	20	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	20	20	20	0	0	0	0	0	20	0	0	0	0	0	0	0	0
		R2	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		R4	4	0	19	7	0	0	0	0	0	0	0	0	0	0	7	0	0	0	7	4	7	0	0	0	0	0	48	0	0	0	0	0	0	0	0
		VGMAIN	0	0	13	38	0	0	0	0	0	113	0	75	0	0	13	0	0	0	0	50	25	0	0	0	0	0	100	0	0	0	0	0	0	0	0
		V5	0	0	4	0	0	0	0	0	0	109	0	13	0	9	0	0	0	0	0	0	0	0	0	0	0	0	83	0	0	0	0	0	0	0	0
		V8	0	0	0	0	0	0	0	0	0	5	0	1	0	7	0	0	0	0	0	0	1	0	0	10	0	0	7	0	0	0	0	0	0	0	0

Table F.2: Absolute abundance data of benthic invertebrates identified to lowest possible level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	Family: Lepidostomatidae	*Lepidostoma sp.*	Order: Coleoptera	Family: Dytiscidae	Order: Diptera	Family: Tipulidae	*Antocha sp.*	*Dicranota sp.*	*Hesperoconopa sp.*	*Hexatoma sp.*	*Limnophila sp.*	*Rhabdomastix sp.*	Family: Blephariceridae	*Agathon sp.*	Family: Ceratopogonidae	*Atrichopogon sp.*	*Bezzia/Palpomyia sp.*	*Mallochohelea*	*Probezzia sp.*	Family: Chironomidae	Subfamily : Chironominae	Tribe : Tanytarsini	Micropsectra/Tanytarsus sp.	Cladotanytarsus sp.	Rheotanytarsus sp.	**| Tribe: Chironomini**	*Saetheria sp.*	Stempellinella sp.	Stempellina sp	*Zavrelia sp.*	Subfamily: Diamesinae	**| Tribe: Diamesini**	Diamesa sp.	Pagastia sp.	Potthastia longimana group
2008	Reference	VR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0
		USFR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	138	0	0	92	0	0	0	0	0	0
		NXT	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	0
		R7-1	0	0	0	0	4	4	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	172	0
		R7-2	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	228	0
		FC1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	10	0	0	4	0	0	0	0	0	0	0	0	0	74	0
		BLC-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		BLC-2	0	0	2	0	10	0	0	0	0	2	0	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		BLC-3	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	18	0
		STC	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		BEC	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	185	0	0	0	0	0	0	0	32	17
		HOC	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		GRC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0
		BTT	0	96	0	0	0	0	128	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	0	0	0	0	0	0	0	0	0	0	0
		BUC	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	20	0	0	0	0	0	0	0	10	0
	Exposed	X2-1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9	0	0	32	0	0	1	0	0	0	0	0	0	0	0	40	48	0
		X2-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	32	0	0	0	0	0	0	0	0	0	0	0	88	132	0
		X2-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	232	0
		R2-1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	29	0
		R2-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
		R2-3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	3	0	0	0	6	93	0
2010	Reference	R6	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0
		R7	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	4200	0	0	0	0	0	0	0	0	0	280	0
		FC	0	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5700	0	0	0	0	0	0	0	0	0	350	0
		VR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0
		USFR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	373	0	0	0	0	45	0	0	0	0	36	0
		BLC	0	0	0	0	0	0	0	32	14	0	0	0	0	0	0	0	5	0	9	0	0	0	0	0	0	0	168	86	0	0	0	0	0	0
		BUC	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	10	0	0	10	0	0	0	240	0	0	0	0	370	0	450	0	0	20	90
		HOC	0	0	0	0	0	0	0	6	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Exposed	X2	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15000	0	0	0	0	0	0	0	0	0	400	0
		R2	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	100	100	0	0	0	9500	0	0	0	0	0	0	0	0	0	400	0
		R4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	19	0	0	0	0	37	0
		VGMAIN	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	13	0
		V5	0	0	0	0	4	4	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	148	0	0
		V8	0	0	0	0	1	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	84	0	0

Table F.2: Absolute abundance data of benthic invertebrates identified to lowest possible level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	*Pseudodiamesa sp.*	Prodiamesa sp.	Subfamily: Orthocladiinae	*Brillia sp.*	Cardiocladius sp.	Cricotopus/Orthocladius sp.	*Cricotopus sp.*	Eukiefferiella sp.	*Eurythapsis sp.*	Heleniella sp.	*Hydrobaenus sp.*	*Orthocladius sp.*	*Rheosmittia sp.*	Tvetenia sp.	Chaetocladius sp.	Corynoneura sp.	Diplocladius sp.	Nanocladius	Rheocricotopus sp.	Synorthocladius sp.	Thienemanniella sp.	Subfamily: Tanypodinae	**| Tribe: Pentaneurini**	Thienemannimyia Group	Procladius sp.	**| Family: Empididae**	*Chelifera/ Metachela*	*Oreogeton sp.*	Family: Psychodidae	*Pericoma sp.*	Family: Simuliidae	*Simulium sp.*	*Prosimulium sp.*	Family: Deuterophlebiidae	*Deuterophlebia sp.*
2008	Reference	**VR**	0	0	0	0	0	5	0	15	0	0	0	0	0	11	6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	86	0	0
		USFR	0	0	0	0	0	52	0	0	0	0	0	0	0	8	0	8	0	0	28	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0
		NXT	0	0	0	0	0	107	0	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
		R7-1	0	0	0	0	0	361	0	2	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	12	0	0	0	0
		R7-2	0	0	0	0	0	143	0	24	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	1	0	7	9	0	0
		FC1	0	0	0	0	10	120	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		BLC-1	0	0	0	0	0	41	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0
		BLC-2	0	0	0	0	0	371	0	8	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	3	0	0
		BLC-3	0	0	0	0	0	289	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		STC	0	0	0	0	0	17	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		BEC	0	0	0	0	0	363	0	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	49	0	0
		HOC	0	0	0	0	0	2	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		GRC	0	0	0	0	0	2	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		BTT	0	0	4508	0	0	298	0	0	0	0	0	0	0	4006	0	0	0	0	0	0	0	533	0	0	0	0	0	0	0	0	0	0	0	0
		BUC	0	0	0	0	0	110	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	20	0	0
	Exposed	**X2-1**	0	0	0	0	0	421	0	80	0	0	0	0	0	0	0	0	0	0	0	12	25	15	0	1	0	0	0	0	1	0	2	10	0	0
		X2-2	0	0	0	0	0	660	0	132	0	0	0	0	0	0	0	0	0	0	0	0	76	32	0	0	0	0	0	0	0	0	16	44	0	0
		X2-3	0	0	0	0	0	1832	0	312	0	0	0	0	0	0	0	0	0	0	0	0	152	32	0	0	0	0	0	0	0	0	0	8	0	0
		R2-1	0	0	0	0	0	52	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	6	0	0
		R2-2	0	0	0	0	0	22	0	8	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	19	0	0	0	0	0	1	0	4	1	0
		R2-3	0	0	0	0	0	57	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	7	0	0	0	0	0	1	2	13	0	1
2010	Reference	**R6**	0	0	0	0	0	0	0	38	0	0	0	1300	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	25	0	0	0	0
		R7	0	0	0	0	0	0	0	0	0	0	0	1780	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0	0	40	0	0	0	0
		FC	0	0	0	0	3200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0
		VR	11	0	47	0	0	0	16	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	5	0	11	0
		USFR	0	0	0	9	0	0	0	0	0	0	0	64	0	73	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
		BLC	0	0	105	0	0	0	0	0	14	50	159	0	282	0	0	0	0	0	0	0	0	0	0	132	0	0	77	0	0	50	0	0	0	0
		BUC	0	0	0	0	0	0	0	0	0	0	0	140	0	130	0	0	0	0	0	0	0	0	0	170	0	0	0	0	0	70	0	110	0	0
		HOC	0	0	0	0	0	0	0	18	0	0	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	10	0	51	0	0	0	0
	Exposed	**X2**	0	0	0	0	0	0	0	0	0	0	0	300	0	14000	0	0	0	0	0	0	0	0	0	0	0	20	120	0	0	40	0	20	0	0
		R2	0	0	0	0	0	0	0	0	0	0	0	180	0	0	0	0	0	0	0	0	0	300	0	0	0	0	100	0	0	20	0	0	0	0
		R4	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	7	0	0	0
		VGMAIN	0	0	163	50	0	0	0	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	13	0	0	0	0	63	0
		V5	0	0	0	0	0	0	0	0	0	4	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	9	4	0	0	191	0
		V8	0	0	0	0	0	0	0	0	0	0	0	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	1	3	0	0	0	0

Table F.2: Absolute abundance data of benthic invertebrates identified to lowest possible level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	Family: Empididae	*Chelifera/Metachela sp.*	*Oreogeton sp.*	*Clinocera sp.*	Order: Lepidoptera	Order: Hemiptera	Family: Corixidae	Order: Collembola	**| Class: Entognatha**	**| Family: Poduridae**	Class: Crustacea	Order: Cladocera	Order: Ostracoda	Order: Copepoda	**| Order: Cyclopoida**	**Subphylum: Chelicerata**	**| Class: Arachnida**	**| Order: Trombidiformes**	deutonymph	Family: Aturidae	*Aturus*	Family: Feltriidae	*Feltria*	Family: Hygrobatidae	*Hygrobates*	Family: Lebertiidae	*Lebertia*	Family: Sperchontidae	*Sperchon*	*Sperchonopsis sp.*	**Suborder: Prostigmata**	**| Order: Oribatei**	Family: Hydrozetidae	Family: Torrenticolidae	*Torrenticola*
2008	Reference	**VR**	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		USFR	0	4	0	4	0	0	0	0	0	0	0	0	0	8	0	0	0	0	8	0	44	0	8	0	4	0	4	0	12	0	0	0	0	0
		NXT	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	8	0	0	0	0	0	0	0	8	0	0	0	0	0
		R7-1	0	28	0	0	0	0	0	4	0	0	0	0	4	0	0	0	0	0	8	0	84	0	28	0	0	0	4	0	48	0	0	0	0	0
		R7-2	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	16	0	0	0	8	0	17	0	0	0	0	0
		FC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	46	0	8	0	4	0	22	0	22	0	0	0	0	0
		BLC-1	0	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	1
		BLC-2	0	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	16	0	6	0	4	0	5	0	8	0	0	0	0	1
		BLC-3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
		STC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	5	0	0	0	0	0	2	0	0	0	0	0
		BEC	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	81	16	0	0	0	0
		HOC	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
		GRC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		BTT	0	330	0	0	0	0	0	0	0	0	0	0	0	384	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	149	0	96
		BUC	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5
	Exposed	**X2-1**	0	19	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	4	0	17	0	12	0	0	0	10	0	12	0	0	1	0	0
		X2-2	0	0	0	0	0	0	0	4	0	0	0	0	8	0	0	0	0	0	28	0	72	0	8	0	4	0	32	0	36	0	0	4	0	0
		X2-3	0	24	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	24	0	112	0	64	0	32	0	176	0	120	0	0	0	0	0
		R2-1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	2	0	1	0	0	0	3	0	8	0	0	0	0	0
		R2-2	0	6	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	6	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
		R2-3	0	8	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	6	0	3	0	1	0	1	0	0	0	3	0	0	0	0	0
2010	Reference	**R6**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	38	0	25	0	0	0
		R7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	20	0	0	0	0	0	0	0
		FC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	150	0	100	0	300	0	200	0	150	0	50	0
		VR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
		USFR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	9	0	18	0	0	0	0	0
		BLC	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	14	0	9	0	0	0	5	0	0	0
		BUC	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	10	0	10	0	20	0	40	0	0	0	0	0	0	0
		HOC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	2	0	0	0
	Exposed	**X2**	0	0	0	0	0	0	0	0	0	0	0	0	280	0	0	0	0	0	0	0	80	0	40	0	0	0	200	0	80	0	80	0	0	0
		R2	0	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	100	0	0	0
		R4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	4	0	4	0	0	0
		VGMAIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0
		V5	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
		V8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	16	0	0	0	0	0

Table F.2: Absolute abundance data of benthic invertebrates identified to lowest possible level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	Family: Linmesiidae	*Limnesia*	Family: Hydryphantidae	*Wandesia*	Family : Mideopsidae	*Mideopsis sp.*	Order: Bivalvia	Family: Sphaeriidae	*Pisidium sp.*	*Sphaerium simile*	**Phylum: Mollusca**	Order: Gastropoda	Family: Valvatidae	Family : Physidae	*Physa sp.*	Family : Planorbidae	Phylum: Annelida	**Subphylum: Clitellata**	Class: Oligochaeta	**| Order: Tubificida**	**| Family: Enchytraeidae**	*Enchytraeus*	Family: Naididae	Phylum: Nematoda	**Phylum: Platyhelminthes**	**| Class: Turbellaria**	Order: Tricladida	**| Family: Planariidae**	*Polycelis coronata*	Hydra sp.
2008	Reference	**VR**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0
		USFR	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	16	52	0	0	0	0	0	0
		NXT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	0	0	0	0	0	0
		R7-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	20	0	0	0	0	0	0
		R7-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	31	0	0	0	0	0	0
		FC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
		BLC-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
		BLC-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0
		BLC-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
		STC	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	2	0	0	0	0	1	0
		BEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	25	0	0	0	0	0	0	85	6	0	0	0	0	0	16
		HOC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
		GRC	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
		BTT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	245	0	0	0	0	0	0	0	831	245	0	0	0	0	0	0
		BUC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
	Exposed	**X2-1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	9	0	0	0	0	0	0
		X2-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	12	0	0	0	0	0	0
		X2-3	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	24	0	0	0	0	0	0
		R2-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0
		R2-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
		R2-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	0	0	0	0	0	0
2010	Reference	**R6**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
		R7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		FC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		VR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	195	0	0	0	0	0	0	0
		USFR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	36	0	0	0	0	0	0
		BLC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
		BUC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		HOC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Exposed	**X2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	60	0	0	0	0	0	0
		R2	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	20	0	60	0	0	0	0	0	0
		R4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
		VGMAIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		V5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	0	0	0	0	0	0	0
		V8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	0	0	0	3	0

Table F.3: Absolute abundance data of benthic invertebrates identified to family level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	Ameletidae	Baetidae	Ephemerellidae	Heptageniidae	Leptophlebiidae	Capniidae	Chloroperlidae	Leuctridae	Nemouridae	Perlodidae	Perlidae	Taeniopterygidae	Apataniidae	Brachycentridae	Glossosomatidae	Hydropsychidae	Limnephilidae	Rhyacophilidae	Philopodamidae	Uenoidae	Hydroptilidae	Lepidostomatidae	Dytiscidae	Tipulidae	Blephariceridae	Ceratopogonidae	Chironomidae	Empididae
2008	Reference	VR	0	83	22	23	0	114	28	0	26	7	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	59	0
		USFR	10	28	322	224	0	8	8	9	764	5	0	8	0	0	36	39	0	6	0	0	0	0	0	0	0	0	326	0
		NXT	30	5	144	378	0	61	44	2	226	0	0	0	0	0	0	1	4	18	0	0	0	0	0	4	0	4	221	0
		R7-1	4	4	115	34	0	50	56	4	74	5	0	8	0	0	16	1	0	2	0	0	0	0	0	8	0	4	551	0
		R7-2	19	7	144	79	0	239	21	0	141	1	0	11	0	0	0	0	0	0	0	0	0	0	0	21	0	0	428	0
		FC1	20	4	36	18	0	30	14	0	122	2	0	4	0	0	0	0	2	2	0	0	0	0	0	4	0	0	228	0
		BLC-1	1	7	9	64	0	55	4	0	5	2	0	12	0	0	0	2	0	4	0	0	0	0	0	0	0	0	51	0
		BLC-2	5	11	37	118	0	181	20	0	13	2	0	12	0	0	0	2	2	6	0	2	0	0	0	2	0	4	385	0
		BLC-3	0	19	37	50	0	120	8	0	29	16	0	17	0	0	0	0	2	6	0	0	0	0	0	4	0	0	350	0
		STC	0	0	4	4	0	6	2	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	39	0
		BEC	0	30	0	0	0	0	0	0	28	0	0	0	0	43	100	1	0	0	2	0	0	0	0	0	0	0	755	0
		HOC	0	32	8	2	0	4	0	0	4	0	0	18	0	0	0	0	0	2	0	0	0	0	0	0	1	0	16	0
		GRC	0	7	0	2	0	9	0	0	9	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0
		BTT	64	437	0	32	373	0	0	0	384	0	575	0	0	96	0	0	596	0	0	0	0	96	0	224	0	0	10465	0
		BUC	0	365	85	480	0	15	20	5	410	5	0	85	0	0	20	95	0	0	0	0	0	0	0	5	0	0	210	0
	Exposed	X2-1	1	37	85	130	0	200	8	1	53	1	0	6	0	0	13	2	0	10	0	0	0	0	0	1	0	9	675	0
		X2-2	0	28	28	4	0	64	0	0	56	4	0	4	0	0	12	0	0	16	0	0	0	0	0	0	0	8	1152	0
		X2-3	0	24	32	8	0	48	0	0	136	8	0	0	0	16	0	8	0	8	0	0	0	0	0	0	0	64	2560	0
		R2-1	0	103	44	89	0	36	29	0	11	5	0	2	0	0	2	0	0	1	0	0	0	0	0	3	0	1	121	0
		R2-2	0	100	13	94	0	59	16	0	8	4	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	7	58	0
		R2-3	0	109	41	116	0	76	11	0	26	5	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	6	171	0
2010	Reference	R6	0	1338	238	113	0	50	50	63	88	13	0	25	0	0	0	0	0	0	0	0	0	0	0	25	0	0	1838	25
		R7	0	140	320	80	0	180	120	0	340	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	6260	80
		FC	1050	300	350	150	0	50	150	0	2400	50	0	0	0	0	0	0	50	0	0	0	0	0	0	200	0	0	9250	50
		VR	37	53	163	332	0	637	253	0	164	22	0	5	0	0	0	0	5	0	0	0	0	0	0	0	0	0	116	10
		USFR	45	1037	299	146	0	9	36	0	527	9	0	18	0	0	0	54	0	18	0	0	0	0	0	0	0	0	600	9
		BLC	18	23	5	50	0	100	5	5	0	14	0	5	0	0	0	0	0	9	0	0	0	0	0	46	0	14	996	77
		BUC	0	340	70	200	0	10	0	10	630	0	0	70	0	0	10	10	0	30	0	0	0	0	0	20	0	20	1610	0
		HOC	0	90	32	108	0	57	49	0	61	4	0	78	0	0	0	0	0	12	0	0	0	0	0	6	2	0	71	14
	Exposed	X2	0	1300	360	0	0	80	0	0	500	20	0	0	0	0	20	40	0	20	0	0	0	0	0	20	0	0	29700	140
		R2	0	300	0	0	0	40	20	0	60	40	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	200	10380	100
		R4	0	430	82	389	0	22	33	11	41	30	0	0	0	7	7	11	0	48	0	0	0	0	0	0	0	11	63	0
		VGMAIN	25	1238	38	201	0	375	76	88	976	51	0	113	0	13	0	75	0	100	0	0	0	0	0	100	0	0	451	26
		V5	0	230	4	82	0	52	87	0	230	4	0	109	9	0	0	0	0	83	0	0	0	0	0	13	0	0	187	4
		V8	6	118	8	67	0	58	13	16	88	0	0	5	7	0	0	1	10	7	0	0	0	0	0	7	0	0	184	13

*** Benthic invertebrates not included in data analysis as per CABIN protocol (Environment Canada 2010)**

Table F.3: Absolute abundance data of benthic invertebrates identified to family level of taxonomy for stations sampled by Minnow (2009) and Laberge (2011).

Year	Area Type	Station ID	Psychodidae	Simuliidae	Deuterophlebiidae	Empididae	Collembola	Cladocera*	Ostracoda*	Copepoda*	Aturidae	Feltriidae	Hygrobatidae	Lebertiidae	Sperchontidae	Hydrozetidae	Torrenticolidae	Linmesiidae	Hydryphantidae	Valvatidae	Physidae	Planorbidae	Enchytraeidae	Naididae	Nematoda*	Planariidae*
2008	Reference	VR	0	86	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	41	0	0
		USFR	0	8	0	8	0	0	0	8	44	8	4	4	12	0	0	0	0	4	0	0	0	16	52	0
		NXT	0	5	0	4	0	0	0	0	8	0	0	0	8	0	0	0	0	0	0	0	0	8	8	0
		R7-1	12	0	0	28	4	0	4	0	84	28	0	4	48	0	0	0	0	0	0	0	0	21	20	0
		R7-2	1	16	0	9	0	0	0	0	32	16	0	8	17	0	0	0	0	0	0	0	0	24	31	0
		FC1	0	0	0	0	0	0	0	0	46	8	4	22	22	0	0	0	0	0	0	0	0	0	8	0
		BLC-1	3	3	0	3	0	0	2	0	0	2	0	1	0	0	1	0	0	0	0	0	0	2	1	0
		BLC-2	13	3	0	3	0	0	2	0	16	6	4	5	8	0	1	0	0	0	0	0	0	2	3	0
		BLC-3	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	8	0
		STC	0	0	1	0	0	0	0	0	3	5	0	0	2	0	0	0	1	0	0	0	0	12	2	1
		BEC	0	49	0	0	0	0	32	0	0	0	16	0	97	0	0	0	0	0	1	25	0	85	6	0
		HOC	0	1	0	1	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	7	0	0
		GRC	0	2	0	1	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1	2	0
		BTT	0	0	0	330	0	0	0	384	0	0	0	0	0	149	96	0	0	0	245	0	0	831	245	0
		BUC	5	20	0	0	0	0	5	0	5	0	0	0	0	0	5	0	0	0	0	0	0	10	0	0
	Exposed	X2-1	1	12	0	19	0	0	6	0	17	12	0	10	12	1	0	0	0	0	0	0	0	17	9	0
		X2-2	0	60	0	0	4	0	8	0	72	8	4	32	36	4	0	0	0	0	0	0	0	8	12	0
		X2-3	0	8	0	24	0	0	16	0	112	64	32	176	120	0	0	8	0	0	0	0	0	32	24	0
		R2-1	3	6	0	4	0	0	0	0	2	1	0	3	8	0	0	0	0	0	0	0	0	1	4	0
		R2-2	1	5	0	6	0	2	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0
		R2-3	1	15	1	8	0	0	1	3	3	1	1	0	3	0	0	0	0	0	0	0	0	7	7	0
2010	Reference	R6	25	0	0	0	0	0	0	0	25	0	0	25	38	0	0	0	0	0	0	0	0	0	13	0
		R7	40	0	0	0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0
		FC	0	0	0	0	0	0	0	0	200	150	100	300	200	50	0	0	0	0	0	0	0	0	0	0
		VR	0	16	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	16	195	0	0
		USFR	0	0	0	0	0	0	0	0	9	0	0	9	18	0	0	0	0	0	0	0	55	0	36	0
		BLC	50	0	0	0	0	0	9	0	0	0	14	9	0	0	0	0	0	0	0	0	0	5	0	0
		BUC	70	110	0	0	0	0	60	0	10	10	20	40	0	0	0	0	0	0	0	0	0	0	0	0
		HOC	51	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
	Exposed	X2	40	20	0	0	0	0	280	0	80	40	0	200	80	0	0	0	0	0	0	0	120	0	60	0
		R2	20	0	0	0	0	0	400	0	0	0	0	160	0	0	0	0	0	0	0	0	20	0	60	0
		R4	63	7	0	0	0	0	0	0	0	0	0	7	4	0	0	0	0	0	0	0	7	0	0	0
		VGMAIN	0	63	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0
		V5	13	191	0	0	22	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	61	0	0
		V8	4	0	0	0	0	0	0	0	1	0	0	0	16	0	0	0	0	0	0	0	1	2	2	3

Table F.4: Benthic community characteristics of exposure areas sampled in 2008 relative to reference areas that were sampled in 2008 and 2010 (N = 7). Results are presented for traditional central (cP) t-tests and non-central (ncP) t-tests.

K&S 2008		CA1	CA2	CA3	Family Richness	% EPT	% E	% P	% Chironomidae
Reference									
BLC-Mean		n/a	n/a	n/a	20	53.9	23.1	29.1	39.10
BUC 2008		n/a	n/a	n/a	18	85.2	50.0	29.0	11.29
FC1 2008		n/a	n/a	n/a	18	42.2	13.0	28.6	37.87
HOC 2008		n/a	n/a	n/a	15	70.0	42.0	26.0	16.00
R7-Mean		n/a	n/a	n/a	21	42.5	16.7	25.0	40.57
USFR 2008		n/a	n/a	n/a	23	76.8	30.6	42.0	17.07
VR 2008		n/a	n/a	n/a	14	60.9	25.5	35.1	11.78
Mean		**n/a**	**n/a**	**n/a**	**18**	**61.6**	**28.7**	**30.7**	**24.81**
SD		**n/a**	**n/a**	**n/a**	**3**	**16.6**	**13.3**	**5.9**	**13.62**
Exposure									
X2-2008	value	**-85.59**	**-51.21**	**-29.95**	**22**	**20.7**	**8.1**	**11.1**	**64.48**
	t	12.30	6.37	3.37	7.46	42.28	16.65	76.04	59.37
	cP	0.01	0.05	0.12	0.03	0.00	0.01	0.00	0.00
	ncP	0.90	0.99	1.00	0.98	0.32	0.80	0.11	0.18
R2-2008	value	**-61.77**	**-11.27**	**-23.45**	**20**	**67.4**	**47.6**	**19.3**	**22.18**
	t	6.20	0.24	1.95	1.14	0.83	14.02	25.54	0.26
	cP	0.05	0.64	0.21	0.33	0.40	0.01	0.00	0.63
	ncP	0.99	1.00	1.00	1.00	1.00	0.86	0.59	1.00

cP - probability metric value at exposure area is the same as the mean for reference areas.
ncP - probability metric value at exposure area is inside the range of reference values
Different from exposure mean (cP < 0.05) or range (ncP < 0.1).
Uncertain with respect to being similar to or different from reference (ncP 0.1 > p < 0.9).
Similar to reference mean (cP > 0.05) or within reference range (ncP < 0.9).

Table F.5: Benthic community characteristics of exposure areas sampled in 2010 relative to reference areas that were sampled in 2008 and 2010 (N = 7). Results are presented for traditional central (cP) t-tests and non-central (ncP) t-tests.

K&S 2010		CA1	CA2	CA3	Family Richness	% EPT	% E	% P	% Chironomidae
Reference									
BLC 2010		n/a	n/a	n/a	18	16.1	6.6	8.9	68.69
BUC 2010		n/a	n/a	n/a	20	41.9	18.5	21.9	48.94
FC1 2010		n/a	n/a	n/a	18	29.9	12.2	17.4	60.86
HOC 2010		n/a	n/a	n/a	16	76.6	35.9	38.8	11.08
R7 2010		n/a	n/a	n/a	12	15.5	7.1	8.4	82.15
USFR 2010		n/a	n/a	n/a	16	75.8	52.7	20.7	20.70
VR 2010		n/a	n/a	n/a	14	82.2	28.8	53.1	5.70
Mean		**n/a**	**n/a**	**n/a**	**16**	**48.3**	**23.1**	**24.2**	**42.59**
SD		**n/a**	**n/a**	**n/a**	**3**	**29.4**	**17.0**	**16.3**	**30.15**
Exposure									
X2-2010	value	**-75.52**	**-0.11**	**-19.37**	**18**	**7.1**	**5.0**	**1.8**	**90.27**
	t	6.37	0.00	3.12	2.84	13.72	7.88	13.12	17.51
	cP	0.05	0.99	0.13	0.14	0.01	0.03	0.01	0.01
	ncP	0.99	1.00	1.00	1.00	0.87	0.97	0.88	0.78
R2-2010	value	**-109.49**	**-26.27**	**7.46**	**12**	**4.0**	**2.6**	**1.4**	**90.26**
	t	12.01	1.32	0.30	17.76	15.87	10.15	13.64	17.50
	cP	0.01	0.29	0.60	0.01	0.01	0.02	0.01	0.01
	ncP	0.91	1.00	1.00	0.77	0.82	0.94	0.87	0.78
V8 2010	value	**23.84**	**24.40**	**-14.22**	**19**	**63.7**	**31.4**	**28.4**	**29.02**
	t	0.53	1.63	0.86	7.13	1.92	1.66	0.47	1.42
	cP	0.49	0.24	0.38	0.04	0.21	0.25	0.52	0.28
	ncP	0.47	0.21	0.36	0.98	1.00	1.00	1.00	1.00

cP - probability metric value at exposure area is the same as the mean for reference areas.
ncP - probability metric value at exposure area is inside the range of reference values

Different from exposure mean (cP < 0.05) or range (ncP < 0.1).
Uncertain with respect to being similar to or different from reference (ncP 0.1 > p < 0.9).
Similar to reference mean (cP > 0.05) or within reference range (ncP < 0.9).

ATTACHMENT G

FISH DATA

Table G.1: Historical fisheries information from the Rose/Anvil and Vangorda Creek watersheds. √ indicates species was captured or observed, and letters represent A - Adult, J - Juvenile, R - Redd.

Waterbody / Sampling Area		Report	Year / Timing	Chinook Salmon (*Oncorhynchus tshawytscha*)	Srctic Grayling (*Thymallus arcticus*)	Slimy Sculpin (*Cottus cognatus*)	Burbot (*Lota lota*)	Round Whitefish (*Prosopium cylindraceum*)	Longnose Sucker (*Catostomus catostomus*)	Lake Chub (*Couesius plumbeus*)
North Fork Rose u/s of Haul Road	North Fork Rose (headwaters)	Leverton 1986	July 1986		√ (J,A,)					
	North Fork Rose (headwaters)	Harder & Bustard 1988	May, June 1988		√	√				
	North Fork Lake	Harder & Bustard 1988								
	North Fork Rose (headwaters)	Harder 1991a	1989		√	√				
	North Fork Rose above Haul Road	Harder 1991a	August 1989		√	√				
	North Fork Rose above Haul Road	Harder 1991a	1989		√ (A)					
	North Fork Rose	Harder 1993b	August 1992							
	North Fork Rose above Haul Road	WMEC 2005b	June, August 2005		√ (A)					
	North Fork Rose (headwaters)	WMEC 2005b	June, August 2005		√ (J,A,)	√	√	√		
	North Fork Rose above Haul Road	WMEC 2006	March 2006			√				
	North Fork Rose (R7)	Minnow and WMEC 2009	May 2008							
	North Fork Rose (u/s Haul Road to R7)	de Graff 2013	August, October, 2009		√ (J,A,)	√				
	North Fork Rose u/s of Haul Road	EDI 2013a	2012 to 2013		√ (A)					
North Fork Rose Creek d/s of Haul Road	North Fork Rose below Haul Road	Harder & Bustard 1988	May, June 1988		√ (A)					
	North Fork Rose below Haul Road	Harder 1991a	1989		√	√				
	North Fork Rose below Haul Road	Harder 1991a	August 1989		√	√				
	North Fork Rose below Haul Road	WMEC 2005b	June, August 2005		√ (J,A,)	√				
	North Fork Rose below Haul Road	de Graff 2013	August, October, 2009		√ (J,A,)	√	√	√		
	North Fork Rose below Haul Road	EDI 2013a	2012 to 2013		√ (A)					
South Fork Rose Creek u/s of Haul Road	Upper South Fork Rose (above Haul Road)	Harder 1991a	1989		√	√				
	South Fork Rose (above Haul Road)	Montreal 1976	August			√				
	South Fork (above Haul Road to Dixon Lake)	Harder & Bustard 1988	May, June 1988		√					
	Upper South Fork Rose (USFR)	Minnow and WMEC 2009	May 2008		√					
	Dixon Lake	EDI 2013a	2012 to 2013		√ (A)					
South Fork Rose Creek	South Fork Rose (below Access Road)	Montreal 1976	August							
	South Fork Rose R1	Baker 1979	1974 to 1976		√	√				
	South Fork Rose (Pumphouse Pond to Reservoir)	Weagle 1981a	May 1981		√ (A)					
	South Fork Rose (confluence to Access Road)	Weagle 1981b	May to September		√ (J,A,)					
	Reservoir/ Pumphouse Pond	Harder & Bustard 1988	May, June 1988		√					
	Lower South Fork Rose	Harder 1991a	1989		√	√				
	Reservoir	Harder 1991a	1989		√ (J,A,)					
	South Fork Rose (to Access Road)	Harder 1991a	August 1989		√	√	√			
	South Fork Rose (Reservoir)	Harder 1993b	August 1992		√					
	South Fork Rose	WMEC 2005c	August 2005	√ (J)	√ (J,A,)	√	√	√		
	South Fork Rose	WMEC 2008	August 2008		√ (A)	√				
	Former Reservoir area	AECOM 2009	2004 to 2007		√	√	√	√		
	South Fork (to former Reservoir)	EDI 2013a	2012 to 2013		√ (A)					
Rose Creek Diversion Channel	Diversion Channel	Harder & Bustard 1988	May, June 1988		√ (A)			√		
	Diversion Channel	Harder 1991a	1989		√					
	Diversion Channel	Harder 1993b	August 1992		√	√	√	√		
	Diversion Channel	WMEC 2010b	2009	√						
	Diversion Channel	de Graff 2013	August, October, 2009		√	√	√			
	Diversion Channel	EDI 2013a	2012 to 2013		√ (A)					
Rose Creek below Faro Mine Complex	Rose Creek R4	Baker 1979	1975	√	√		√			
	Rose Creek R3	Baker 1979	1975		√					
	Rose Creek R2	Baker 1979	1974 to 1975		√					
	Rose Creek	Harder 1991a	August 1989,1990		√	√		√		
	Rose Creek (R2)	WMEC 2005c	August 2005	√ (J)	√ (A)	√	√			
	Rose Creek at Anvil (R4)	WMEC 2005c	August 2005	√ (J)	√ (J,A,)	√				
	Rose Creek (R2)	WMEC 2008	August 2008		√ (J,A,)	√	√			
	Rose Creek at Anvil (R4)	WMEC 2008	August 2008	√ (J)	√ (J,A,)	√				
	Rose Creek (R2)	Minnow and WMEC 2009	May 2008							
	Rose Creek (X14)	AECOM 2009	2004 to 2007		√	√	√			
	Rose Creek (R2 to Anvil)	WMEC 2010b	August 2010	√ (R)	√			√		
Anvil Creek	Anvil Creek (R11/A1)	Baker 1979	1974 to 1976	√	√	√		√	√	
	Anvil Creek (R6)	Baker 1979	1976	√	√		√	√	√	
	Lower Anvil below Rose Creek	Harder 1991a	August 1989,1990	√ (J,A,R)	√	√	√	√		
	Lower Rose (R1,2 in report)	Harder 1991a	1989							
	Lower Anvil (A1)	Harder 1993b	August 1992	√ (J)	√	√	√			
	Upper Anvil (R6)	Harder 1993b	August 1992			√				
	Anvil Creek upstream of Rose Creek (R6)	WMEC 2005c	August 2005		√ (A)	√				
	Anvil Creek (A1 to A4)	Laberge, Access, WMEC 2006	2004 - 2005	√ (J)	√ (A)	√		√		√
	Anvil Creek upstream of Rose Creek (R6)	WMEC 2008	August 2008		√ (A)	√				
	Lower Anvil Creek	WMEC 2010a	2009	√						
Lower Vangorda Creek	Lower Vangorda Creek	Montreal 1976	May	-	-	-	-	-	-	
	Lower Vangorda Creek	Montreal 1978	August 77		√	√				
	Lower Vangorda Creek below town road culvert	Harder 1987	August, September	√ (J)	√ (J)	√	√	√	√	
	Lower Vangorda Creek	Harder 1989	April 1989	√ (J)	√ (J)	√		√		
	Lower Vangorda Creek below town road culvert	Harder 1989	spring, summer, fall	√ (J)	√	√		√		
	Lower Vangorda Creek below town road culvert	Harder 1992	August 1990	√ (J)	√ (A)	√	√	√	√	
	Lower Vangorda Creek (V8)	WMEC 2005c	August 2005	√ (J)	√ (A)	√		√		
	Lower Vangorda Creek (V8)	WMEC 2008	August 2008	√ (J)	√ (J,A,)	√	√	√		
	Lower Vangorda Creek (V8)	Minnow and WMEC 2009	May 08	√ (J)	√	√		√		√

Table G.2: Mean arctic grayling muscle metal concentrations (mg/kg wet weight), Rose-Anvil and Vangorda Creek systems, 1975 to 2005.

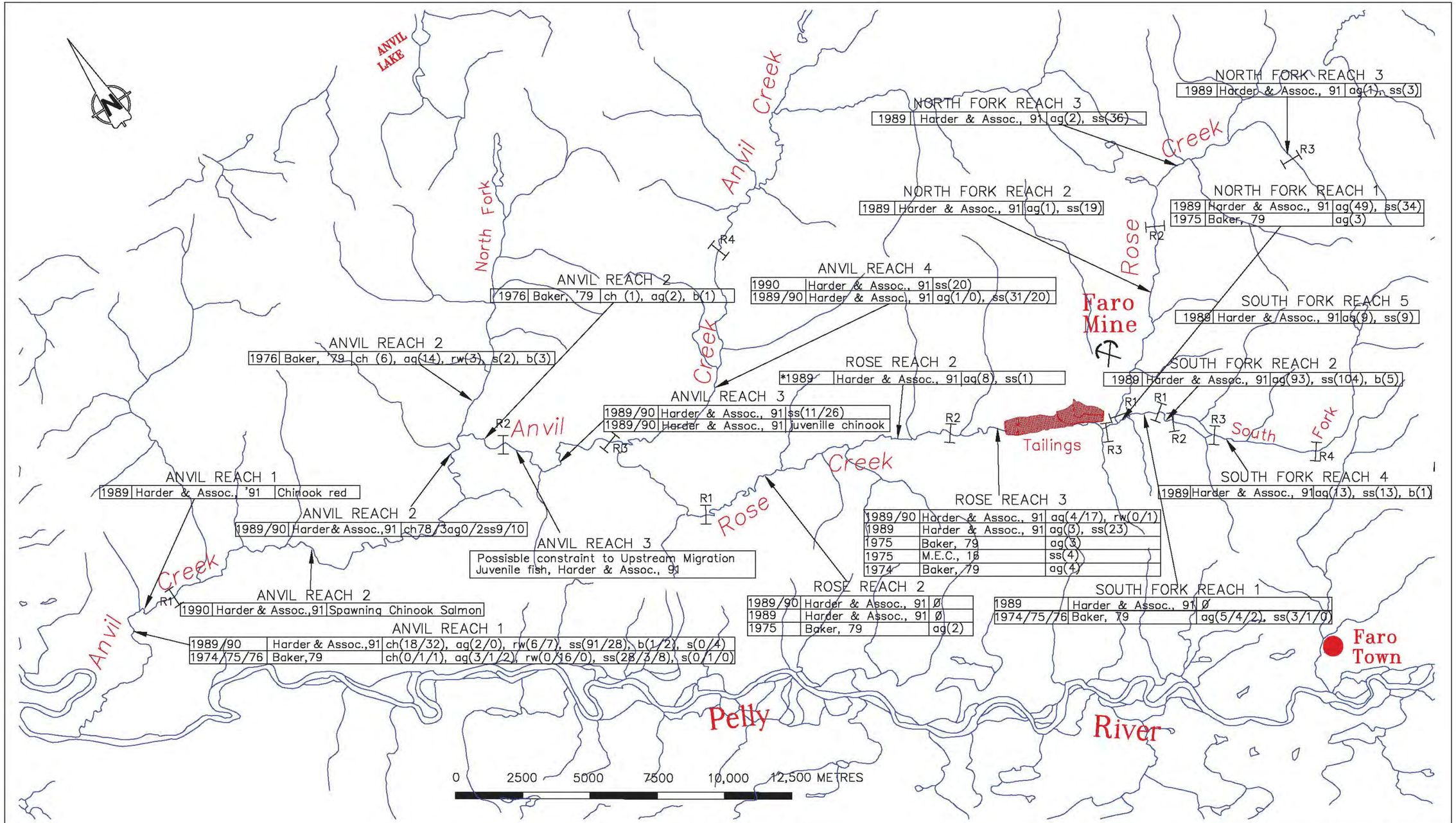
Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
Arsenic	1997		0.300	0.515						0.581	0.540
	2002		0.028	0.045						0.038	0.038
	2004						< 0.1	< 0.1			
	2005	< 0.3	< 0.3		< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Cadmium	1992		< 0.1								
	1997		0.013	0.013						0.038	0.093
	2002		< 0.005	0.010						0.011	0.351
	2004						0.019	0.006			
	2005	< 0.05	0.060		0.090	0.062	0.068	0.062	0.075	0.090	0.120
Copper	1975								0.40	0.76	0.75
	1976										0.96
	1977										0.86
	1992		2.45								
	1997		0.32	1.38						0.39	0.83
	2002		0.62	0.73						0.30	1.15
	2004	0.77	0.68	0.74	0.96		0.84	0.65		0.50	0.53
	2005	0.71	0.76		0.80	0.58	0.45	0.57	0.52	0.59	0.67
Lead	1975								0.2	1.0	1.1
	1976										0.9
	1977										< 1.0
	1992		< 2								
	1997		0.479	0.684						0.917	0.940
	2002		0.076	0.075						< 0.02	0.045
	2004	< 0.05	< 0.05	<0.05	< 0.05		0.09	< 0.05		< 0.05	< 0.05
	2005	< 0.5	< 0.5		< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Manganese	1975									0.60	1.5
	1976										2.9
	1977										< 0.50
	1997		4.98	7.97						3.48	3.60
	2004	< 2.0	< 2.0	< 2.0	< 2.0		2.7	< 2.0		< 2.0	< 2.0
	2005	2.76	8.30		10.4	7.85	4.99	4.46	3.75	1.88	2.76
Mercury	1975									0.13	0.08
	1976	0.11	0.07						0.10		0.01
	1977										< 0.062
	1992		0.066								
	1997		0.058	0.052						0.030	0.020
	2002		0.053	0.023						0.022	0.040
	2004	0.042	0.042	0.030	0.041		0.070	0.059		0.046	0.051
Zinc	1975								4.0	9.2	11.8
	1976										14.6
	1977										8.5
	1992		23.7								
	1997		17.9	18.3						17.1	27.3
	2002		11.0	14.6						11.1	24.3
	2004	8.29	9.37	7.74	9.44		8.30	7.48		6.49	8.09
	2005	17.7	13.1		12.6	14.8	10.5	12.8	18.5	10.6	17.7

Table G.3: Mean arctic grayling liver metal concentrations (mg/kg wet weight), Rose-Anvil and Vangorda Creek systems, 1975 to 2005.

Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
Arsenic	1997		1.17	0.72						2.97	6.74
	2002		0.04	0.05						0.04	0.03
Cadmium	1997		0.244	0.689						1.220	1.296
	2002		0.149	1.25						1.35	0.8
Copper	1975								1.8	3.9	
	1992		8.3								
	1997		2.82	2.76						3.53	3.01
	2002		2.14	5.32						2.81	1.85
Lead	1975								0.20	2.0	
	1992		2.35								
	1997		0.740	0.639						3.81	7.28
	2002		0.138	0.18						< 0.02	< 0.02
Manganese	1975									3.2	
	1997		9.21	5.75						4.97	4.41
Mercury	1975									0.54	
	1976	0.26	0.20						0.11		
	1997		0.161	0.072						0.077	0.056
	2002		0.090	0.054						0.051	0.047
Zinc	1975								20.0	22.2	
	1992		89.8								
	1997		31.1	26.6						29.7	45.9
	2002		22.8	28.8						25.0	19.9

Table G.4: Mean slimy sculpin whole body metal concentrations (mg/kg wet weight), Rose-Anvil and Vangorda Creek systems, 1975 to 2005.

Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
Arsenic	1997		1.33	3.83						3.27	7.69
	2002		0.23							0.14	0.11
	2004					0.14	0.16	0.22	0.12		
	2005	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Cadmium	1997		0.077	0.227						0.133	0.349
	2002		0.030							0.117	0.453
	2004					0.045	0.086	0.073	0.199		
	2005	0.076	0.050	< 0.05	< 0.05	0.066	0.064	0.096	0.260	0.085	0.180
Copper	1975									0.63	0.73
	1976										1.90
	1977										2.93
	1989										1.26
	1992	3.8							3.7	3.1	4.9
	1997		1.14	0.96						0.24	0.32
	2002		1.18							1.00	0.73
	2004	0.93	0.57	1.2	0.88	0.92	1.1	1.4	1.2	0.87	0.79
	2005	0.98	1.12	1.25	0.96	0.89	0.79	0.99	1.19	1.12	0.95
Lead	1975									1.1	1.9
	1976										2.8
	1977										< 1.0
	1989										0.4
	1992	2.0							< 2	< 2	23.0
	1997		3.70	3.04						2.79	3.77
	2002		0.62							0.04	0.27
	2004	0.13	0.41	0.24	0.22	0.16	0.21	0.19	0.35	0.08	0.16
	2005	< 0.50	0.57	1.02	0.56	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Manganese	1975									9.8	5.1
	1976										7.0
	1977										5.5
	1989										4.7
	1997		13.7	30.0						12.7	13.6
	2004	30.8	28.1	31.7	66.5	36.6	18.5	35.2	11.0	9.17	6.7
	2005	26.4	25.0	38.8	47.7	42.7	16.3	17.4	35.2	8.67	7.37
Mercury	1975									0.40	0.190
	1976										0.017
	1977										< 0.050
	1989										0.019
	1997		0.020	0.013						0.027	0.031
	2002		0.032							0.035	0.046
	2004	0.032	0.023	0.029	0.022	0.020	0.021	0.018	0.032	0.036	0.043
Zinc	1975									19.6	26.8
	1976										39.3
	1977										32.0
	1989										27.4
	1992	127							138		184.0
	1997		28.4	44.5						23.2	52.4
	2002		37.4							23.3	71.4
	2004	41.0	53.1	39.3	57.6	47.5	38.3	45.7	48.6	31.3	55.1
	2005	39.1	30.1	51.8	49.9	49.0	33.4	40.1	43.4	26.1	45.7



LEGEND:

YEAR	REFERENCE	FISH SPECIES (NO. CAUGHT)

FISH SPECIES

ch = chinook salmon
ag = arctic grayling
rw = round whitefish
s = sucker
b = burbot
ss = slimy sucker
Ø = no fish
R = Reach Break

* = Combination of two sample sites from same year and source
For Reference list see Table
Note: After Harder & Associates Ltd.

Scale 1:130 000

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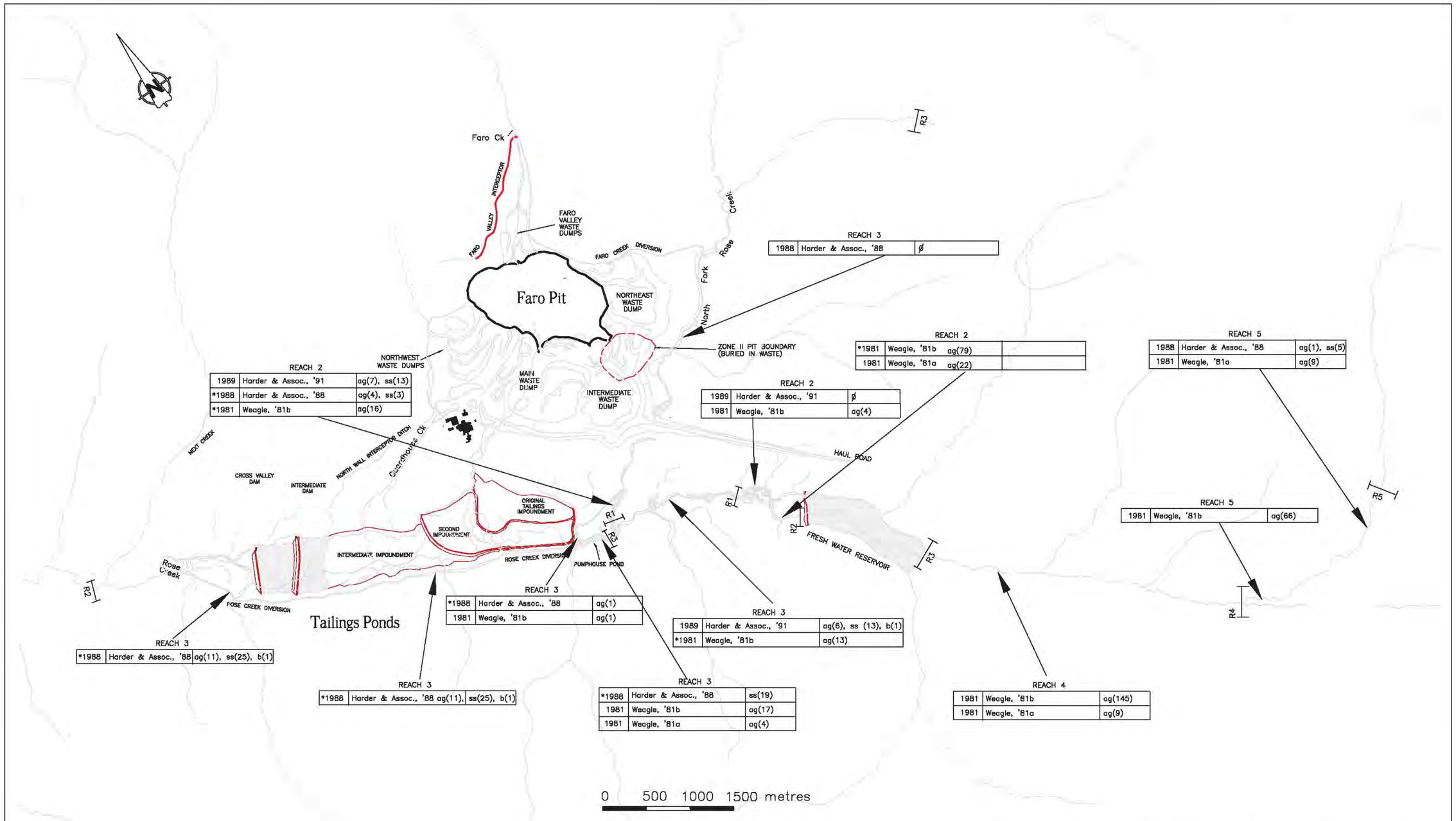
Anvil Range Mining Corporation

Anvil Complex Closure Plan

ROSE/ANVIL CREEK
DRAINAGE
FISHERIES SURVEY SUMMARY

PROJECT NO.	DATE	APPROVED	FIGURE
033001	Nov. 1996		3-40

Source: Robertson 1996



LEGEND

YEAR	REFERENCE	FISH SPECIES (NO. CAUGHT)

FISH SPECIES

ch = chinook slamon
ag = arctic grayling
rw = round whitefish
s = sucker
b = burbot
ss = slimy sculpin
ø = no fish

R = Reach Break

* Combination of two or more sample sites from same year and source

SCALE 1:40 000

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Anvil Complex Closure Plan

ROSE CREEK AT FARO
MINE SITE
FISHERIES SURVEY SUMMARY

PROJECT NO.	DATE	APPROVED	FIGURE
033001	Nov. 1996		3-41

Source: Robertson 1996

LEGEND:

YEAR	REFERENCE	FISH SPECIES (NUMBER CAUGHT)

FISH SPECIES

ch = chinook salmon
ag = arctic grayling
rw = round whitefish
s = sucker
ss = slimy sculpin
Ø = no fish
b = burbot

R = Reach Break

For Reference list see Table 3.25

Vangorda Creek

REACH 7

1987	Harder & Assoc., '87	Ø

REACH 8

1975	MEC, '76	Ø

Grum Mine

Vangorda Mine

Vangorda Dump

Grum Dump

GRUM CREEK

R6

R7

Shrimp Lake

Blind Creek

R5

REACH 4

1987	Harder & Assoc., '87	Ø

REACH 4

1987	Harder & Assoc., '87	Ø

REACH 3

1996	Harder & Assoc., '96	ch(3)
1990	Harder & Assoc., '92	ch(170), ss(18), rw(1)
1989	Harder & Assoc., '89	ch(320), ag(17), ss(20)
1987	Harder & Assoc., '87	ch(21)

R4

Faro Town

R3

R2

R1

REACH 2

1996	Harder & Assoc., '96	ch(204)
1990	Harder & Assoc., '92	ch(107), ag(8), ss(32)
1989	Harder & Assoc., '89	ch(67), ss(32)

REACH 1

1996	Harder & Assoc., '96	ch(282), ag(1), other(5)
1990	Harder & Assoc., '92	ch(28), ss(1), ss(37), s(1), b(1)
1987	Harder & Assoc., '87	ch(57), ag(16), other (38)
1975	MEC, '76	Ø

PELLY RIVER

PELLY RIVER

0 1000 2000 3000 meters

Scale 1:60 000

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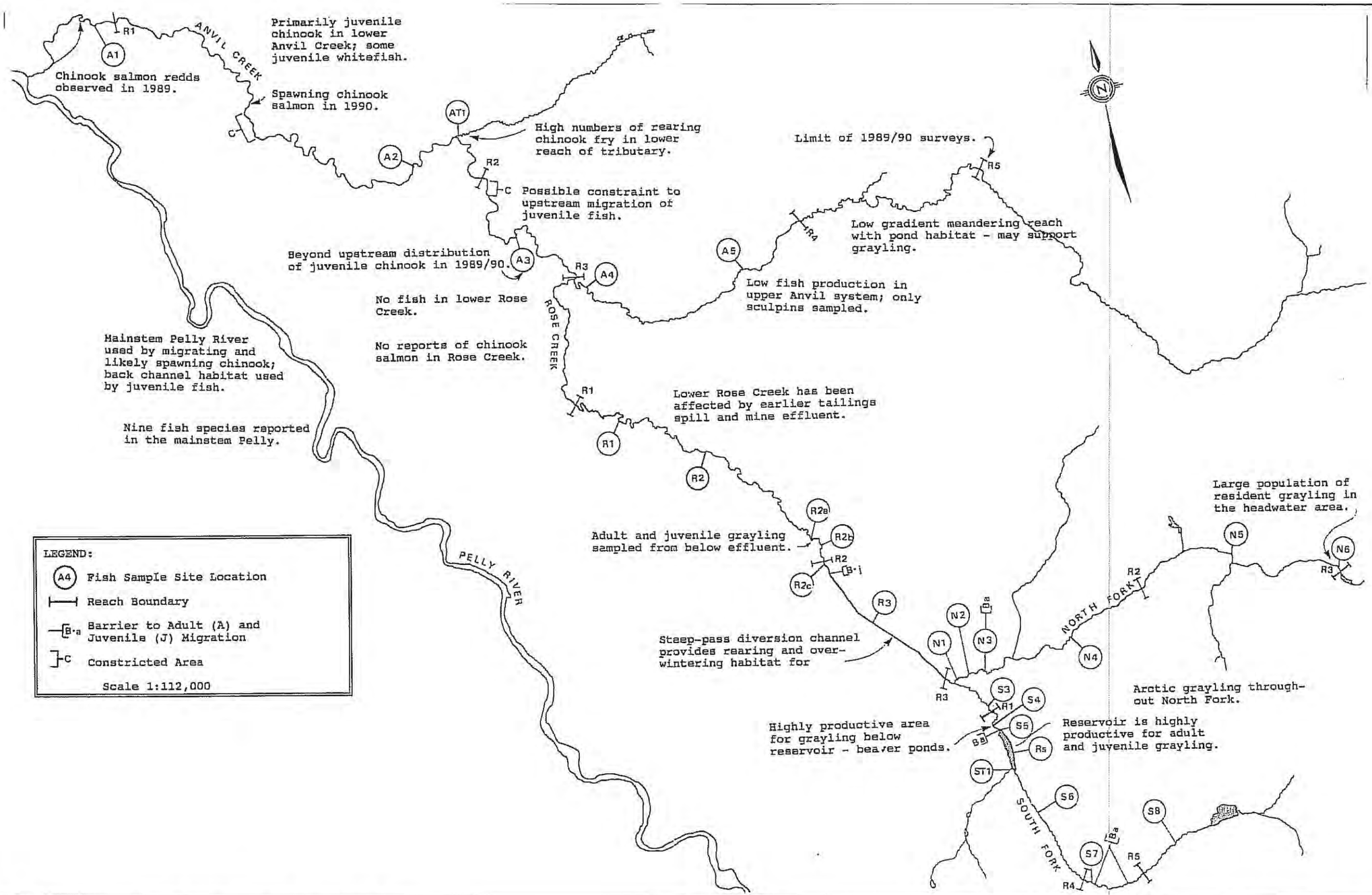
Anvil Range Mining Corporation

Anvil Complex Closure Plan

VANGORDA CREEK FISHERIES SURVEY

PROJECT NO. 033001 | DATE Nov. 1996 | APPROVED | FIGURE 3-43

Source: Robertson 1996



SOURCE OF FIGURE:
DRAWING SHOWN BELOW DRAWN FROM REPORT BY P.A. HARDER AND ASSOCIATES LTD. FOR CURRAGH RESOURCES INC. DATED APRIL, 1991. "OVERVIEW ASSESSMENT OF FISH RESOURCES IN ANVIL AND ROSE CREEKS"

FIGURE 1.1 Location of fish sample sites (1989/90), reach boundaries and annotations on fish habitat use in the Anvil/Rose drainage.

DRAWING INFORMATION:	
REVIEWED BY:	ED
DRAWN BY:	CPW
DATE ISSUED:	APRIL, 2002
PROJECT NUMBER:	22-943
FILE NAME:	22943-01-09.DWG
REVISION:	0

ANVIL/ROSE CREEK WATERSHED
FISH HABITAT

ANVIL RANGE MINE COMPLEX
2002 BASELINE ENVIRONMENTAL INFORMATION

Gartner Lee Limited | Deloitte & Touche | Figure No. 4.29

Source: Gartner Lee 2002

Appendix 6I
Vegetation and Soils Baseline Report

Draft

Faro Mine Vegetation and Soils Baseline Report Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 6, 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon Y1A 2J9

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Acronyms and Abbreviations

%	percent
>	greater than
CH2M HILL	CH2M HILL Canada Limited
cm	centimetre
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
EDI	Ecological Dynamics Incorporated
FMC	Faro Mine Complex
GLL	Gartner Lee Limited
GSC	Grum Sulphide Cell
ha	hectare
IW	Interim Works
kg/ha	kilogram per hectare
km	kilometre
Laberge	Laberge Environmental Services
LSA	Local Study Area
m	metre
mm	millimetre
Pb	lead
ppm	part per million
RGC	Robertson GeoConsultants Ltd.
RSA	Regional Study Area
RTI	Reforestation Technologies International
SARA	*Species at Risk Act*
SD	standard deviation
YG	Government of Yukon
YT	Yukon

SECTION 1

Introduction

This vegetation and soils (terrestrial and wetlands) report provides baseline conditions and trends at the Faro Mine Complex (FMC), to provide data to assess the potential effects of the Interim Works (IW).

This report consists of three main sections. Section 2, Methods, defines the overall study area of the baseline analysis, describes the vegetation (including re-vegetation trials) and soils data analysis methods. Sections 3 and 4 describe the results of the baseline characterizations for soil and vegetation, respectively. Baseline information on terrestrial and wetland vegetation and soils includes Project Local Study Area (LSA) and Regional Study Area (RSA) mapping, and details of rare plants and landscape-level analysis of vegetation and soil distribution (as required for the effects assessment linkages). Characterizing the terrestrial and wetlands vegetation and soils in the Project LSA includes describing the vegetation associations and species, and providing the results of a terrestrial effects study.

SECTION 2

Method

2.1 Study Areas

2.1.1 Local Study Area

The LSA is designed to represent the diversity of vegetation and soils in the immediate IW area. It comprises the area in which there is reasonable potential for effects (direct and indirect) on vegetation and soils from IW activities. Gartner Lee Limited (GLL) (2008) developed a vegetation map at a scale of 1: 20,000 using aerial photography and field data; this has been used as the local study area basis by subsequent studies such as Environmental Dynamics Incorporated (EDI) (2008) and AECOM Canada Ltd. (AECOM) (2009).

The LSA includes the area within a 1-kilometre (km)-wide buffer around FMC facilities, infrastructure, and road corridors, and covers an area of approximately 8,122.8 hectares (ha) (Figure 6I-1). The baseline FMC footprint includes the total current disturbance area of the Faro Mine Area, Vangorda/Grum Mine Area, and associated infrastructure including pits, the Rose Creek Tailings Area, quarries, ponds, and roads. The area of the baseline FMC footprint is 1,612.7 ha (Figure 6I-1).

2.1.2 Regional Study Area

The RSA was defined in order to assess effects at a broader geographical scale and to gain a better regional understanding of vegetation and soils (Figure 6I-2). The RSA includes the area where contaminants have been recorded at greater than background levels (GLL, 2006a), and is 58,803 ha in area. The Pelly River forms the western boundary of the RSA. The northern, eastern, and southern boundaries were delineated using mapped concentrations of contaminants characterizing the extent of mine impact in the area (GLL, 2006a) and geographical features, such as watershed boundaries.

2.2 Sources of Data and Information

The following data and information sources were used to evaluate vegetation and soil baseline conditions:

- Information provided in previous environmental reports and terrestrial effects studies for the LSA.
- Engineering reports for which some soil information was collected.
- Historical vegetation field monitoring results completed by various consulting firms, presented in appendices to environmental reports and in an ecological land classification delineation.
- Regional geology studies in the Anvil Mountain Range, and topography for the post-mining surface provided by 10-metre (m) contour Light Detection and Ranging data and historical orthophotographs.
- Information provided by revegetation activities on the reclaimed water reservoir (Laberge Environmental Services [Laberge], 2007), and current revegetation studies carried out as trials on the Grum Overburden Dump (EDI, 2010, 2013a) and Grum Sulphide Cell (GSC) (EDI, 2013b).
- Canadian federal (*Species at Risk Act* [SARA]) (Environment Canada, 2013) and territorial (Species at Risk) (Government of Yukon [YG], 2013a) lists of rare and endangered plant species and weed species, and national databases (NatureServe, 2013) for plant occurrence in the Yukon (YT).

This baseline study for the IW summarizes the available information gathered to date for vegetation and soil conditions at the LSA and RSA. This information provides a suitable basis for understanding conditions for the IW, from which the effects assessment may be completed.

2.3 Data Analysis and Compilation

The characterization of baseline conditions included a combination of tools and methods. Mainly, this effort consisted of a detailed data compilation and literature review. Descriptions of vegetation and soils from previous reports were reviewed and incorporated into this analysis.

Ecological land classification mapping from previous vegetation surveys (GLL, 2008) was checked against field records and other available vegetation survey results. The classifications are presented according to the GLL (2008) analysis.

Vegetation survey results for species presence/absence were compared with community association for all vegetation and rare plant surveys completed to date. Attachment 6I-1 presents the analysis table. Current SARA status (Environment Canada, 2013) and listing (YG, 2013a) was updated and is also presented in Attachment 6I-1.

Information regarding soils characterization has been collated from previous environmental and engineering studies. The information was used to provide an overview of likely soil conditions for IW activities.

SECTION 3

Soils Baseline Results

The diversity and distribution of soils in natural ecosystems play an important role in ecosystem function. Information about soils within the LSA and the RSA has been collected to determine vegetation patterns on the land and terrain types, and to consider wind and water erosion risks. The objective of the IW soil baseline is to identify the current known soil condition of the FMC and surrounding region.

3.1 Regional Studies

3.1.1 Geography

Upland soils in the study area are part of the Yukon Plateau. Lower lying, alluvial soils are found along the Ross River area. Soils in these two landscapes are described in this section.

3.1.2 Soils of the Yukon Plateau

The physical and chemical processes associated with the regional geography strongly influence soil deposition and formation across the region. The YT is part of the larger Canadian cordilleran region and is characterized by mountainous terrain and the presence of glaciers and icefields in some areas (YG, 2013b). The Faro Ross River Area is included in the Yukon Plateau ecoregion in which, according to Ecoregions of the Yukon, Part 2 (Smith et al., 2004), the majority of soils are classified as Eutric Brunisolic soils. These soils are generally characterized as having a high degree of base saturation and are usually well- to partially well-drained. They typically exhibit partial horizon development. Another major soil classification category found in the region is Turbic Cryosolic, if the soils have active layers greater than 50 centimetres (cm) and show signs of freezing and thawing. Occasional pockets of dystric brunisols occur on coarse-textured morainal and fluvioglacial materials.

The ecoregion is subject to scattered permafrost (Scudder, 1997) and soils often show evidence of mildfrost churning. On the unglaciated portion of the ecoregion, surfaces tend to be composed of long, gentle slopes at less than 10 percent grade, with uniform tussock tundra and shrub tundra vegetation cover. These soils are for the most part Orthic Turbic Cryosols with active layers less than 50 cm. The large active fans provide fresh alluvial materials to the landscapes. Older terraces have permafrost established within them, yet there has been little soil formation and weathering. These soils are Regosolic Static Cryosols.

Geochemically, YT soils are generally deficient in nitrogen and phosphorus. Levels of potassium and sulphur often depend on local geology rather than regional processes. Since 1984, more than half of the soils tested by the Yukon Agriculture Branch have been deficient in potassium (Yukon Ecoregion Working Group, 2004). The most common micro-nutrient deficiencies are boron and magnesium. Soils throughout YT are low in organic matter, and salinity has been identified as a problem in some localized areas.

Results from a Bond and Sanborn study (2006) on upland soils in unglaciated areas in west central YT showed that, from an exploration geochemistry perspective, soil development has had minimal impact on the distribution of elements in older soils because of wasting along the slopes due to gravity. Elemental distribution patterns in these upland soils were the result of (1) bedrock lithologies within the colluvium, (2) slope aspect variability, and (3) the occurrence of loess in the soil as a geochemical dilutant.

3.1.3 Soils of the Faro-Ross River Area

In general, the soils of the Faro- Ross River area are coarse-textured if fluvial in origin and medium- to coarse-textured if deposited in a morainal environment. There are approximately 60,000 ha of fluvial soils with the Magundy River and Ross River soils in the lower valleys and the Glenlyon, Lapie River, and Van Gorder soils on the upland regions (Rostad et al., 1977). There are also about 51,000 ha of morainal soils, consisting of the Fisheye Lake and Hoole River Associations. All soils are neutral to slightly alkaline below the surface (Rostad et al., 1977).

3.2 Previous Studies

The characterization of soil baseline conditions has been compiled and described based on studies completed in the FMC and the RSA. The results for the FMC have been completed on areas that were either disturbed when the study took place, or if undisturbed, were identified as potential future disturbance areas.

Table 6I-1 summarizes studies that provide information about surficial soil conditions. Figure 6I-3 shows the sampling locations from the studies focusing on soils in the LSA.

TABLE 6I-1
Soil Sampling Location and Data Summary at Faro Mine Complex
Vegetation and Soils Baseline – Faro Mine Interim Works

Source	Mine Area	Data Summary
Bond, Jeffrey D., 2001.	RSA	Surface geochemistry mapped for the RSA and classified by depositional environment. Soils data collected from soil pits and exposed distinct deposits in the RSA and LSA.
	Vangorda Open Pit	Zinc concentrations highest within 2 m of bedrock in Vangorda Open Pit exposed till, while lead concentration more uniformly distributed throughout the profile.
SRK Consulting Engineers and Scientists. 2003.	Faro Mine Road Borrow Site	Summary of Quarry and Borrow Locations and Estimated Material Reserves. Pictures of 60 test pits with qualitative descriptions by depth based on depositional environment from Bond (2001) mapping units in appendix.
	South Side of the Tailings Impoundment	
	Haul Road Borrow Site	
	Rose Creek Borrow Site	
	Rose Creek Haul Road Borrow Site	
	Tailings Borrow Site	
	Organic Soils	
	Granular Deposits east of the Fresh Water Supply Reservoir	
	Faro Mine Road Granite Outcrop	
Gartner Lee Limited. 2006a.	RSA	Surface organic material lead concentrations 10 ppm (median) and 18 ppm (maximum) in reference area
	FMC	Mineral soil lead concentrations 15 ppm (median) and 61 ppm (maximum) in reference area
Gartner Lee Limited. 2006b.	Faro Lube Shack	Borehole data describes colour and texture over 0.5-m depth intervals for 8 sites at the Faro and Vangorda Mine Areas
	Faro Tank Farm	
	Mill Diesel Tank	A total of 4 out of 6 sites on the Faro Mine Area exceeded hydrocarbon guidelines. Emergency Generator Yard likely exceeded hydrocarbon guidelines. Emergency Tailings Area listed as unknown.
	Emergency Generator Yard	
	Waste Oil Tank	
	Emergency Tailings Area	Both Lube Shack and Tank Farm sites at the Vangorda Mine Area exceeded hydrocarbon guidelines.
	Vangorda Lube Shack	
	Vangorda Tank Farm	
SRK Consulting Engineers and Scientists. 2006a.	Vangorda Waste Dump	Specifications on surface materials used and design of trial covers. Treatments range from no cover, to geotextiles with highly compacted till.

TABLE 6I-1
Soil Sampling Location and Data Summary at Faro Mine Complex
Vegetation and Soils Baseline – Faro Mine Interim Works

Source	Mine Area	Data Summary
SRK Consulting Engineers and Scientists. 2006b.	East of Grum Pit Vangorda Creek East of Vangorda Pit	Surface organic material lead concentrations 10 ppm (median) and 18 ppm (maximum) in reference area
SRK Consulting Engineers and Scientists. 2006c.	FMC Low-grade Ore Stockpile A, Stockpile B, Stockpile C, adjacent to Faro Open Pit	Indicated highly variable physical surficial characteristics. Drilling stopped when natural soils encountered pits visually logged and samples taken. Boreholes logged at 1-m intervals or as appropriate
SRK Consulting Engineers and Scientists. 2006d.	North Slope above the Cross Valley Dam Pond, between the Faro Valley Waste Dump and the Original Tailings Impoundment East of the Fresh Water Supply Reservoir, east of the North Fork Rock Drain and northwest of the Faro Valley Waste Dump	Potential borrow pit area investigation with latitude/longitude of 17 boreholes and descriptions . Locations are in relatively undisturbed areas of the LSA.
SRK Consulting Engineers and Scientists. 2007.	Well PW3 in Zone II Outwash Area	The PW3 well is representative of the hydrostratigraphy in the Zone II Outwash Area. The general soil profile near PW3 consists of the following: • 0-2.5 m gravelly sand with trace silt • 2.5 – 3.5 m silty sand and sandy silt with organics (lowest conductivity) • 3.5 – 6.7 m sand and gravel with cobbles (highest conductivity)
Environmental Dynamics Inc. 2008.	Faro Valley Waste Dump/Till Deposits	Faro Valley Waste Dump toe has small areas of intact (biologically active) surface soils Faro Valley Waste Dump was free-dumped till materials with coarse texture and high fragment content
	Vangorda Overburden Dump	Vangorda Overburden Dump material was heterogeneous with elevated levels of lead and zinc.
	Grum Overburden Dump	Grum Overburden Dump: glacial till with sampled textures ranging from sandy loams to loams with coarse fragment contents of approximately 15 to 75%.
	Vangorda and Grum Waste Dumps	Both WRDs were freely dumped till materials with coarse texture and high-fragment content
	Rose Creek West Pit Area	West Pit Locations ranged from coarse sands and gravels to finer-textured materials, predominantly sand or silt
	Rose Creek Haul Road	Haul Road textures were loamy sands to loams with approximately 30 to 60% coarse fragments (> 2 mm)
	Tailings Borrow Areas	Tailings Borrow ranged from sandy loams to silt loams with coarse fragment contents of approximately 5 to 55%
	Haul Road Borrow Area	Textures were sandy loams to loams with 40-60% coarse fragments

TABLE 6I-1
Soil Sampling Location and Data Summary at Faro Mine Complex
Vegetation and Soils Baseline – Faro Mine Interim Works

Source	Mine Area	Data Summary
SRK Consulting Engineers and Scientists. 2008a.	Vangorda Waste Dump	Subsurface geology is comprised of silt and clay till. The till unit generally extends to bedrock. In borehole 2001-1, the clay till unit was observed to extend to the depth of the borehole (38.1 m below grade). Clay content increased at depths ranging from 7.6 to 9.1 m, although there was no quantification of the content. Two additional borehole descriptions at the Vangorda Waste Dump in the report describe clay till extending from the surface through the full extent of the borehole. Data collection issues and design make it difficult to draw conclusions on soil property differences between treatments.
Environmental Dynamics Inc. 2009. (Soil Analysis – Appendix A [EDI, 2009])	Grum Overburden Material Dump	Potential reclamation soil cover source for FMC described average % particle size and pH for 13 samples over 2 sampling years. Sand = 47.8, SD = 7.4 Silt = 38.1, SD = 5.9 Clay = 14.1, SD = 3.9 pH = 7.8, SD = 0.2
SRK Consulting Engineers and Scientists. 2009.	FMC	General description of surficial geology.

Notes:
% = percent
mm = millimetre
ppm = parts per million
SD = standard deviation

GLL (2006a) completed a terrestrial effects study that examined 168 samples (by depth and parent material) for 29 elements, to evaluate whether elevated elemental levels attributed to mine-generated airborne deposition could be due instead or in part to the influence of underlying mineralized soil materials. Out of the 29 elements evaluated, the study found patterns of elevated lead and zinc concentrations in surface organic soil similar to patterns found in in lichen (see Section 4.2.2.2), but no similar pattern of elemental concentrations existed in subsurface organic or mineral soils. Furthermore, no correlation was found to exist between underlying materials and surface-based observations.

This suggests that the spatial pattern of elevated elemental levels observed in the study area are the result of deposition from the FMC (called the Anvil Range Mine Complex in GLL [2006a]) and eliminates the possibility that these levels can be attributed to natural effects present prior to mining. Lead, zinc, and copper concentrations were elevated when compared to a reference site. Lead and zinc were weakly complexed within the soil and have the greatest potential for mobility within the soil profile. Additionally, cadmium was determined to be weakly complexed within the soil profile, therefore increasing its availability for vascular plant uptake.

Summary of Baseline Soil Conditions

In conclusion, evidence from previous studies regarding the baseline soils conditions in the FMC and in studies conducted within the LSA and RSA suggest that there are variable surficial conditions. Characterization of geochemical patterns conducted across the site by GLL (2006a) indicate that the zone of highest elemental levels is centered on the Rose Creek Tailings Area and FMC mill. This zone extends primarily northwest down the Rose

Creek Valley, and northeast up the North Fork of Rose Creek Valley in the surface organic soils. As demonstrated by the studies included in Table 6I-1, soil physical characteristics for areas within the LSA have been characterized on a case by case basis. Areas not impacted directly by mining activities are expected to conform to regional patterns of physical soil development determined predominantly by depositional environment, position on the landscape, and climate, as noted in Section 3.1.

SECTION 4

Vegetation Baseline Results

The diversity, distribution, and health of vegetation in natural ecosystems play an important role in ecosystem function. Vegetation patterns on the land are influenced by climate, terrain, substrate, water availability, and nutrient regime. Characteristic groupings of species develop in response to these conditions. Different vegetation associations provide a variety of habitats used by wildlife. Wildlife and people can influence vegetation abundance and diversity. Industrial development, in particular, has the potential to affect vegetation ecosystem health.

The objective of the IW vegetation baseline is to identify the known vegetation condition at the FMC and in the surrounding region.

4.1 Regional Studies

The FMC is located within the Yukon Plateau-North Ecoregion, in the Boreal Cordillera Ecozone of the YT (Yukon Ecoregion Group, 2004). The vegetation of the Yukon Plateau–North Ecoregion ranges from boreal to alpine. The northern boreal forest exists at elevations of up to 1,500 m. Vegetation at higher elevation in the sub-alpine zone is characterized by shrub and lichen tundra; and the alpine by low ericaceous shrubs, prostrate willows, and lichens. Talus slopes are common at high elevations, and support communities of crustose lichens. The thickness of the vegetation and humus layer are controlled by forest fire history (Smith et al., 2004).

In the boreal zone, open black spruce (*Picea mariana*) stands with a moist moss, or drier lichen understory is the dominant forest type. Black spruce dominates the moister sites and cooler north-facing slopes, while often mixed with subalpine fir (Yukon Ecoregion Group, 2004). White spruce (*Picea glauca*), occasionally with trembling aspen (*Populus tremuloides*) or lodgepole pine (*Pinus contorta*), grows on warmer, better drained soils. The mixed canopy forests are common because of frequent fires, and trembling aspen and balsam poplar (*Populus balsamifera*) are commonly found on disturbed sites (Smith et al., 2004). Feathermoss dominates the understory vegetation of nearly closed coniferous stands, but as trees become less dense, willows and ericaceous shrubs become prevalent. (Smith et al., 2004).

The 450-km-long Tintina Trench forms a defining landscape feature, traversing the ecoregion from the northwest to the southeast. The trench is an important migration corridor for large numbers of Sandhill Crane and waterfowl breeding in Alaska (Smith et al., 2004). The Pelly, Ross, Macmillan, Stewart, Hess, McQuesten, and Klondike River valleys all traverse the ecoregion. The region consists of relatively rolling highlands with an east-west orientation. Permafrost is discontinuous but widespread in this region, although less extensive near the town of Faro (Smith et al., 2004).

The ecoregion supports populations of most of the YT's typical boreal forest mammals, such as the following:

- Moose
- Woodland caribou
- Stone sheep
- Grizzly bear
- Black bear
- Wolverine
- Marten

Many forest birds reach their northern limit of breeding in the ecoregion (Smith et al., 2004).

CH2M HILL Canada Limited (CH2M HILL) completed a literature review of vegetation information specific to the Faro Mine region. Regional information about vegetation was taken from the Montreal Engineering Company Ltd in 1975 (cited in Robertson GeoConsultants Ltd. [RGC], 1996) study that included an initial inventory of vegetation in the area. In 1998, vegetation classification for Sheep Mountain, as well as a broader-scale classification of vegetation communities in the Carmacks-Ross River area, provide some general vegetation information for the

region (Oswald et al., 1983; Staniforth, 1998) that was used as the basis for Yukon Ecoregions Working Group (Smith et al., 2004).

4.2 Previous Studies

4.2.1 Plant surveys

Four vegetation surveys have been completed on and around the FMC (RGC, 1996; GLL, 2008; EDI, 2008; AECOM, 2009). An initial survey prior to later vegetation survey work was completed by Montreal Engineering in 1975 (cited in RGC, 1996). RGC (1996) described and mapped six broad vegetation zones within the FMC and surrounding region: (1) flood plain forest, (2) upland forest, (3) bog forest, (4) alpine tundra, (5) subalpine transition, and (6) alluvial plain shrub. GLL's (2008) vegetation baseline was completed on the LSA and included a slightly different region than RGC (1996); however, many of the vegetation associations from GLL (2008) may be linked to some of RGC's overall vegetation groups.

Two vegetation plot surveys were completed in 2007 (GLL, 2008; EDI, 2008), and a rare plant survey was completed in 2008 (AECOM, 2009). GLL's vegetation baseline study, completed throughout the summer of 2007, was designed to build a vegetation association map of the LSA (GLL, 2008). The EDI (2008) plant survey between July 20 and 24, 2007, described different vegetation groups that could be found within and around the LSA (EDI, 2008). The 2008 rare plant survey was completed to determine whether there were rare plants in the LSA (AECOM, 2008).

4.2.1.1 Vegetation Associations and Groups

GLL's 2007 vegetation survey included 17 ground plots and 59 visual inspections within the LSA (GLL 2008).Thirteen vegetation associations were found within the LSA (GLL, 2008) (Table 6I-2 and Figure 6I-4). The most prominent vegetation association found during GLL's (2008) vegetation baseline was the closed white spruce/willow forest, which covered 45 percent (3,657 ha) of the LSA. The second most prominent vegetation association was the mixed coniferous-deciduous forest covering 8.4 percent (682 ha) of the LSA (GLL, 2008). The white spruce/willow forest is located in both the boreal and the subalpine zones, on various upland and lowland slopes. White spruce dominates the tree canopy, with the occasional presence of subalpine fir. A well-developed shrub layer is dominated by a high cover percentage of 1-m-tall willow species, with a lower cover percentage of dwarf birch, Labrador tea, and shrubby cinquefoil. The dwarf shrubs in the ground cover layer include bog billberry, common bearberry, net-veined willow, and crowberry. Common horsetail and bluegrass species were also found frequently in this area. The following mosses and lichens are common throughout this vegetation association:

- Stair-step moss (*Hylocomium splendens*)
- Reindeer lichens (*Cladina rangifera*)
- Pelt lichens (*Peltigera* spp.)

TABLE 6I-2
Faro Mine Closure Project Local Study Area Vegetation Associations Baseline Area[a]
Vegetation and Soils Baseline – Faro Mine Interim Works

	LSA Baseline Area	
Vegetation Association	**Area (ha)**	**% of LSA**
Sedge/Willow	54.6	0.7
Willow/Sedge	254.7	3.1
Willow/White Spruce	326.0	4.0
Willow/Dwarf Birch	182.2	2.2
Dwarf Birch/Willow	232.2	2.9
Dwarf Birch/Lichen/Subalpine Fir	357.8	4.4
Dwarf Birch/Subalpine Fir	279.9	3.4

TABLE 6I-2
Faro Mine Closure Project Local Study Area Vegetation Associations Baseline Area[a]
Vegetation and Soils Baseline – Faro Mine Interim Works

	LSA Baseline Area	
Vegetation Association	**Area (ha)**	**% of LSA**
White Spruce/Willow	3657.4	45.0
White Spruce/Feathermoss	105.1	1.3
Pine	52.4	0.6
Mixed Coniferous-Deciduous	682.0	8.4
Deciduous	276.6	3.4
Graminoid	49.3	0.6
Project Footprint	1612.7	19.9
LSA Total Area	**8122.8**	**100.0**

[a] Adapted from GLL (2008)

Figure 6I-4 shows a map of the thirteen vegetation associations within the LSA.

Vegetation associations from GLL (2008) indicated that the northern boreal zone includes forested and wetland associations in the low-elevation valley bottoms and low-lying terrain. The northern boreal zone contains a number of associations, linked to morainal and glacio-fluvial terrain that are influenced by fire. The areas of the Project LSA in the subalpine zone are dominated by tall shrub vegetation. Scattered, open spruce and fir forests occur at the lower limits, and grade into lower stature shrub, herb, and lichen communities at upper elevations. Attachment 6I-2 describes all thirteen vegetation associations for the LSA from the GLL (2008) vegetation survey.

A concurrent study by EDI took place July 20 to 24, 2007. The survey included 70 plots established on and adjacent to the FMC (Figure 6I-5).

Vegetation was arranged into five groups (EDI, 2008), presented in Table 6I-3. Vegetation groups ranged from disturbed forests, where fire removed the mature spruce trees, to older, undisturbed forests.

TABLE 6I-3
Vegetation Types in the Faro Mine Complex
Vegetation and Soils Baseline – Faro Mine Interim Works

Vegetation Group	Species Present	Habitat characteristics
Pleurozium	*Pleurozium shreberi* *Abies lasiocarpa* *Peltigera sp.* *Cladina mitis*	Older undisturbed forest
Mertensia	*Mertensia panicluata* *Potentilla fruticosa* *Salix myrtillifolia* *Salix reticulata*	Rich forests in a transitional state
Ledum	*Ledum groenlandicum* *Empetrum nigrum* *Vaccinium vitis-idaea* *Vaccinium uliginosum* *Arctostaphylos rubra* *Betula glandulosa*	Link between the undisturbed forests and the lightly disturbed sites around the FMC

TABLE 6I-3
Vegetation Types in the Faro Mine Complex
Vegetation and Soils Baseline – Faro Mine Interim Works

Vegetation Group	Species Present	Habitat characteristics
Populus	*Populus balsamifera* *Salix arbusculoides* *Salix bebbiana* *Agrostis scabra* *Salix planifolia*	Characteristic species of disturbed mineral soils
Shepherdia	*Shepherdia canadensis* *Linnaea borealis* *Pinus contorta* *Geocaulon lividum* *Calamagrostis inexpansa*	Dry forest stands, often where past forest fires have removed the mature spruce. Dry forests with open grassy areas.

Notes:
Modified from EDI (2008), *Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment*. Data was collected July 20 to 24, 2007.

4.2.1.2 Rare or Threatened Plant Species

Douglas et al. (1981) defined rare plants as "*one that has a small population within the area, may be restricted to a small geographical area where it may be locally common, or may occur in low numbers over a wide area. A threatened plant is one that is likely to become endangered within the forseeable future over all or a significant portion of its range, and an endangered plant is one that is in danger of extirpation throughout all or a significant portion of its range in a province, territory or state.*"

Species at Risk are plant species that are considered extirpated, endangered, threatened, or of special concern by the federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The SARA regulates Species at Risk and legislates activities within their critical habitat. SARA does not officially protect species that are listed by COSEWIC but are classified as "no status" under SARA.

The Species at Risk in YT are listed based on their COSEWIC standing (YG, 2013a). Under the COSEWIC ranking, there are currently three plant species that are considered species at risk and one plant species that is under review in Yukon (Table 6I-4).

TABLE 6I-4
Plant Species at Risk in Yukon
Vegetation and Soils Baseline – Faro Mine Interim Works

Species	Common Name	COSEWIC[a] (date listed)	SARA [b]	NatureServe [c] Ranking Status in YT
Draba yukonensis	Yukon draba	Endangered (November 2011)	No Status	S1 [d]
Micranthes spicata	spiked saxifrage	Threatened (May 2013)	No Status	S2 [e]
Carex sabulosa	Baikal sedge	Threatened (May 2005)	Threatened	S2 [e]
Podistera yukonensis	Yukon podistera	Under review for November 2014	Not Listed	S2 [e]

[a] COSEWIC (2013)

[b] Environment Canada (2013)

[c] NatureServe (2013)

[d] S1 ranking means the species is critically imperiled, ranking ranges from S1 (critically imperiled) to S5 (secure).

[e] S2 ranking means the species is imperiled, ranking ranges from S1 to S5 (secure).

GLL did not find rare plant species during a rare plant survey conducted between August 7 and 12, 2008 (AECOM, 2008). There was one potential rare plant within the Grum survey area. Field identification indicated the presence of *Botrychium spathulatum,* which has the ranking of S1S2 (uncertainty of ranking between critically imperiled and imperiled) in YT (NatureServe, 2009); however, Bruce Bennett (former NatureServe Yukon botanist, currently with Government of YT) examined the plant species (Bruce Bennett, Personal Communication, 2008) and re-identified it as *B. minganense* (ranking S3S4; uncertainty of ranking between vulnerable and apparently secure). These species are commonly confused, and *B. minganense* is not a rare species.

The 2008 GLL rare plant survey focused on areas that are to be disturbed as part of waste rock re-sloping that will be part of the overall Faro Mine Remediation Project. GLL investigated four survey areas along the edge of the waste rock slopes, three in the Faro Mine Area, and one in the Grum area. The rare plant survey used a maximum transect distance of 200 m beyond the base of the waste rock (Figures 6I-6 and 6I-7).

CH2M HILL assessed all plant species identified in GLL (2008), EDI (2008), and AECOM (2009) vegetation surveys for status and ranking on Environment Canada (2013) and COSEWIC (2013) lists (Table 6I-1-1 in Attachment 6I-1). None of the plant species from the three vegetation surveys were listed on either of these databases (Table 6I-1-4 in Attachment 6I-1). Attachment 6I-1 (Table 6I-1-4) lists the NatureServe (2013) ranking for the surveyed plant species. Based on Nature Serve (2009) status rank for Yukon, the species of conservation concern which are ranked S1 and S2 (critically imperiled and imperiled, respectively) in the previous vegetation surveys include *Alnus crispa* ssp*. sinuate, Carex aeneta, Carex phaeocephala, Cassiope mertensiana,* and *Helictotrichon hookeri.*

All surveyed areas by GLL (AECOM, 2008) experienced some human disturbance in the form of dirt roads, old trails, scraped-up areas and piled-up earth, and large boulders at the bases of the waste rock slopes. Native shrubs, grasses, sedges, and forbs in various combination form the dominant vegetation along the sides of the roads and trails, and on the dirt piles. Young white spruce, willows, and other shrubs typically grow between the boulders at the slope bases, where the boulders have fallen into the existing vegetation.

Little-to-no soil accumulated between the boulders on the waste rock slopes themselves, and vegetation was sparse. A few willow shrubs, white spruce seedlings, and occasionally forbs (such as fireweed, and hawksbeard) grew on the slopes, but lichens and mosses were uniformly absent on and between the boulders. In a few areas, where slopes were composed of finer materials, sparse grasses also grew. Seepages and silt flows at the bases of the slopes were common, forming wet muddy patches and sometimes forming small brooks. Moisture-loving graminoids, forbs, mosses, and shrubs colonize these sites. Patches of orange-coloured deposits were seen in one of these seepage sites, mostly lacking vegetation in the exposed deposits and surrounded by dense tall Willow shrubs (AECOM, 2008).

Before GLL began its field work, Bruce Bennett provided a list of Yukon rare plants, their rare status rankings, and their expected habitats (Bruce Bennett, Personal Communication, 2007). Maps and descriptions of vegetation types in the Faro Mine Area were consulted to determine the likelihood of finding rare vascular species in the survey areas. The described vegetation types are typical of much of central YT, and do not generally host rare species. Throughout the survey, habitats and vegetation types were examined for the presence of rare species.

4.2.1.3 Introduced Plant Species

The GLL and EDI vegetation surveys identified introduced plant species in the FMC area (GLL, 2008; EDI, 2008); Attachment 6I-1 identifies these species. Further introduced plant species may be growing in mine disturbance areas and in revegetation areas.

4.2.1.4 Summary of Vegetation Surveys

CH2M HILL assembled an overall species list for the two 2007 studies (GLL, 2008; EDI, 2008) and the 2008 rare plant survey (AECOM, 2008) for comparison (Attachment 6I-1). This list excluded the following plots that were outside the LSA: VP29, VP 54, VP 55, VP 56, VP57, VP58, VP59, VP60, VP62, VP63, VP64, VP65, VP66, VP67, VP68, VP69, and VP70 from the July 20 to 24, 2007, EDI study (2008).

4.2.2 Terrestrial Contaminants

Past operations at the FMC have resulted in metals concentrations in the area that are greater than the reference/background levels. Initial studies in 2002 (C.E. Jones & Associates Ltd., 2003) indicated elemental deposition in the study area was the result of mining operations; however, no information was provided about its timing. A Terrestrial Effects Study (GLL, 2006a) took place in 2004 and 2005 to determine if deposition was ongoing. This study component was designed to determine whether measured elemental concentrations were at their maxima or would continue to increase. The report concluded that concentrations of metals that originated from the FMC are generally higher near the mine and decline with distance from the mine. Furthermore, deposition of some metals from the FMC is still occurring in the immediate area, mostly during the snow-free period. A summary of the findings from GLL (2006a) are in the following subsections.

4.2.2.1 Terrestrial Contaminants – Sampling

There is no pre-mining baseline information about contaminant levels in soils and vegetation collected from Anvil Range; therefore, information from Swim Lake, approximately 9 km southeast of the Vangorda Pit, was used for reference information for metal concentrations in soils and vegetation. Swim Lake was chosen as a reference location because it was far enough from the Anvil Range Mine Complex to be free of mine-generated airborne deposition but within the same deposit type (C.E. Jones & Associates Ltd., 2003).

To isolate the effects of airborne deposition from mineralization, GLL (2006a) determined the spatial distribution of elevated elemental concentrations, primarily by sampling lichens. GLL (2006a) selected lichens (*Cladina* spp.) as the indicator species because they are long-living, non-deciduous, and depend entirely on airborne material and precipitation for nutrients (and are therefore unaffected by the mineralization of underlying soils). Soils also accumulate metals and provide an additional record of cumulative airborne deposition; however, metal concentrations can also result from natural mineralization and larger landscape processes, such as erosion and glacial transport. GLL (2006a) sampled soil to confirm the results of lichen sampling, and detect naturally elevated elemental concentrations (that is, those unrelated to the mine).

Concurrent to the lichen study, a moss bag study was conducted (GLL, 2006a). Moss was rinsed, dried, analyzed for pre-exposure concentrations and placed into polypropylene mesh bags. An increase in elemental concentrations to above pre-exposure levels would indicate ongoing airborne deposition (GLL, 2006a).

Figure 6I-8 shows the sampling locations for 2002, 2004, and 2005.

4.2.2.2 Elemental Concentrations in Vegetation

Select plant species were collected by GLL (2006a) in the study area to determine the uptake of various elements in vegetation used by wildlife (e.g., forage species) or humans (e.g., medicinal use or ingestion). Elemental concentrations in vascular vegetation can be influenced by elemental uptake via root systems, and by airborne elemental deposition through deposits on plant surfaces or surface soils. It was necessary to distinguish between these sources and establish the difference between mining-related and natural sources. To do so, soils were collected, subsampled, and analyzed where plants important to wildlife or humans were collected.

Potential mechanisms to disperse elements in the FMC study area include windblown dusts and a historical tailings spill into Rose and Anvil Creeks, which drain portions of the FMC. Lead (Pb) is the least mobile of the heavy metals (as opposed to zinc, which can be highly mobile in both soils and plants); therefore, it likely represents the best historical record of elevated elemental levels resulting from FMC operations. GLL (2006a) used Pb in lichen tissue as the principal indicator of how elemental levels at the FMC were spatially distributed. High lichen Pb levels in the integrated 2002 / 2004 / 2005 data set are evidence of significant mine-generated accumulations. Lead in floodplain soils is probably largely the result of the 1975 tailings dam breach, while accumulations in other areas are likely the result of airborne transport.

Pb isotope tracing was used to determine the origin of lead in samples of dust, soils, and moss bags from the study area. Because it is possible for lead from naturally occurring and outside sources to affect the study area, local “background” levels had to be distinguishable from those resulting from the FMC. The lead isotope analysis for moss bag sampling (GLL, 2006a) indicated that the mine ores were the source of almost 100 percent of the lead that is currently found in the study area.

The information collected by GLL (2006a) showed that lead concentrations in lichen near the mine were up to 450 times those at Swim Lake. The concentrations of lead are generally higher near the mine, and decline with distance from the mine (Figure 6I-9).

As Figure 6I-9 shows, the zone of elevated lead concentrations in lichen extended as follows:

- Southeast to the Blind Creek Valley / Swim Lake basin (1 to 10 km from the Vangorda/Grum Area)
- Southwest to the Pelly River Valley (5 to 10 km from the FMC)
- At least 20 to 25 km from the FMC up the North Fork Rose Creek drainage
- At least 40 to 50 km from the FMC down the Rose / Anvil / Pelly drainages

The elevated concentrations of elements from the FMC down the Rose / Anvil / Pelly drainages may have been contributed from the 1975 tailings dam breach. Although the area sampled for lichens was expanded in 2004 and again in 2005, it did not necessarily determine how far the maximum spatial extent of elevated lichen-lead concentrations extended from the FMC (GLL, 2006a).

4.2.2.3 Summary of Results for Elemental Levels in Lichen

The following paragraphs summarize elemental levels found compared with Swim Lake levels (reference area) (GLL 2006a; AECOM 2009).

High Elevation Relative to Reference Levels – Lead and Arsenic

Maximum lichen lead (747.7 ppm) and arsenic (23.7 ppm) concentrations in areas affected by the mine were 450 and 250 times the Swim Lake maximum, respectively (GLL, 2006a). Equivalent-to-reference levels were found southwest of the FMC, across the Rose Mountain range, and around the southeast to north perimeters of the study area. To the northeast and northwest, however, equivalent-to-reference concentrations are at least 20 to 25 km and 40 to 50 km, respectively, from the FMC. Approximately 76,900 ha of land showed lichen-lead concentrations that were at least 3 times the observed Swim Lake maximum.

Moderate Elevation Relative to Reference Levels – Zinc, Copper, Iron, Silver, and Thallium

In mine-affected areas, the maximum lichen concentrations of zinc, copper, iron, silver, and thallium were 15 to 75 times higher than Swim Lake maxima. Equivalent-to-reference concentrations were generally reached at distances of 0 to 2 km from the Vangorda/Grum Area, northeast along the exposed (mine-side) slopes of Mount Mye, and southwest along the exposed slopes of Rose Mountain. Elevated elemental levels generally extend northeast along North Fork Rose Creek, north up and past Mount Aho, and northwest down the Rose Creek Valley.

Low Elevation Relative to Reference Levels – Barium, Chromium, Mercury, Nickel, and Selenium

In mine-affected areas, maximum lichen concentrations of barium, chromium, mercury, and nickel in mine-affected areas were three to nine times the Swim Lakes maxima. Zones of elevated elemental levels are generally smaller than those for lead and other elements in the High and Moderate categories. Although selenium concentrations near the mine were 25 times the Swim Lake maximum, this element has been placed in the “low elevation” category because the area affected by elevated concentrations is very small.

Marginal Elevation Relative to Reference Levels – Antimony, Cadmium, and Cobalt

There is some evidence that elevated lichen concentrations of antimony, cadmium, and cobalt are associated with the FMC. The concentrations are, however, either within reported YT reference ranges for lichens for antimony and cobalt (Gamberg, unpublished), or are similar to other high levels in the study area that do not appear to be related to the mine (cadmium) (GLL, 2006a).

No Elevation Relative to Reference Levels – Boron, Molybdenum, Titanium, Vanadium, Aluminum, Beryllium, Calcium, Magnesium, Manganese, Phosphorus, Potassium, Silicon, Sodium, Tellurium, Tin, and Uranium

Elevated lichen concentrations of these elements either occurred in areas that were not affected by the mine or else there was no apparent pattern of elevated levels.

Consequently, elevated concentrations of these elements cannot be attributed to FMC operations.

4.2.2.4 Elemental Concentrations in Vegetation and Mineral Licks

The following paragraphs summarize the elemental level found in vegetation in the region around the FMC (GLL 2006a; AECOM 2009).

High Elevation Relative to Reference Levels – Lead

Lead concentrations for all plant species groups were greatly elevated in the area immediately adjacent to the tailings impoundment/mill complex, which indicates the mine has affected lead concentrations in vascular plants and mushrooms, as well as in lichens and soils. Lead levels near the mine ranged from 2.5 (horsetails) to 410 (tree sap) times Swim Lake reference means. Willows, grasses, forbs, horsetails, mushrooms, and bear root all had lead levels greater than Swim Lake ranges. There were no YT background levels for comparison with tree sap.

Moderate Elevation Relative to Reference Levels – Zinc

Zinc levels were significantly elevated in berries, willows, and forbs collected next to the tailings impoundment/mill complex. The magnitude of elevation ranged from three times the Swim Lake reference mean (berries) to 20 times (forbs). In most zones affected by the mine, zinc levels in forbs, willow, mushroom, and bear roots exceeded documented YT background ranges (Gamberg, unpublished).

Low Elevation Relative to Reference Levels – Copper, Nickel, Silver, Mercury, and Thallium

Copper, nickel, silver, mercury, and thallium had isolated occurrences of significantly elevated concentrations compared to Swim Lake reference levels. Concentrations ranged from approximately two (copper in willows) to nine times (silver in willows and thallium in Labrador tea) Swim Lake reference means. There is no conclusive evidence that the elevated nickel concentration in lichens can be attributed to the presence of the FMC. The maximum nickel concentrations are within published YT background ranges.

Compared with Swim Lake or YT reference levels (Gamberg, unpublished), there were elevated concentrations of the following elements in northern rough-stemmed mushrooms, bear root, and tree sap collected in mine-affected areas:

- Antimony
- Arsenic
- Barium
- Cadmium
- Chromium
- Cobalt
- Iron
- Mercury

Maximum arsenic concentrations in northern rough-stemmed mushroom and tree sap in mine-affected areas were 11 times reference levels (Swim Lake), and the maximum iron concentration in tree sap was 22 times reference levels.

Soil samples were collected from two mineral lick sites. The analysis of soils collected at Mineral Lick Site 2 indicates the potential for ungulates to consume soils that contain marginally elevated levels of mine-related elements, particularly lead; however, the effect of the mine is expected to be small. Lead levels at Mineral Lick Site 2 are no higher than Swim Lake or published maxima.

4.2.2.5 Summary

The results of the terrestrial effects study for the FMC indicated mining has resulted in elevated concentrations of several elements at the FMC and in the surrounding area (GLL, 2006a). Metal concentrations (lead, zinc, copper, nickel, silver, mercury, thallium, antimony, arsenic, barium, cadmium, chromium, cobalt, iron, and mercury) that were greater than the reference/background levels were detected in plants, small mammals, and other wildlife in the area (Gamberg, unpublished; GLL, 2006a). The presence of elevated elemental concentrations in plants

consumed by humans and animals indicates these elements are entering the environmental food chain and could also be incorporated into the human food chain (GLL, 2008).

4.2.3 Revegetation

Because some revegetation has already been undertaken at the FMC, this baseline report describes the revegetation trials and studies, and the results of those programs. Two areas have been examined for revegetation: the Vangorda/Grum Area and the Reclaimed Water Reservoir. Seven revegetation trials and activities have been undertaken in these two areas (Laberge, 2007; EDI, 2010, 2013a, 2013b):

- 2007 Vangorda Waste Rock Lysimeter Plot No. 1
- 2009 Vangorda Waste Dump revegetation
- 2008 Grum Overburden Dump Trial A and Trial B
- 2009 Grum Overburden Dump
- 2012 Grum Sulphide Cell Revegetation
- 2003 and 2004 Dewatered Freshwater Reservoir revegetation

Vangorda Waste Rock Revegetation

In 2007, a 25-m-by-25-m plot was tilled and planted with live balsam poplar and willow stakes, and seeded with alder seed (EDI, 2010). Because of shallow cover depth, live stakes were only planted to an average depth of 0.5 m, rather than the planned 1-m depth. The success of the live stake revegetation was monitored by counting the stakes and identifying them as living (signs of sprouting with no signs of drying out) or dead (signs of drying out with no signs of sprouting) in 2008 (September) and 2009 (July). In 2009, 18.5 percent of the originally planted willow stakes and 67.3 percent of the poplar stakes were still alive. The larger-diameter cuttings (>3 cm) of both species appear to be growing more successfully than smaller diameter cuttings. There was no germination from alder seed (Table 6I-5).

TABLE 6I-5
Survival of Willow and Poplar Stakes at Vangorda Lysimeter Plot No. 1. [a]
Vegetation and Soils Baseline – Faro Mine Interim Works

Species	Number Planted	% Living 2008	% Living 2009
Willow	54	28	18.5
Balsam Poplar	47	74	67.3
Alder seed	Unquantified	0	0

Source: adapted from EDI (2010)

Between September 13 and 17, 2009, potential revegetation grass mixes were applied and fertilized and alder and horizontal stakes were fertilized and planted (Table 6I-6) on a series of cover plots on the Vangorda Waste Dump (Figure 6I-10). The revegetation effort included seeding and fertilizing of the test areas. Information obtained from the test areas were used to design the Grum Overburden Dump revegetation trial.

TABLE 6I-6
Revegetation on Vangorda Waste Dump Cover Treatments [a]
Vegetation and Soils Baseline – Faro Mine Interim Works

Location	Prescribed Surface Treatment	Actual Surface Treatment	Actual Vegetation Treatment	Fertilizer
CT#1	None	None	None	None
CT#2A	Micro-scale downslope rills	Hand rake	Agronomic grass-legume mix	8-38-15 400 kg/ha
CT#2B	Micro-scale downslope rills	Hand rake	Agronomic grass-legume mix	8-38-15 400 kg/ha
CT#3A	Micro-scale downslope rills	Hand rake	Agronomic grass-legume mix	8-38-15 400 kg/ha

TABLE 6I-6
Revegetation on Vangorda Waste Dump Cover Treatments [a]
Vegetation and Soils Baseline – Faro Mine Interim Works

Location	Prescribed Surface Treatment	Actual Surface Treatment	Actual Vegetation Treatment	Fertilizer
CT#3B	Micro-scale downslope rills	Hand rake	Agronomic grass-legume mix	8-38-15 400 kg/ha
CT#4	Micro-scale downslope rills	Hand rake	Agronomic grass-legume mix	8-38-15 400 kg/ha
Lysimeter #1; this plot was planted with willow and poplar in 2007	Rough and loose (completed in 2007)	Hand rake	Agronomic grass-legume mix	8-38-15 400 kg/ha
Vangorda waste rock cover 1994; upper section with 2.5H:1V slope	Micro-scale downslope rills	Smooth out first with dozer and then created down-slope rills	Annual nurse crop + native grass mix + alder seedlings and horizontal stakes	8-38-15 400 kg/ha

Source: adapted from EDI (2010)

kg/ha = kilogram per hectare

Grum Overburden Dump Revegetation

Three revegetation studies took place at the Grum Overburden Dump between 2008 and 2009 (Figure 6I-10). In 2008, EDI completed Trial A near the bottom of the northeast side of the Grum Overburden Dump (EDI, 2010). The overburden material was loosened to a depth of 30 to 40 cm, and in autumn 2008, it was planted with willow and balsam poplar stakes (placed horizontally or vertically), and alder seed or whole cones.

In July 2009, 72 percent of the willows and 58 percent of the poplar stakes, all planted vertically, were alive (EDI, 2010a) (Table 6I-7). In August 2009, numerous alder seedlings were noted at both areas seeded with alder (i.e., alder seed and alder cones).

TABLE 6I-7
Survival of Willow and Poplar Stakes at 2008 Trial A Grum Overburden Dump
Vegetation and Soils Baseline – Faro Mine Interim Works

Species	Number Planted	% Living in 2009
Willow	36	72
Balsam Poplar	58	58
Alder seed	numerous	numerous

Source: EDI (2010)

The Trial B site was developed in 2008, and consists of nine 20-m-by-20-m test plots and one control plot on top of the Grum Overburden Dump (EDI 2010). The trial work consisted of applying four different grass seed mixes, at different rates and mixed with alder seed. One year after planting Trial B, there was sporadic grass emergence that provided little cover on any plot (Table 6I-8). Willow, fireweed, and other mature plants noted at the site were likely present because of natural introduction from the surrounding area and incomplete turning of the soil during site preparation. The soil surface is hard and is difficult to penetrate when dry; when the soil surface is wet, it becomes muddy and cements into clumps. The unfavourable growing conditions (such as higher altitude and poor soil) are likely contributors to the lack of grass cover.

TABLE 6I-8
Summary Results of Vegetation Growth Observation (July 2009) of Grum Overburden Trial B
Vegetation and Soils Baseline – Faro Mine Interim Works

Location	Plot #	Application Rates	2009 Observations
M1: Highlander slender wheatgrass (20%)	1	Low: 25 kg/ha	Grass plants 1-5 cm tall with purple leaves. Foxtail barley seed blown in. Approximately 12 fireweed and similar amounts of willow seedlings. Cover 0.5% grass, fireweed, and willow.
	2	Med: 50 kg/ha	Higher grass coverage than Plot 1. Similar amounts of willow as Plot 1, largest 60 cm tall Fireweed (5 plants). Cover 0.5 to 1 % grass, <0.5% willow, <0.25% fireweed.
M2: Awned wheatgrass (25%) Tufted hairgrass (20%) Fringed brome (15%) Alkali grass (10%) Alpine bluegrass (10%) Spike trisetum (10%)	3	Low: 25 kg/ha	Grass cover low. One horsetail present, similar amount of willow as Plots 1 and 2. Five fireweed plants. Cover 0.25% grass, <0.5% willow, <0.25% fireweed.
	4	Med: 50 kg/ha	Grass cover 0.25 to 0.5%. Willow <30 cm tall, less abundant than Plot 3. Approximately 7 fireweeds. About 0.25 m^2 of horsetail in Northwest plot corner. Several individuals of foxtail barley and other grasses.
M3 Spike trisetum (25%) Slender wheatgrass (20%) Tufted hairgrass (15%) Fringed brome (10%) Fowl bluegrass (10%) June grass (10%) Tickle grass (10%)	5	Low: 25 kg/ha	Grass emergence nearly zero. 2 willows, some clumps of foxtail barley, 2 fireweed, 1 yarrow plant (~10 cm).
	6	Med: 50 kg/ha	Grass cover minimal (<0.25%). 5 to 10 fireweed individuals, with some broad fireweed. Some purple rye outside of the Plot. 1 willow (20 cm).
M4: Violet wheatgrass (40%) Slender wheatgrass (10%) Tickle grass (5%) Sheep fescue (20%) Arctic fescue (25%)	8	Low: 20 kg/ha	Some small grass, 2 cm to 6 cm, 0.25 to 0.5% cover. 10-15 fireweed plants. Same species as seen in other Plots. 2 horsetails, several foxtail barleys. 1 tufted hairgrass and 1 slender wheatgrass plant.
	9	Med: 30 kg/ha	Slightly more grass than in Plot 8 (<0.5%). 3 tufted hairgrass plants. Fireweed (*E. angustifolium* and *E. latifolium*) plants, 2 willow, 2 horsetail plants.
	10	High: 30 kg/ha	Grass growth slightly higher than Plots 8 and 9. Several foxtail barley individuals. 3 fireweed plants. 2 horsetails. Several yarrow and 1 hairgrass plant.

Source: EDI (2010)
Notes:
= number
< = less than
~ = approximately
kg/ha = kilogram per hectare
m2 = cubic metre
M1 = Mix 1
M2 = Mix 2
M3 = Mix 3
M4 = Mix 4
Med = medium

In 2009, a third revegetation trial by EDI was set up at the Grum Overburden Dump (EDI, 2013a). This area was selected because it provided material representative of that planned for final cover when the FMC is reclaimed.

Three different grass mixes were seeded with and without fertilizer, on each of three surface cover treatments (rough and loose, micro-rilled, and planar). Willow cuttings, poplar cuttings (horizontally and vertically), and alder

seedlings were also planted in smaller plots throughout the trial site. Finally, a limited amount of spruce and dwarf birch seed was spread in two locations.

Revegetation monitoring results for this trial included the following observations:

- Herbaceous vegetation requires fertilizer to establish any substantial vegetation cover.
- Alder seedlings grow in fertilized and unfertilized areas, but success is limited within fertilized areas. Competition with herbaceous vegetation thriving in fertilized areas may be a potential stressor.
- Staking willow and poplar vertically and horizontally successfully established woody plants; in third-year results, horizontal staking continued to generate greater stem numbers than vertical staking. Horizontal staking may result in better erosion control than vertical staking.
- Seeding a nurse crop can provide short-term herbaceous vegetation cover; however, native grass species are important to establish longer-term cover.

During the revegetation trial, the most important contributing factors to success were the fertilizer application, appropriate seeding, and shrub planting. Site preparation methods, such as rough-and-loose surface treatment, appear to be vital to control soil erosion. Table 6I-9 provides averaged resulting vegetation cover in fertilized plots for 2010 to 2012, summarized by seed mix (Agronomic, Native, and Native with nurse crop) and surface treatment methods. The agronomic seed mix included 15 percent red fescue, 11 percent common meadow foxtail, 5 percent Kentucky bluegrass, 49 percent slender wheatgrass, and 20 percent Alsike clover. The native seed mix included 10 percent slender wheatgrass, 20 percent northern rocky mountain fescue, 37 percent glaucous bluegrass, and 33 percent tufted hairgrass. The native and nursery seed mix included 14 percent slender wheatgrass, 27 percent northern rocky mountain fescue, 58 percent glaucous bluegrass and 0.5 percent barley.

TABLE 6I-9
Average Vegetation Cover (%) in Fertilized Plots (n=54)
Vegetation and Soils Baseline – Faro Mine Interim Works

	Agronomic			Native			Nurse-and-native		
Surface	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**
Rough-and-loose	20	22	41	11	16	41	6	25	36
Micro-rills	7	20	37	9	12	43	8	21	46
Planar	9	13	41	6	10	44	6	11	34

Source: EDI (2013a)

Woody plant survivorship has decreased overall since 2011. Table 6I-10 provides results from 2010 to 2012, summarized by surface and fertilizer treatment.

TABLE 6I-10
Average Number of Alder and Willow/Poplar Stems per Plot
Vegetation and Soils Baseline – Faro Mine Interim Works

		Fertilized			Unfertilized		
Woody Plant Treatment	**Surface**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**
Alder seedlings per plot (n=36)	Rough-and-loose	9.3	2.6	0.8	11.5	5.9	2.7
	Micro-rills	4.7	4.7	3.8	10.5	8.8	7.1
	Planar	3.2	1.8	3.2	4.8	5.0	4.7

Source: EDI (2013a)

Grum Sulphide Cell Revegetation

Grum Overburden Dump revegetation trials focused on grass mixes, physical surface treatments, fertilizer effects, and inter-planting woody and herbaceous species (EDI, 2013a). Key treatments in the 2012 GSC revegetation program were guided by outcomes from the Grum Overburden Dump trials and other revegetation efforts at the FMC (Figure 6I-11). These include the following treatments and rationales:

- Nurse and native seed mix – Success between grass seed prescriptions were similar at the GSC; however, in retrospect the native and nurse crop had a low nurse seed composition. Experience from GSC hydroseeding (2011) indicated nurse crops (if applied properly) have an immediate effective response that helps address short-term revegetation goals. The native grass mix allows for better establishment over the long term.
- Fertilizer included in hydroseeding – The key driver to revegetation cover at the GSC was fertilizer. Revegetation success was dependent on the application of fertilizer.
- Surface treatment similar to rough-and-loose, ripping across the slope – Rough-and-loose was the best treatment to establish and maintain cover with little–to-no erosion at the GSC. Surface treatment implemented across the slope (perpendicular ripping) was a more cost-effective approach that should achieve similar results to the rough-and-loose treatment.
- Horizontally staked willow and poplar cuttings – Horizontal staking was successful at the GSC and can produce multiple stems per cutting, compared to the one stem a vertical stake produces. Monitoring the Grum Overburden Dump revegetation trials has shown that horizontal staking has successfully survived the unfavourable soil conditions at the FMC. Horizontal staking also has the potential to assist in the reduction of erosion because of positioning the stake across the slope, which slows runoff from moving down the slope.

Revegetation took place using the following six treatments (Figure 6I-12):

- Plugs only (P plots)
  - Woody vegetation plugs were planted without any amendments
- Stakes only (S plots)
  - Balsam poplar and willow species stakes were collected at the FMC, near the GSC, within days of planting. Stakes were collected at the following locations:
    - West and northwest of the Vangorda Waste Dump
    - South of the Vangorda Waste Dump
    - East side of the Haul Road between the gatehouse and the Grum pit
    - East of the GSC, along the access road to the Grum Overburden revegetation trials
- Plugs and stakes (PS plots)
  - Stakes were planted alternately with plugs, both across and with the slope
- Plugs with Fertilizer-pak (Chilcotin blend; Reforestation Technologies International (RTI)) teabag (Pf)
  - Chilcotin blend teabags (17-5-7) are used for disturbed planting sites with low levels of organic matter. One 10-gram teabag was placed in a separate hole, immediately upslope of the plug, about 5 cm below the soil surface. The Chilcotin blend teabag releases the following ingredients over 12 months:
    - Total nitrogen 17%
    - Urea nitrogen 9.66%
    - Ammoniacal nitrogen 8.12%
    - Available phosphate 5.00%
    - Soluble potash 7.00%
    - Magnesium 1.20%
    - Sulphur 10.40%
    - Humic acid (Leonardite-derived) 4.50%
    - Kelp extract (*Ascophyllum nodosum*) 4.00%

- Plugs with Hydration-pak (RTI) teabag (Ph)
  - Hydration-pak teabags (16-8-5) are similar to the Chilcotin-pak fertilizer, but they also contain more moisture-retaining polymer to assist seedlings establish during times of moisture stress. One 10-gram hydration-pak teabag was placed in the planting hole with the plug. The hydration-pak includes the following ingredients:
    - Total nitrogen 16.00%
    - Urea nitrogen 12.61%
    - Ammoniacal nitrogen 1.70%
    - Nitrate nitrogen 1.69%
    - Available phosphate 8.00%
    - Soluble potash 5.00%
    - Sulphur 6.60%
    - Co-polymers of acrylamide 19.00%
- Plugs with Genesis-pak (RTI) teabag (Phf)
  - One 40-gram Genesis-pak was placed in the planting hole and broken open before planting the plug. Genesis-paks release the following ingredients over 12 months:
    - Total nitrogen 8.00%
    - Urea nitrogen 4.2%
    - Ammoniacal nitrogen 3.6%
    - Nitrate nitrogen 0.2%
    - Available phosphoric acid 5.00%
    - Soluble potash 5.00%
    - Sulfur 2.00%
    - Boron 0.037%
    - Humic acid (Leonardite-derived)7.5%
    - Kelp meal (Ascophyllum nodosum) 5.0%
    - Composted vegetative matter 30%

In addition to the experimental plots, larger plots were set up in areas to add woody plant material treatments on a larger scale. The following treatments were implemented:

- S2 Plots: Poplar and willow stakes were buried at a spacing of 2.5 m between centre points of stakes.
- Pr Plots: This area was planted with plugs that remained after all experimental plots were planted. Approximately 3,354 plugs were planted on the uppermost slope in a random arrangement. Some areas were planted at very high densities to simulate a more natural setting; other areas were planted with equidistance.

Continued monitoring of the revegetation on the GSC is currently underway.

Dewatered Freshwater Reservoir

The dewatered freshwater reservoir at the FMC was revegetated in 2003 and 2004 (Arctic Alpine Seed Ltd., 2005), with annual follow-up monitoring until 2007 (Laberge, 2005, 2006, 2007). The revegetation included the following activities:

- Seeding (June and September 2003, and June, July, September and October 2004) with a mix of northern native grass species
- Transplanting stem cuttings of seven shrub and one tree species (*Salix pulchra*, *S. alaxensis*, *S. scouleriana*, *S. barclayi*, *Populus tremuloides*, *P. balsamifera*, *Shepherdia canadensis,* and *Picea glauca*; September 2003, May and October 2004)
- Staking (September 2003) at the east end of reservoir

- Staking willow stem cuttings (June 2004) on a riparian area of the Rose Creek main channel
- Staking willow stem cuttings (September and October 2004) along two main tributaries and floodplains adjacent to the reservoir dam breach.

The most recent monitoring data was collected in 2007 (Laberge, 2007). The grass seeded in June and September of 2003 has grown up to nearly 100 percent cover, except for the area immediately upstream of the dam, where cover is only 30 to 40 percent. Most of the area was dominated by sheep's fescue, except for the far-eastern portion, where there is a more even distribution of species. The newly exposed reservoir bottom (approximately 17 ha) that was seeded in June and July of 2004 has grown up to nearly 90 percent cover and is characterized by a more diverse group of grasses, as well as large amount of non-seeded native plants (Laberge, 2007).

The fourth seeded area is made up of the dam area, the disturbed area downstream of the dam, and the floodplains adjacent to the dam breach. This area was the last to be seeded in September and October of 2004. In the floodplains adjacent to the dam, the vegetation has grown up to 20 to 40 percent cover, with a few areas of up to 70 percent. In 2004 and 2005, the seeded areas of the floodplains were flooded and seed was lost. On the dam wall itself, there is little grass growth on the northwest side, 40 to 60 percent cover on the southeast side, and 5 to 20 percent cover on the sides of the dam breach. The core of the dam breach is made of highly compacted clay and is nearly barren of vegetation. Areas downstream of the dam have a grass cover of approximately 80 percent. Plant height and rooting depths for the dominant grass species (sheep's fescue and tufted hairgrass) are 55 cm high and 95 mm deep, and 90 cm high and 330 mm deep, respectively.

In general, grass seeding prescriptions have addressed short-term erosion concerns in the old freshwater reservoir. Monitoring results in a 2006 assessment of the floodplains upstream and downstream of the dam breach demonstrated 80 percent survival of staked willows (the most successful species were *S. pulchra, S. alaxensis* and *P. balsamifera*). Many staked willows died at the top but were sprouting at ground-level. Willows in the Rose Creek riparian zone and tributaries demonstrated an 80 percent survival rate, with *S. alaxensis* being most successful. A lower survival rate was found for willows in the upper reaches of the two tributaries (10 to 30 percent).

The results from Laberge (2007) monitoring of live staking treatments in 2007 showed that overall survival rates for all shrub species on the floodplains upstream and downstream of the dam breach varied between 50 and 90 percent. In the Rose Creek riparian zone and the lower reaches of the tributaries, overall survival was approximately 80 percent. Willows staked along the upper reaches of the tributaries and along the upper reaches of Rose Creek had a survival rate of only 5 to 30 percent. Among the species that were staked initially, Diamond-leaf willow and Felt-leaf willow were the most successful. Stem cuttings planted around Rose Creek and tributary riparian zones (in 2003 and 2004) had high survival rates (Laberge, 2007).

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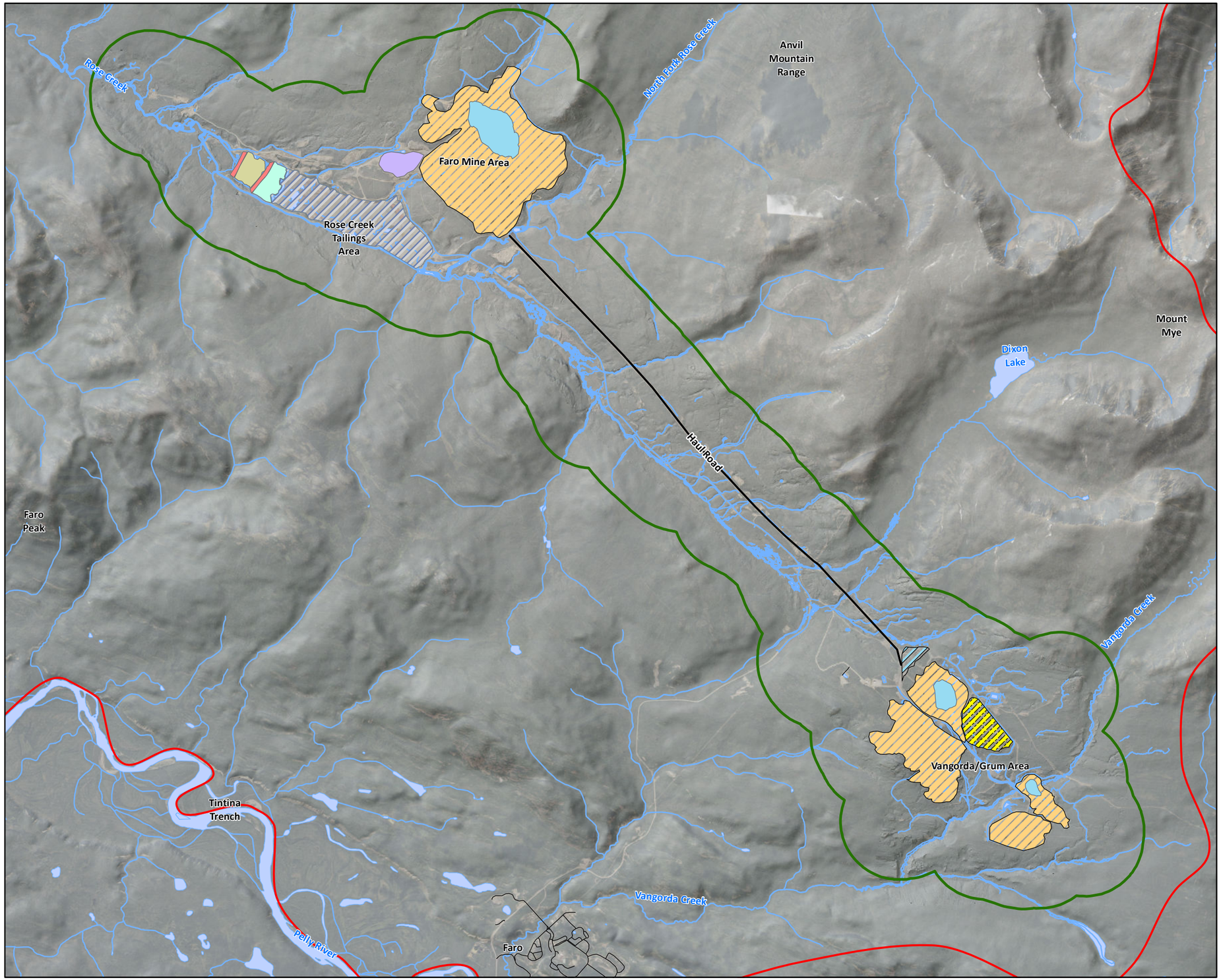
Staniforth, J. 1998. *Vegetation Communities of Sheep Mountain, Faro, Yukon. DRAFT.* Prepared for Yukon Department of Environment, Fish and Wildlife Branch.

Figures





Legend

- Minor Road
- Local Study Area
- Regional Study Area

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Faro = Town of Faro

N

0 750 1,500 2,250 3,000

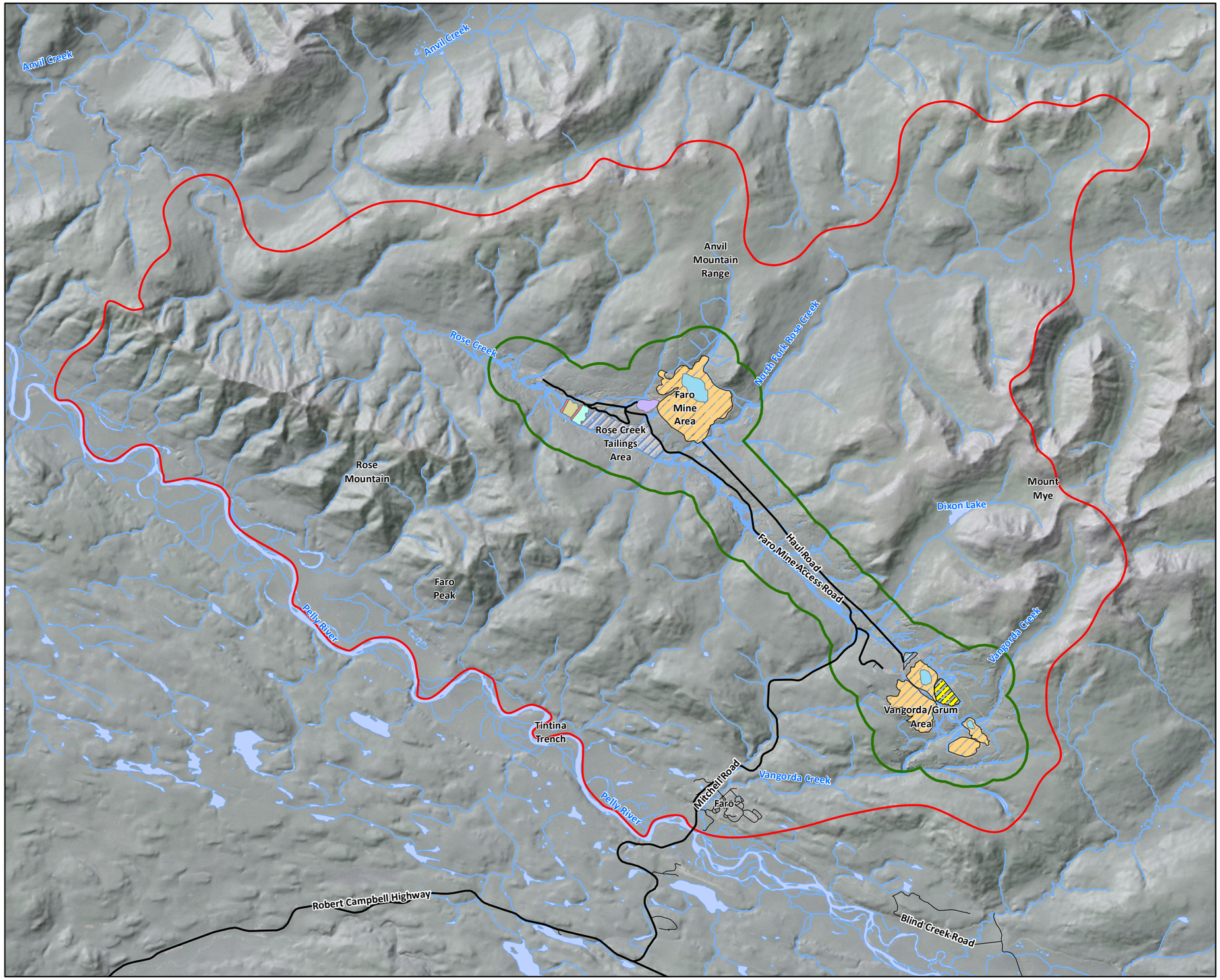
Metres

Created by: CRITIGEN

FIGURE 6I-1

Vegetation and Soil Baseline Local Study Area - Faro Mine Complex

Faro Mine Interim Works



VICINITY MAP



Legend

- Local Study Area
- Regional Study Area

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

N

0 1,250 2,500 3,750 5,000

Metres

Created by:
CRITIGEN

FIGURE 6I-2

Vegetation and Soil Baseline Regional Study Area - Faro Mine Complex

Faro Mine Interim Works

CH2MHILL

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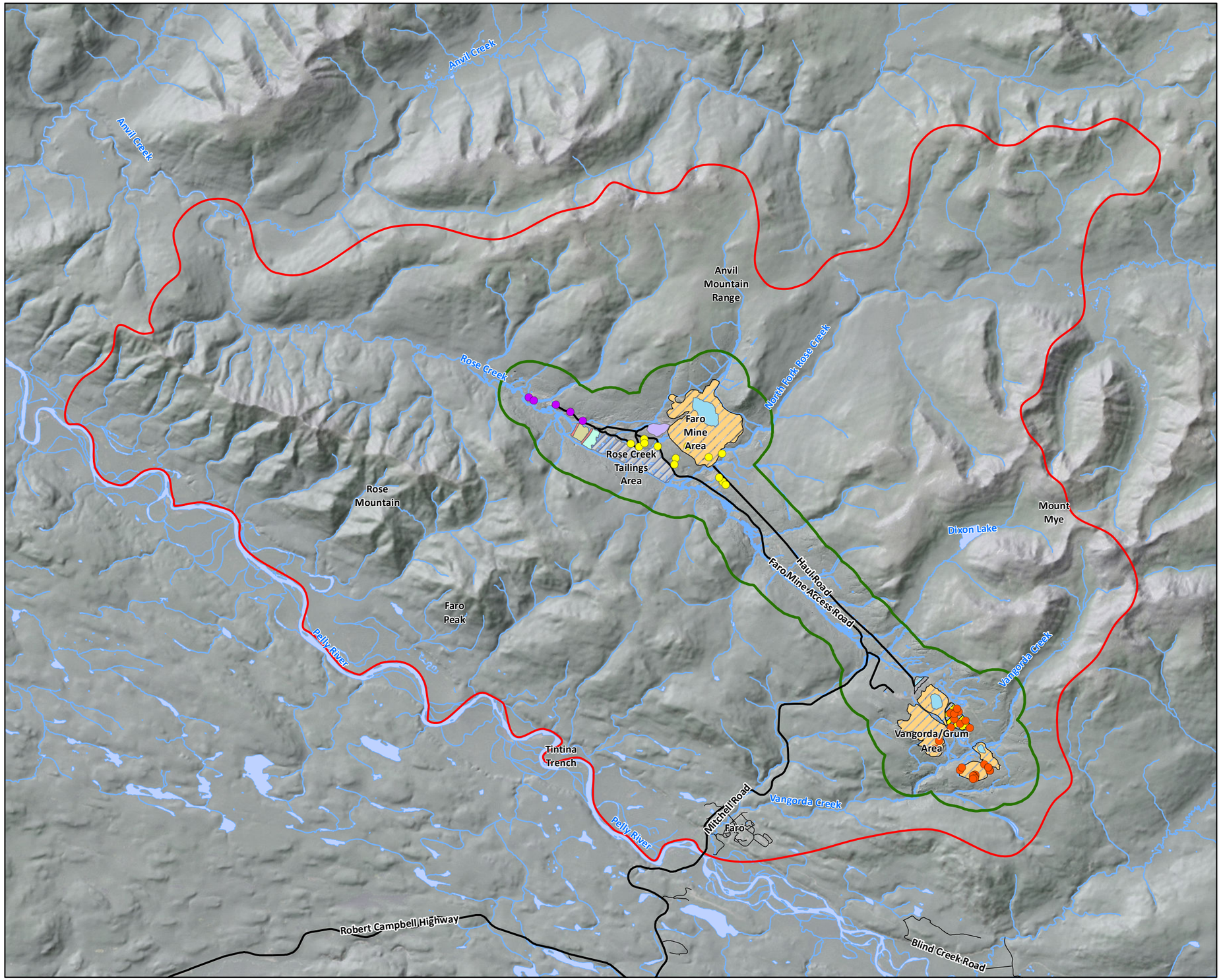


VICINITY MAP



Legend

- Rose Creek Area Soil Sampling
- Faro Mine Area Soil Sampling
- Vangorda/Grum Area Soil Sampling
- Local Study Area
- Regional Study Area

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

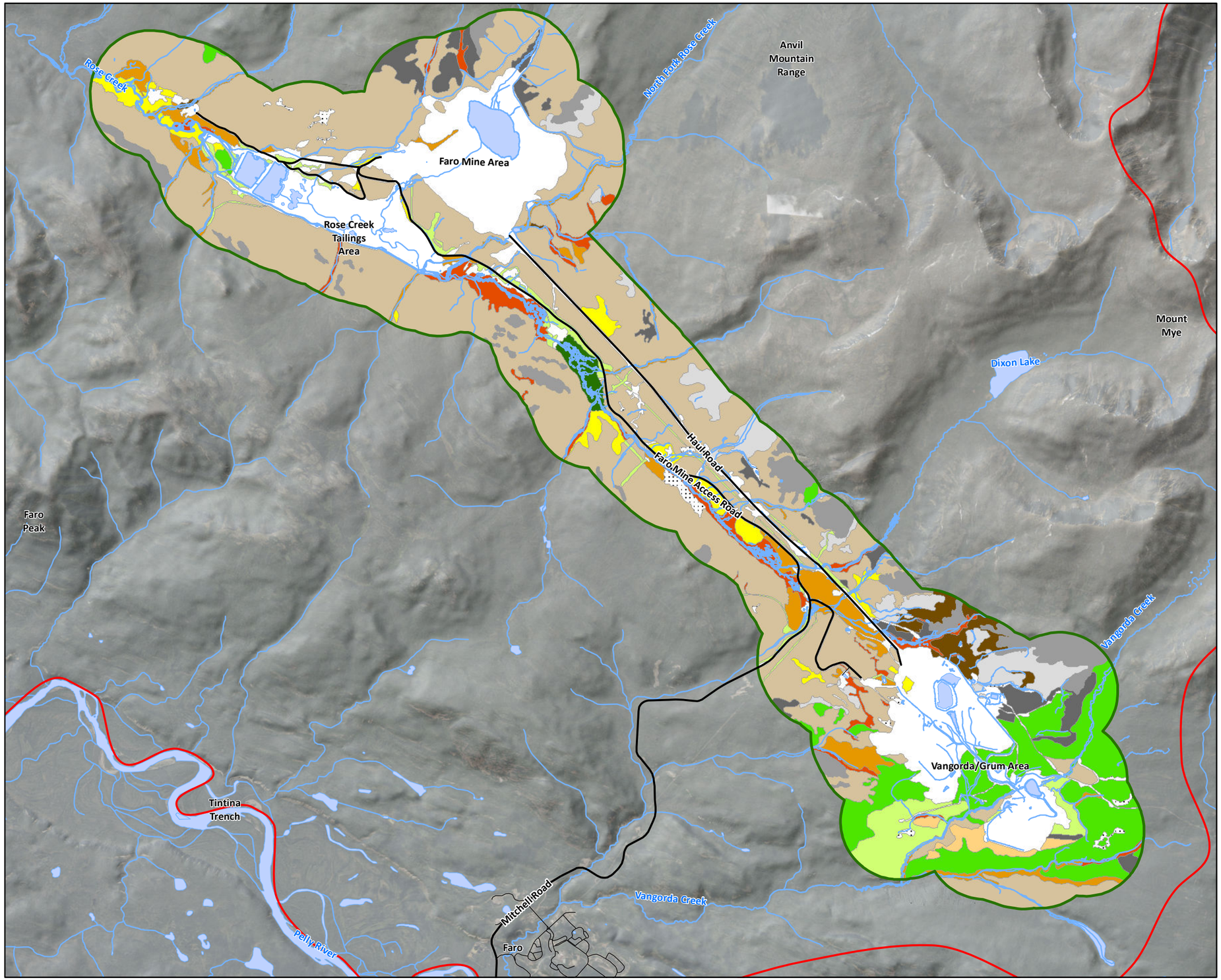
N

0 1,250 2,500 3,750 5,000

Metres

Created by:
CRITIGEN

FIGURE 6I-3
Soil Survey Locations
Faro Mine Interim Works





Legend

- Local Study Area
- Regional Study Area
- Project Footprint

Vegetation Association

- Dwarf Birch/Subalpine Fir
- Dwarf Birch/Lichen/Subalpine Fir
- Dwarf Birch/Willow
- Deciduous
- Graminoid
- Mixed Coniferous-Deciduous
- Pine
- Sedge/Willow
- White Spruce/Feather Moss
- White Spruce/Willow (Sw/W)
- Willow/Dwarf Birch
- Willow/Sedge
- Willow/White Spruce

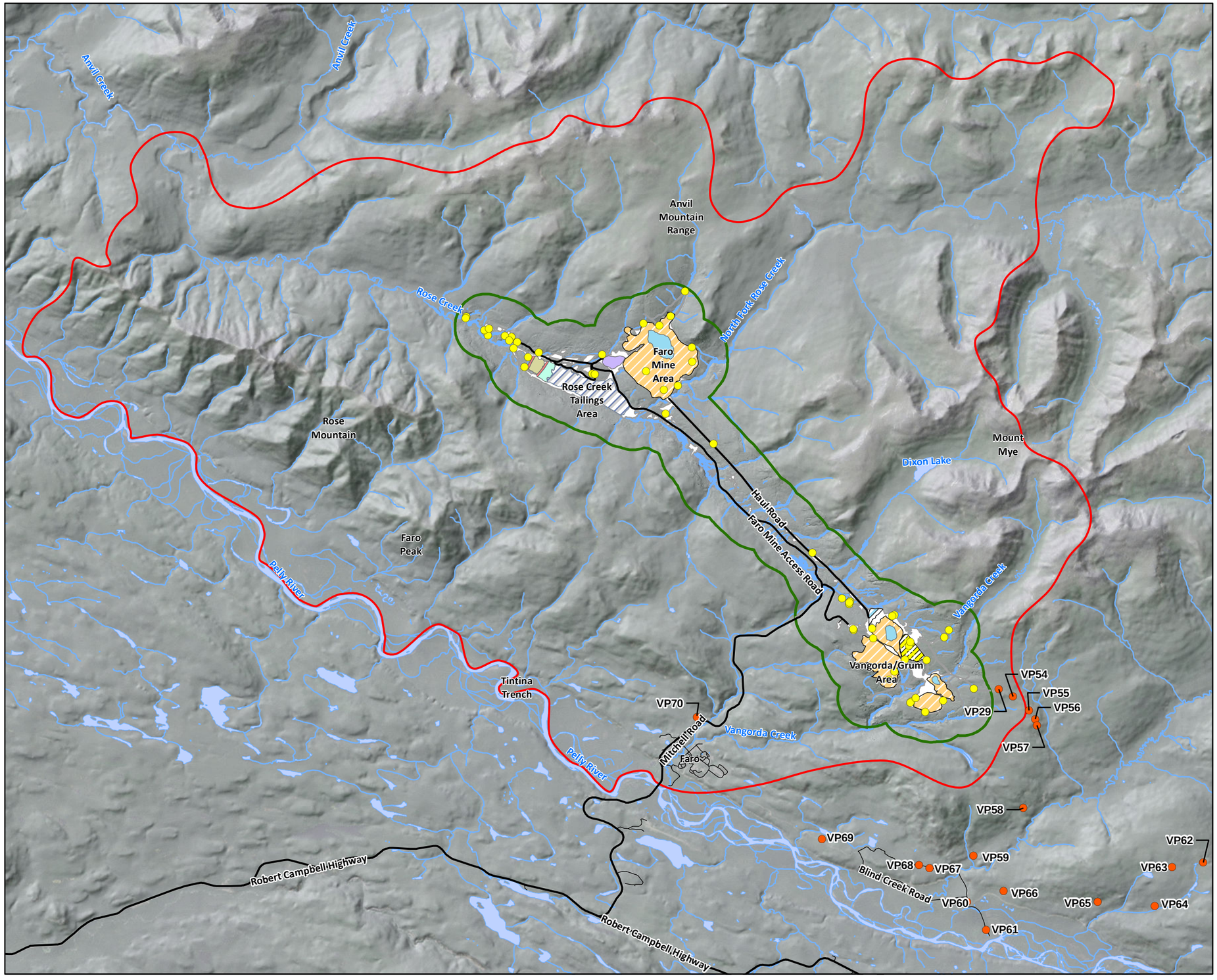
Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Faro = Town of Faro

N

0 750 1,500 2,250 3,000
Metres

Created by: CRITIGEN

FIGURE 6I-4
Local Study Area with Thirteen Vegetation Associations from GLL 2007 Summer Vegetation Baseline
Faro Mine Interim Works



VICINITY MAP



Legend

- Vegetation Sampling Location
- Vegetation Sampling Location Outside Local Study Area
- Local Study Area
- Regional Study Area
- Project Footprint

Mine Infrastructure:

- Open Pit
- Grum Ore Transfer Pad
- Waste Dump
- Impoundment Area
- Overburden Dump
- Polishing Pond
- Tailings Pond
- Dam
- Mill Buildings Area

Notes:

1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
2. Faro = Town of Faro

N

0 1,250 2,500 3,750 5,000

Metres

Created by: CRITIGEN

FIGURE 6I-5

Vegetation Plots for EDI 2007 Vegetation Survey - Faro Mine Complex and Adjacent Area

Faro Mine Interim Works

CH2MHILL



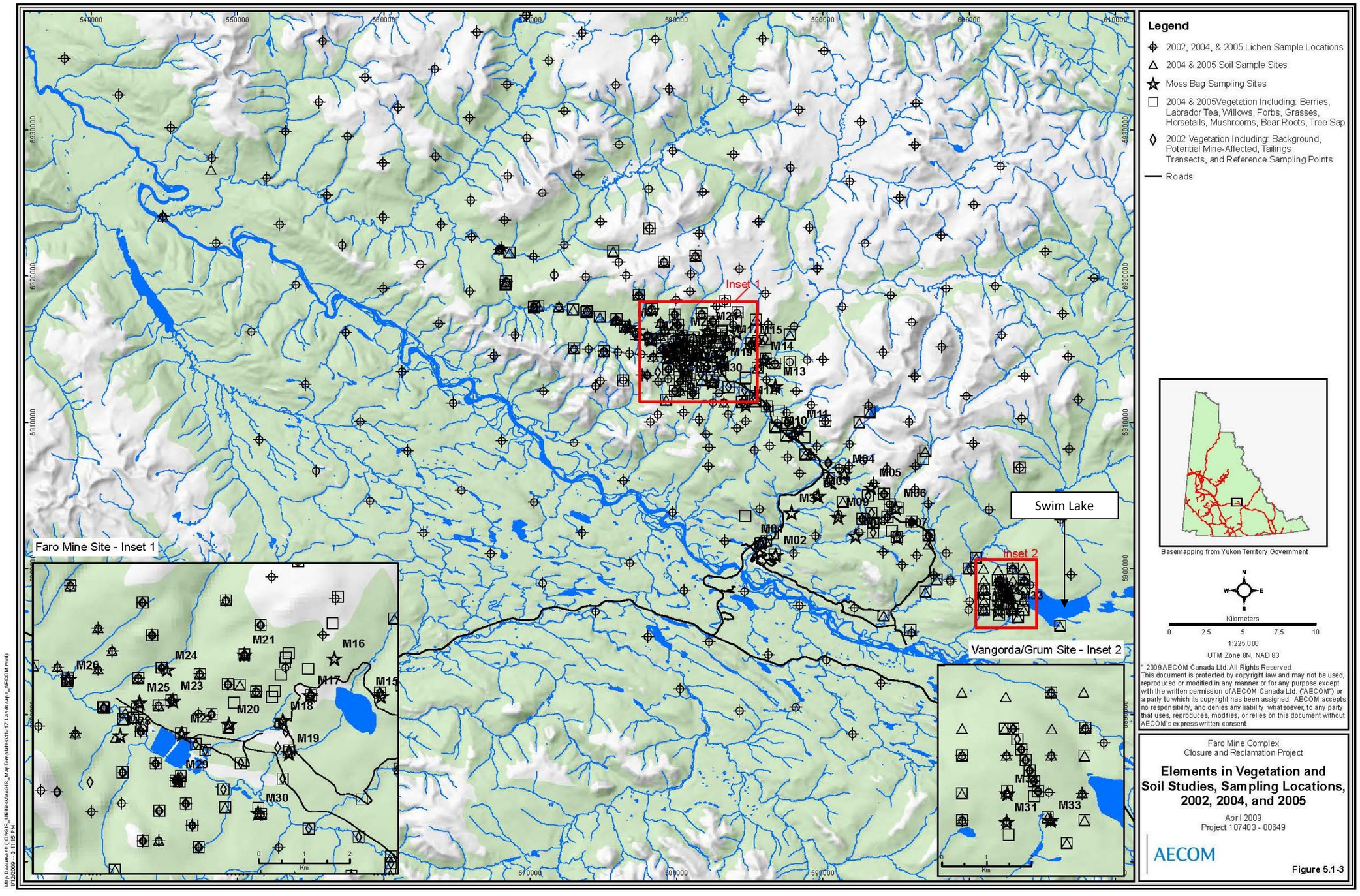
Source: AECOM. 2008. Report on Faro Mine Site Rare Plant Survey. Prepared for Gartner Lee Limited. October. Reproduced with the Government of Yukon's permission

FIGURE 6I-6
Three Vegetation Survey Areas for Rare Plant Survey – Faro Pit Area
Faro Mine Interim Works



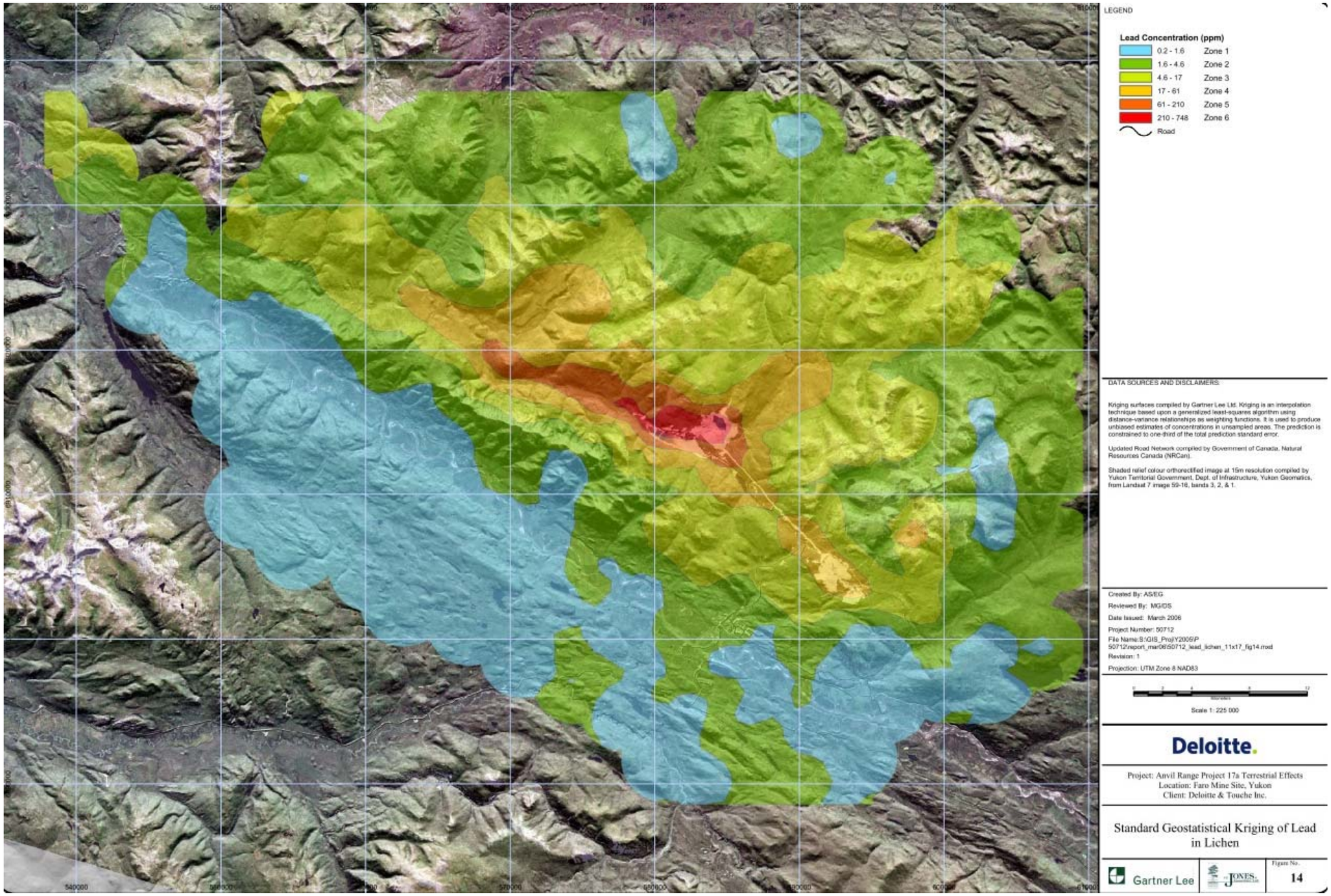
Source: AECOM. 2008. Report on Faro Mine Site Rare Plant Survey. Prepared for Gartner Lee Limited. October. Reproduced with the Government of Yukon's permission

FIGURE 6I-7
One Vegetation Survey Area for Rare Plant Survey – Grum Pit Area
Faro Mine Interim Works



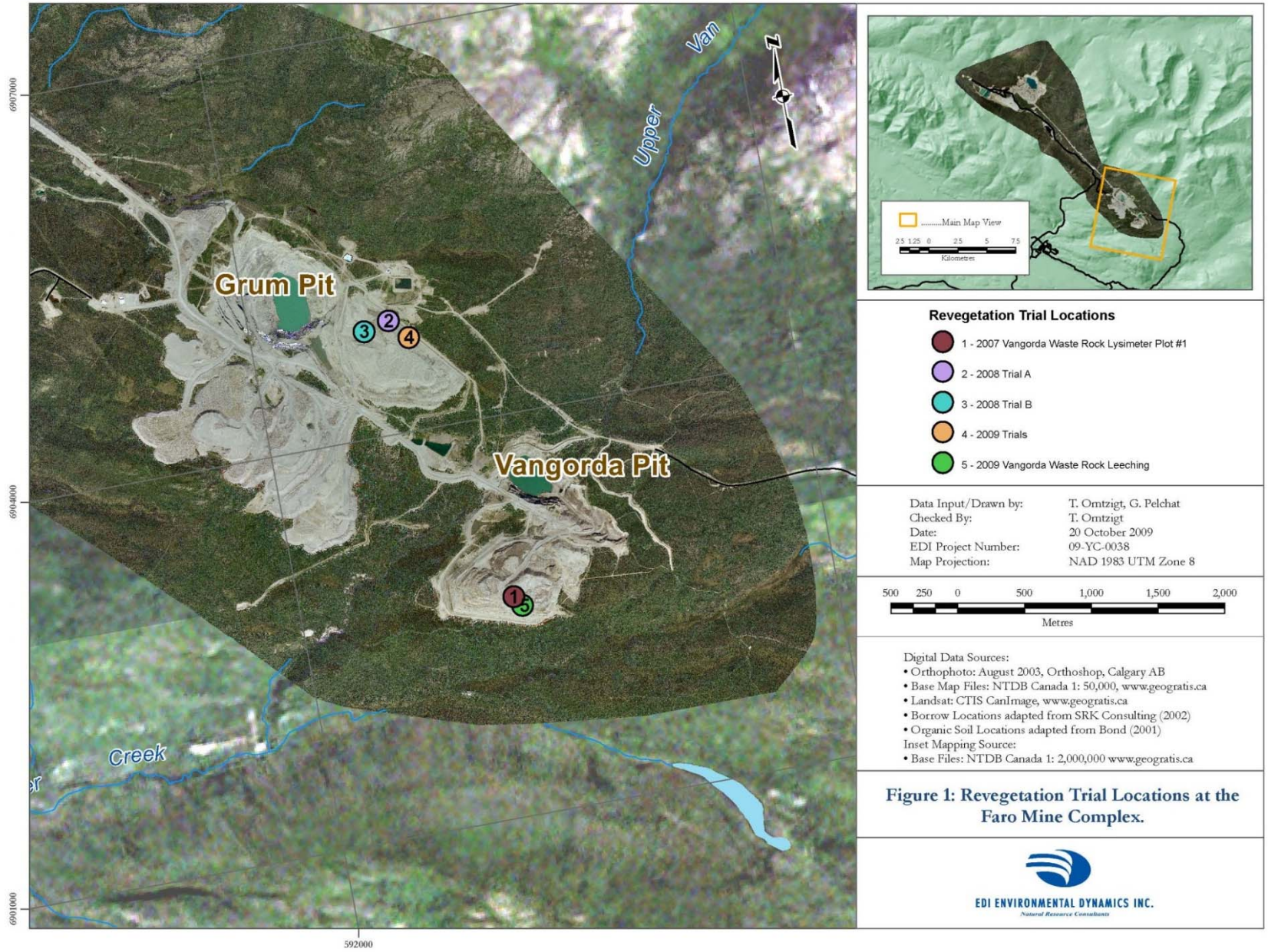
Source: AECOM Canada Ltd. (AECOM). 2009. *Faro Mine Complex Closure and Reclamation – Project Proposal.* Current Environmental Conditions Supporting Document. Prepared for Faro Project Management Team. March. Unpublished.
Reproduced with the Government of Yukon's permission

FIGURE 6I-8
Vegetation and Soil Study Sampling Locations (2002, 2004, 2005)
Faro Mine Interim Works



Source: Gartner Lee Limited (GLL). 2006. Anvil Range Complex – Terrestrial Effects Study: Investigation into Metal Concentrations in Vegetation, Wildlife and Soils. March.
Reproduced with the Government of Yukon's permission

FIGURE 6I-9
Range of Lead Concentration in Lichen from Anvil Range Mine Complex - Terrestrial Effects Study
Faro Mine Interim Works



Source: Environmental Dynamics Inc. (EDI). 2010. Faro Mine Complex – 2009 Revegetation Trials and Monitoring. Prepared for Assessment and Abandoned Mines Branch, Government of Yukon. February. Reproduced with the Government of Yukon's permission

FIGURE 6I-10
Location of Revegetation Trials Between 2007 and 2009 - Vangorda/Grum Area
Faro Mine Interim Works





Legend

- 2009 Grum Overburden Dump Slope Trials*
- Grum Sulphide Cell
- Access Road
- Trail
- Watercourse
- Waterbody

* Approximate extent

0 100 200 300 400 500
metres

Map scale 1:15,000 (printed at 8.5x11)
Map Projection: North American Datum 1983 UTM Zone 8N

Revegetation Locations at the Faro Mine Complex

Data Sources

Project data displayed is site specific. Grum Sulphide Cell and Grum Overburden Dump Slope Trials digitized by EDI Environmental Dynamics Inc. (2012 / 2013).

Detailed topographic features of the Faro, Grum and Vangorda mine sites were provided by Yukon Government - Energy, Mines and Resources - Assessment and Abandoned Mines Branch (March 2012).

1:50,000 topographic spatial data provided by Geomatics - Yukon Government data online source (Corporate Spatial Warehouse) www.geomatics.yukon.ca.

Background image provided by SRK Consulting.

Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.

Drawn:	Checked:	Date:	
LG	PT/MP	28/03/2013	FIGURE 1

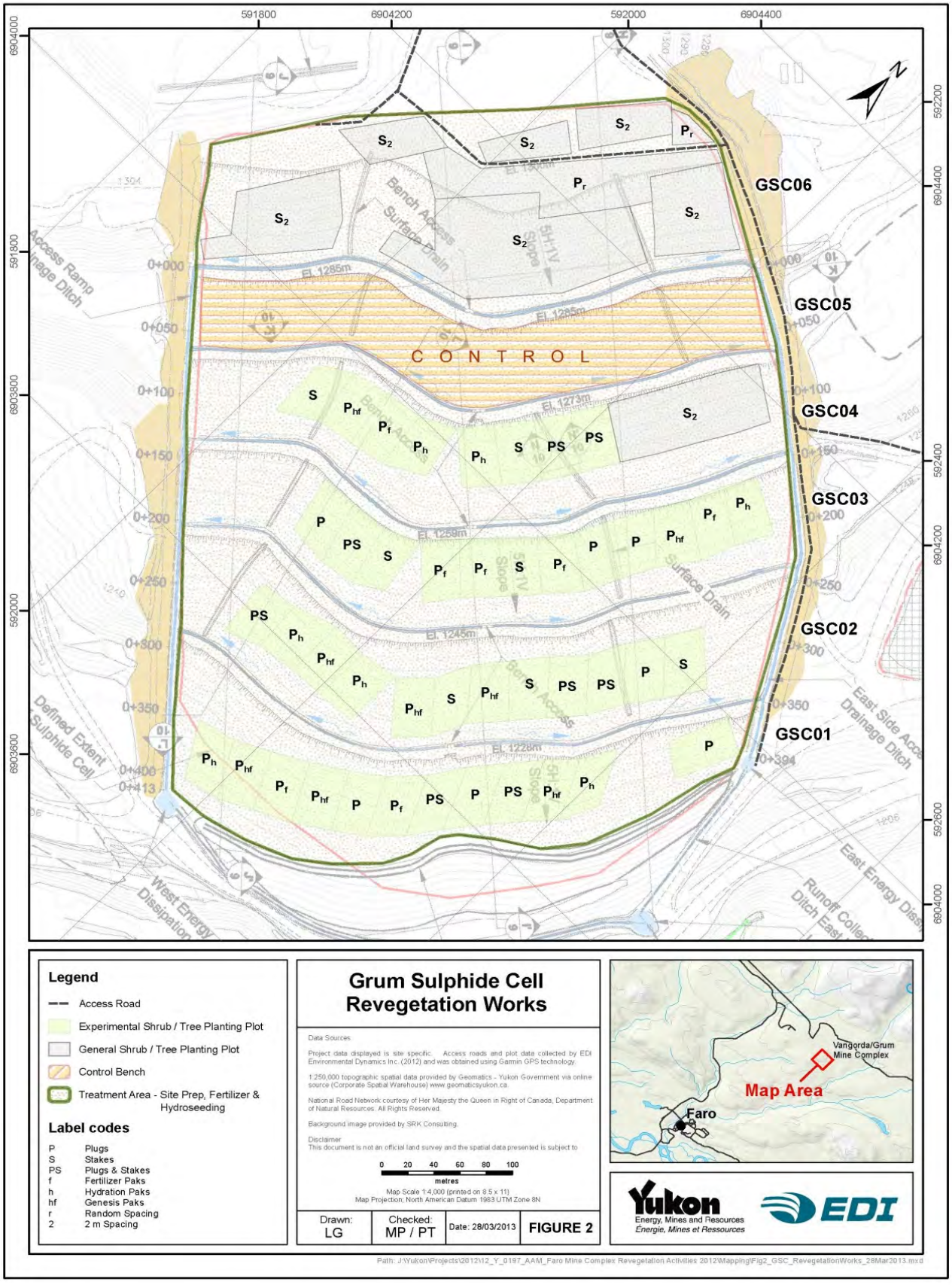
Yukon Energy, Mines and Resources / Énergie, Mines et Ressources

EDI

Path: J:\Yukon\Projects\2012\12_Y_0197_AAM_Faro Mine Complex Revegetation Activities 2012\Mapping\Reveg_Locations_FMC_28Mar2013.mxd

Source: Environmental Dynamics Inc. (EDI). 2013b. Faro Mine Complex Revegetation Activities 2012. Draft. Prepared for Energy Mines and Resources, and Assessment and Abandoned Mines, Yukon Government. March. Reproduced with the Government of Yukon's permission

FIGURE 6I-11
Revegetation Locations - Vangorda/Grum Area
Faro Mine Interim Works



Source: Environmental Dynamics Inc. (EDI). 2013b. Faro Mine Complex Revegetation Activities 2012. Draft. Prepared for Energy Mines and Resources, and Assessment and Abandoned Mines, Yukon Government. March. Reproduced with the Government of Yukon's permission

FIGURE 6I-12
Revegetation Plot Layout - Grum Sulphide Cell
Faro Mine Interim Works

Attachment 6I-1
Species Lists

TABLE 6I-1-1

Committee On the Status of Endangered Wildlife In Canada[a] Status Ranking Definition

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Ranking	Definition
DD	A category that applies when the available information is insufficient to resolve a wildlife species' eligibility for assessment or to permit an assessment of the wildlife species' risk of extinction.
NAR	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
SC	A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
T	A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
E	A wildlife species facing imminent extirpation or extinction.
XT	A wildlife species that no longer exists in the wild in Canada, but exists elsewhere.
X	A wildlife species that no longer exists.

[a] Source: Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2012. http://www.cosewic.gc.ca/ Accessed: November 1, 2013.

Notes:

DD = Data Deficient

E = Endangered

NAR = Not at Risk

SC = Special Concern

T = Threatened

X = Extinct

XT = Extirpated

TABLE 6I-1-2

NatureServe [a] Status Rank for Yukon

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Ranking	Definition
S1	Critically Imperiled – at very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.
S2	Imperiled – at high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
S3	Vulnerable – At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
S4	Apparently Secure – At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
S5	Secure – At very low or no risk of extirpation in the jurisdiction due to a very extensive range, abundant populations or occurrences, with little to no concern from declines or threats.
SNR	Unranked – national or subnational conservation status not yet assessed.
SNA	Not Applicable – a conservation status rank is not applicable because the species or ecosystem is not a suitable target for conservation activities

[a] Source: NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. Accessed: November 1, 2013.

TABLE 6I-1-3

Invasiveness Rank [a]

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Ranking	Definition
1	Highly invasive – may displace or replace native ecosystems
2	Aggressive – widespread, persistent, but may not replace native species or change ecosystem function
3	Taxa present in the eh territory that area not known to be invasive here – but have been found to be invasive in other jurisdictions
4	Has been reported in the territory. Has not been shown to be problematic; may not persist
5	Species that likely do not persist
6	False reports
7	Native and introduced populations exist

[a] Source: Government of Yukon (2013). Yukon Invasive Plants. http://www.env.gov.yk.ca/animals-habitat/invasiveplants.php.
Accessed: November 1, 2013

TABLE 6I-1-4

Vegetation types Faro Mine Complex [a]

Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. X indicates presence of species in vegetation survey

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Abies lasiocarpa	Subalpine Fir	x	x	x	S5	
Achillea milefolium	Common Yarrow		x	x	S5	
Aconitum delphiniifolium	Larkspurleaf Monkshood		x		S5	
Aconitum delphiniifolium ssp. *delphiniifolium*	Larkspurleaf Monkshood			x	S5	
Agrostis alba (syn. *A. gigantea*)	Giant Bentgrass		x		SNA	3
Agrostis glauca (syn. *Calamagrostis coarctata*)	Agroseris Nuttall's Reedgrass		x		Not listed	
Agrostis scabra	Rough Bentgrass		x	x	S5	
***Alnus crispa* ssp. *sinuate* *(sym. Alnus viridis* ssp. *sinuata*)**	**Sitka Alder**	**x**	**x**		**S2**	
Alnus crispa ssp. *crispa* (syn. *Alnus viridis* ssp. *crispa*)	Mountain Alder			x	Not listed	
Anemone multifida	Cut-leaved Anemone		x		SNR	
Anemone parviflora	Small-flower Anemone		x	x	SNR	
Anemone richardsonii	Yellow Anemone			x	SNR	
Antennaria rosea	Rosy Pussytoes			x	S5	
Arabis drummondii	Drummond's Rockcress			x	S5	
Arabis hirsuta	Western Hairy Rockcress		x		S5	
Arabis holboellii	Holboell's Rockcress		x	x	Not listed	
Arabis kamchatica (syn. *A. Lyrata* var.	Lyreleaf Rockcress			x	S5	

TABLE 6I-1-4

Vegetation types Faro Mine Complex [a]

Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. X indicates presence of species in vegetation survey

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Kamchatica)						
Arctagrostis latifolia	Broadleaf Arctagrostis	x	x		S5	
Arctostaphylos rubra	Red Manzanita	x	x	x	S5	
Arctostaphylos uva-ursi	Bearberry	x	x	x	S5	
Artemisia campestris	Pacific Wormwood			x	SNR	
Artemisia norvegica (syn. *A. Arctica* ssp. *Arctica*)	Boreal Wormwood		x		S5	
Artemisia tilesii ssp. *tilesii*	Tilesius Wormwood			x	SNR	
Astragalus alpinus	Alpine Milkvetch			x	S5	
Astragalus eucosmus	Pretty Milkvetch			x	S5	
Aster sibiricus (syn. *Eurybia merita*)	Subalpine Aster			x	Not listed	
Asteraceae Family		x				
Aulacomnium palustre	Aulacomnium Moss	x		x	S5	
Barbilophozia sp.[f]		x				
Betula glandulosa	Dwarf Birch	x	x	x	Not listed	
Betula neoalaskana	Alaska Paper Birch		x	x	S5	
Betula occidentalis	Spring Birch			x	S5	
Botrychium lunaria	Common Moonwort			x	S4	
Botrychium minganense	Mingan Moonwort			x	S3S4	
Boutellia sp.[g]			x			
Braya humilis	Low Braya			x	S4	

TABLE 6I-1-4

Vegetation types Faro Mine Complex [a]

Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. X indicates presence of species in vegetation survey

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Brayea sp. [g]			x			
Bryoria species[f]		x				
Bryum sp.[f]				x		
Calamagrostis canadensis	Blue-joint Reedgrass		x	x	S5	
Calamagrostis inexpansa (Authors may mean *C. Stricta* ssp. *Inexpansa*)	New England Northern Reedgrass		x		S5	
Calamagrostis purpurascens	Purple Reedgrass			x	S5	
Calamagrostis sp.[f]		x				
Callitriche verna (syn. *C. palustris*)	Vernal Water-starwort			x	SNR	
Carex aquatilis	Water Sedge	x	x	x	S5	
***Carex aeneta* (syn. *Carex siccata*)**	**Dry-spike Sedge**		**x**		**S1**	
Carex atrata (syn. *Carex atrosquama*)	Blackened Sedge		x		S4	
Carex brunnescens	Brownish Sedge			x	SNR	
Carex capillaris	Hairlike Sedge		x		S5	
Carex 3apillaries ssp. *chlorostachys*				x	Not listed	
Carex concinna	Beautiful Sedge			x	S5	
Carex macloviana	Falkland Island Sedge			x	Not listed	
Carex media (syn. *C. norvegica* ssp. *inferalpina*)	Intermediate Sedge			x	S5	
Carex mertensii	Mertens' Sedge		x		SNR	

TABLE 6I-1-4

Vegetation types Faro Mine Complex [a]

Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. X indicates presence of species in vegetation survey

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Carex phaeocephala	**Mountain Hare Sedge**		**x**		**S2S3**	
Carex rossii	Short Sedge		x		SNR	
Carex saxatilis	Russet Sedge			x	SNR	
Carex scirpoidea	Bulrush Sedge		x	x	SNR	
Carex sp.[f]		x		x		
***Cassiope mertensii* (authors may mean *C. mertensiana*)**	**Western Bell-heather**		**x**		**S1**	
Cassiope tetragona	Arctic Bell-heather	x			S5	
Cerastium beeringianum	Bering Sea Chickweed		x	x	SNR	
Chamaerhodos erecta ssp. *nuttallii*	Nuttall's Ground-rose			x	SNR	
Cladina mitis	Green Reindeer Lichen	x	x	x	S5	
Cladina rangiferina	Gray Reindeer Lichen	x	x	x	S5	
Cladina stellaris	Star-tipped Reindeer Lichen			x	S5	
Cladonia spp.[f]		x		x		
Corallorhiza trifida	Early Coralroot			x	SNR	
Cornus canadensis	Dwarf Dogwood	x	x	x	SNR	
Cornus stolonifera (syn. *C. sericea*)	Red-osier/silky Dogwood		x		SNR	
Crepis elegans	Elegant Hawk's-beard		x	x	SNR	
Crepis tectorum	Narrowleaf Haw's-beard			x	SNA	1
Cypripedium sp.[g]			x			

TABLE 6I-1-4

Vegetation types Faro Mine Complex [a]

Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. X indicates presence of species in vegetation survey

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Descurainia sophia	Herb Sophia		x		SNA	4
Descurainia sophioides	Northern Tansy-mustard			x	S5	
Dodecatheon frigidum	Northern Shootingstar		x		S5	
Dryas drummondii	Yellow Mountain-avens		x	x	SNR	
Drays sp.[f]		x				
Drepanocladus uncinatus (syn. *Sanionia uncinata*)	Sanionia Moss			x	S5	
Elymus glaucus	Smooth Wild Rye		x		SNR	
Elymus trachycaulus	Slender Wild Rye		x		SNR	
Empetrum nigrum	Black Crowberry	x	x	x	SNR	
Epilobium angustifolium (syn. *Chamerion angustifolium*)	Fireweed	x	x	x	SNR	
Epilobium cilatum	Hairy Willowherb	x			SNR	
Epilobium latifolium (syn. *Chamerion latifolium*)	River Beauty		x	x	SNR	
Equisetum arvense	Field Horsetail	x	x	x	SNR	
Equisetum fluviatile	Water Horsetail			x	SNR	
Equisetum pratense	Meadow horsetail			x	SNR	
Equisetum scirpoides	Dwarf Scouring-rush	x		x	SNR	
Equisetum sylvaticum	Woodland Horsetail		x	x	SNR	
Equisetum sp.[f]		x				

TABLE 6I-1-4

Vegetation types Faro Mine Complex [a]

Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. X indicates presence of species in vegetation survey

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Erigeron acris	Bitter Fleabane		x		SNR	
Erigeron acris ssp. *Politus*	Northern Daisy			x	SNR	
Erigeron humilis	Low Fleabane		x		S5	
Erigeron peregrines	Subalpine Fleabane		x		SNR	
Festuca altaica	Rough Fescue		x		SNR	
Festuca rubra	Red Fescue			x	SNR	3
Flavocetraria nivalis	Crinkled Snow Lichen	x		x	S5	
Fragaria virginiana	Virginia Strawberry			x	SNR	
Fragaria glauca (authors may mean *Fragaria virginiana* ssp. *glauca*)	Virginia Strawberry		x		SNR	
Galium trifidum	Small Bedstraw			x	S5	
Gentiana glauca	Glaucous Gentian			x	SNR	
Gentiana propinqua (authors may mean *Gentianella propinqua*)	Four-part Gentian		x	x	S5	
Geocaulon lividum	Northern Comandra	x	x		SNR	
Geum macrophyllum	Largeleaf Avens		x		SNR	
Goodyera repens	Dwarf Rattlesnake-plantain		x		SNR	
Hedysarum alpinum	Alpine Sweet-vetch	x		x	S5	
Hedysarum mackenzii (authors may mean *Hedysarum boreale* ssp. *mackenzii*)	Boreal Sweet-vetch		x		S5	
Helictotrichon hookeri	**Spike-oat**		**x**		**S2**	

TABLE 6I-1-4

Vegetation types Faro Mine Complex [a]

Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. X indicates presence of species in vegetation survey

Vegetation and Soils Baseline – Faro Mine Interim Works Project Proposal

Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Hieracium gracile			x		SNR	
Hordeum jubratum	Foxtail Barley		x		SNR	
Hylocomium splendens	Stairstep Moss	x	x	x	S5	
Juniperus communis	Ground Juniper	x	x		S5	
Juncus alpinoarticulatus	Northern Green Rush			x	S4	
Juncus balticus	Baltic Rush			x	S5	
Juncus castaneus	Chestnut Rush			x	S5	
Kalmia polifolia	Pale Laurel		x		Not listed	
Ledum decumbens (authors may mean *Ledum palustre* ssp. *decumbens*)	Marsh Labrador-tea		x		S5	
Ledum groenlandicum	Common Labrador-tea	x	x	x	S5	
Leymus innovates	Northwestern Wildrye	x			SNR	
Linnaea borealis	Twinflower	x	x	x	SNR	
Lupinus arcticus	Arctic Lupine	x	x	x	SNR	
Luzula parviflora	Small-flower Woodrush		x		SNR	
Luzula parviflora ssp. *parviflora*	Small-flower Woodrush			x	SNR	
Lycopodium annotinum	Stiff Clubmoss		x		S5	
Lycopodium annotinum var. a*nnotinum*	Stiff Clubmoss			x	SNR	
Lycopodium clavatum	Running-pine		x		Not listed	
Mertensia paniculata	Tall Bluebells		x	x	SNR	

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Minuartia dawsonensis	Rock Stitchwort			x	SNR	
Mitella nuda	Naked Bishop's-cap			x	SNR	
Mnium sp.[f]		x				
Moehringia lateriflora	Grove Sandwort			x	SNR	
Monesus uniflora (authors may mean *Moneses uniflora*)	One-flower Wintergreen		x	x	SNR	
Orthilia secunda	One-side Wintergreen	x		x	SNR	
Oxytropis campestris	Northern Yellow Point-vetch		x		S5	
Oxytropis deflexa	Pendant-pod Ponit-vetch		x		SNR	
Parnassia palustris	Marsh Grass-of-Parnassus	x			SNR	
Parnassia palustre (authors may mean *P. palustris*)	Marsh Grass-of-Parnassus		x		SNR	
Parnassia palustris ssp. *neogaea*	Marsh Grass-of-Parnassus			x	Not listed	
Parrya nudicaulis	Naked-stemmed Wallflower			x	S5	
Pedicularis bracteosa	Towering Lousewort		x		Not listed	
Pedicularis labradorica	Labrador Lousewort		x	x	S5	
Pedicularis sudetica	Sudetic Lousewort			x	SNR	
Peltigera aphthosa	Common Freckle Pelt	x		x	SU	
Peltigera spp.[f]		x	x	x		
Petasites frigidus	Arctic Butter-bur	x	x		S5	
Petasites frigidus ssp. *frigidus*	Arctic Butter-bur			x	S5	

TABLE 6I-1-4
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Petasites frigidus ssp. *nivalis*				x	Not listed	
Petasites frigidus ssp. *palmatus*	Sweet Colt's-foot			x	S4	
Picea glauca	White Spruce	x	x	x	SNR	
Piecea mariana	Black Spruce	x		x	SNR	
Pinus contorta	Lodgepole Pine	x	x		SNR	
Platanthera hyperborean	Leafy Northern Green Orchid		x	x	SNR	
Pleurozium shreberi	Feathermoss/Schreber's Big Red-stem Moss	x	x	x	S5	
Poa alpina	Alpine Bluegrass		x		SNR	
Poa arctica	Arctic Bluegrass		x		SNR	
Poa palustris	Fowl Blugrass		x		SNR	
Poa pratensis	Kentucky Bluegrass		x		SNR	3
Poa sp.[f]		x				
Pohlia spp.[f]				x		
Polemonium acutiflorum	Tall Jacob's-ladder			x	SNR	
Polemonium pulcherrimum	Showy Jacob's-ladder		x		SNR	
Polygonum viviparum	Viviparous Knotweed		x	x	S5	
Polytrichum juniperinum	Juniper Moss		x	x	S5	
Polytrichum sp.[f]		x				
Populus balsamifera	Balsam Poplar	x	x	x	SNR	

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Populus tremuloides	Quaking Aspen	x	x	x	SNR	
Potentilla biennis	Biennial Cinquefoil		x		SNR	5
Potentilla diversifolia	Mountain Meadow Cinquefoil			x	SNR	
Potentilla fruticosa (syn. *Dasiphora fruticosa* ssp. *floribunda*)	Shrubby Cinquefoil	x	x	x	S5	
Potentilla norvegica	Norwegian Cinquefoil		x		SNR	
Pucinellia interior	Inland Alkali Grass			x	SNR	
Puccinellia nuttalliana	Nuttall's Alkali Grass		x		SNR	
Pyrola asarifolia	Pink Wintergreen		x	x	S5	
Pyrola chlorantha	Green-flower Wintergreen		x	x	S4S5	
Pyrola secunda	One-side Wintergreen		x		SNR	
Ranunculus aquatilis	White Water Buttercup		x	x	SNR	
Ranunculus hyperboreus	Arctic Buttercup			x	SNR	
Ribes hudsonianum	Northern Black Currant			x	SNR	
Ribes triste	Swamp Red Currant			x	SNR	
Rorippa palustris ssp. *Palustris*	Bog Yellowcress				SNR	
Rosa acicularis	Prickly Rose	x	x	x	SNR	
Rubus arcticus	Nagoonberry		x		SNR	
Rubus arcticus ssp. *Acaulis*	Nagoonberry			x	SNR	
Rubus chamacmorus (authors my mean *R. Chamaemorus*)	Cloudberry		x		SNR	

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Vegetation types Faro Mine Complex [a]
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Rubus idaeus	Common Red Raspberry		x	x	S5	
Rumex arcticus	Arctic Dock			x	S5	
Salix athabascensis	Athabasca Willow	x			SNR	
Salix alaxensis var. *Alaxensis*	Alaska Willow			x	S5	
Salix alaxensis var. *longistylis*	Alaska Willow			x	S5	
Salix arbusculoides	Little-tree Willow		x		S5	
Salix barclayi	Barclay's Willow		x	x	S5	
Salix bebbiana	Bebb's Willow		x	x	S5	
Salix glauca	Gray Willow		x	x	S5	
Salix lucida ssp. *lasiandra*	Pacific Willow			x	S4	
Salix myrtillifolia	Myrtle-leaf Willow	x	x	x	SNR	
Salix planifolia	Tealeaf Willow	x	x		S5	
Salix planifolia ssp. *planifolia*	Planeleaf Willow			x	SNR	
Salix polaris	Polar Willow		x		SNR	
Salix reticulata	Net-veined Willow	x	x		S5	
Salix reticulata ssp. *reticulata*	Net-veined Willow			x	SNR	
Salix scouleriana	Scouler's Willow	x			S5	
Salix sp.[f]		x		x		
Selaginella selaginoides	Low Spikemoss			x	SNR	

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Species	Common Name	Summer 2007 vegetation baseline survey [b]	July 20-24th vegetation survey [c]	Rare Plant Survey (August 2008) [d]	NatureServe Ranking (Yukon) [e]	Introduced Species – Invasiveness Rank [f]
Senecio congestus	Marsh Ragwort			x	SNR	
Senecio indecorus (syn. *Packera indecora*)	Plains Ragwort			x	SNR	
Senecio lugens	Black-tip Groundsel	x		x	S5	
Senecio paupercaulus (authors may mean *S. pauperculus*)	Balsam Ragwort		x		SNR	
Senecio triangularis	Arrow-leaf Groundsel		x		SNR	
Shepherdia canadensis	Canada Buffaloberry	x	x	x	SNR	
Solidago multiradiata	Alpine Goldenrod		x	x	SNR	
Sphagnum spp.[f]		x	x	x		
Splachnum sp.[f]				x		
Stellaria borealis	Northern Stitchwort			x	SNR	
Stellaria longipes	Long-stalked Stitchwort		x		SNR	
Stereocaulon paschale	Easter Foam Lichen	x			S5	
Stereocaulon sp.[f]			x	x		
Taraxacum officinale	Common Dandelion		x		SNR	
Taraxacum sp.[f]				x		
Thlaspi arvense	Field Pennycress			x	SNA	3
Tofieldia pusilla	Scotch False Asphodel		x	x	S5	
Tomenthypnum nitens	Tomentypnum Moss			x	S5	
Trisetum spicatum	Narrow False Oats		x	x	S5	

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Vaccinium oxycoccos (syn. *Oxycoccus microcarpus*)	Small Cranberry			x	SNR	
Vaccinium uliginosum	Alpine Blueberry	x	x	x	S5	
Vaccinium vitis-idaea	Mountain Cranberry	x	x	x	S5	
Veronica wormskjoldii	Alpine Speedwell			x	S4S5	
Viburnum edule	Squashberry		x	x	S5	
Viola renifolia var. *brainerdii*	Gray Kidneyleaf White Violet			x	Not listed	

Notes:

Bolded species are species that are of concern
There were no species listed on COSEWIC or SARA

[a] Modified from Environmental Dynamics Inc.(EDI). 2008. Faro Mine Site Re-vegetation Study: Waste Rock Dumps and Tailings Impoundment. Prepared for Deloitte and Touche Inc. May.

[b] Source: Gartner Lee Limited (GLL). 2008. Faro Mine Complex Closure Vegetation Baseline. Prepared for Faro Project Management Team. February.

[c] EDI (2008)

[d] Source: AECOM. 2008. Report on Faro Mine Site Rare Plant Survey. Prepared by Gartner Lee Limited. October.

[e] Source: NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. Accessed: November 1, 2013

[f] Genus only

[g] Species unknown

Attachment 6I-2
Vegetation Association Descriptions for the Local Study Area (Gartner Lee Limited, 2008)

The following text and photos are taken directly from the Gartner Lee Limited (GLL) *Faro Mine Complex Closure Vegetation Baseline* report prepared for the Faro Project Management Team in February 2008. Please refer to that report for further information.

1) **Sedge/Willow (S/W)**

   This wetland association is common in both the boreal and subalpine zone and occurs in (moist/wet) depression or drainage areas where water collects either above or below the ground, due to bedrock or soil conditions. Wetlands are defined as being "waterlogged soils where in some cases the production of plant materials exceeds the rate of decomposition" (National Wetlands Working Group 1988). Soils are saturated for enough time that excess water and low soil oxygen levels are the main determinants of soil and vegetation development (MacKenzie and Moran 2004). Wetlands, including streams and fens, are common in low gradient valleys and catchment basins in the Faro LSA (Oswald et al. 1983). A mixture of sedge and graminoid species dominates the area, with water sedge (*Carex aquatilis*) being most common. Shrubs such as willows (*Salix spp.*), dwarf birch (*Betula glandulosa*) and some white spruce (*Picea glauca*) are also present around the edges of the wetland. Wetland mosses such as sphagnum (*Sphagnum spp.*) are also abundant.



Figure 6I-2-1: Sedge/Willow vegetation association

2) Willow/Sedge (W/S)

The willow/sedge association is linked with standing or flowing water, usually along lakes, ponds and creek drainages. It is a common riparian vegetation association found over a wide elevation range throughout the study area. Various willow species including tea-leaved willow (*Salix planifolia*) and Athabasca willow (*Salix athabascensis*) are dominant in the shrub layer though dwarf birch and shrubby cinquefoil (*Potentilla fruticosa*) may also be present. Shrub heights vary depending on water availability and exposure to wind and snow, but are generally 0.5 to 1 m tall. Sedge species (*Carex* spp.) such as water sedge are common below the shrub layer along with various wetland mosses (*Sphagnum* spp).

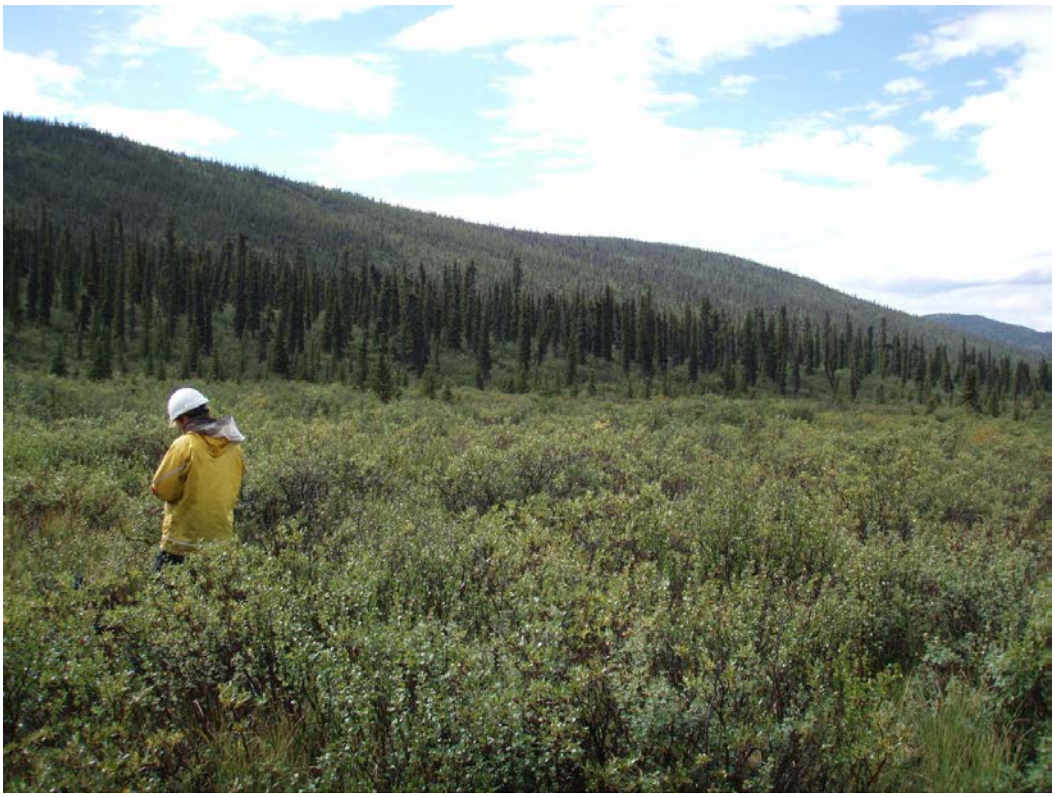

Figure 6I-2-2: Willow/Sedge vegetation association

3) Willow/White Spruce (W/Sw)

The willow/white spruce vegetation association is often found in a riparian drainage or draw, along creeks or rivers primarily in the boreal zone. An open canopy of mature white spruce is scattered among a well-developed shrub layer dominated by various willow species and dwarf birch. Ground cover is often a combination of ericaceous shrubs, sedge species, lichens and mosses. Such species include arctic bearberry (*Arctostaphylos rubra*), net-veined willow (*Salix reticulata*), common horsetail (*Equisetum arvense*) and bluegrasses (*Poa* spp.).



Figure 6I-2-3: Willow/white spruce vegetation association

4) Willow/Dwarf Birch (W/B)

This riparian vegetation association is widespread in lower elevations, occurring on gentle to steep slopes near drainages or open water in the boreal zone. Willow species and dwarf birch are codominant in a well-developed shrub layer wherein willows can reach up to 4 m. Scattered young white spruce trees are common, along with low shrubs such as Labrador tea (*Ledum groenlandicum*), as well as sparse grasses and forbs. Moss and lichen cover varies depending on water and nutrient availability.



Figure 6I-2-4: Willow/Dwarf Birch vegetation association

5) Dwarf Birch/Willow (B/W)

The birch/willow vegetation association is characteristic of slopes at higher elevations in the subalpine zone throughout the study area. Dwarf birch is the dominant shrub, however willow species, Labrador tea, shrubby cinquefoil and bog bilberry (*Vaccinium uliginosum*) are also present. A variety of ground shrubs such as crowberry (*Empetrum nigrum*), mountain cranberry (*Vaccinium vitis-idaea*) and alpine bearberry are found in the understory; however, lichens (*Flavocetraria* spp., *Cladina* spp. and *Stereocaulom* spp.) tend to dominate the groundcover. Krummholtz subalpine fir (*Abies lasiocarpa*) and white spruce occur occasionally.

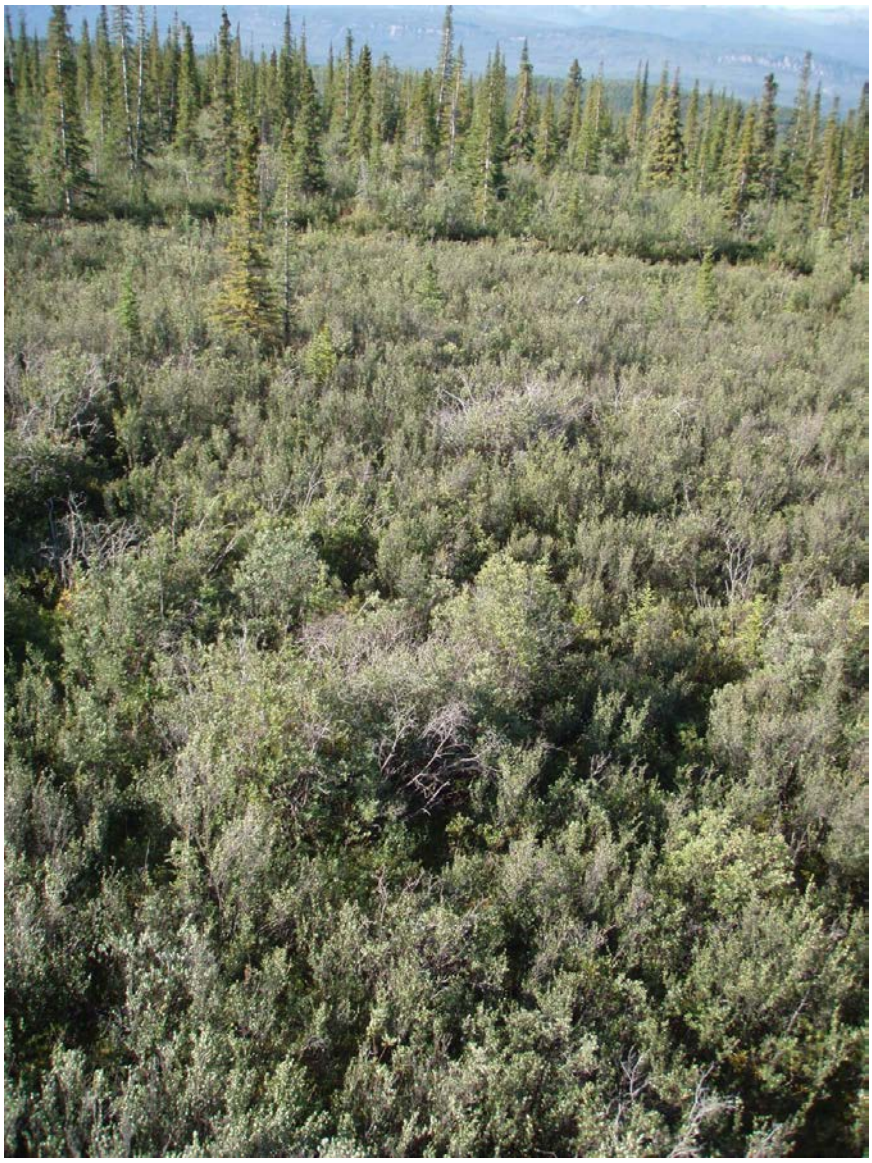

Figure 6I-2-5: Birch/willow vegetation association

6) Dwarf Birch/Lichen/Subalpine Fir (B/L/Fa)

This vegetation association is a subalpine/alpine community characterized by rocky outcrops and windswept ridges at higher elevations. Dwarf birch is the dominant cover species at a height of 0.5 m tall, followed by a high cover of lichen species (*Cladina* spp., *Stereocaulon* spp., and *Flavocetraria* spp.) intermixed with rocky outcrops. Krumholtz subalpine fir is the dominant tree species scattered throughout the vegetation association, although white spruce may also be present. Arctic bearberry, crowberry, bog bilberry and mountain avens (*Dryas* spp.) are also present.



Figure 6I-2-6: Dwarf Birch/Lichen/Subalpine Fir vegetation association

7) Dwarf Birch/Subalpine Fir (B/Fa)

The birch/fir vegetation association is a subalpine community occurring on well-drained soils and slopes at higher elevations. Dwarf birch is the dominant cover species at a height of 0.5 to 1 m tall with scattered subalpine fir as the dominant tree species at 2 – 6 m tall. Willow species, Labrador tea, mountain juniper (*Juniperus communis*) and white spruce may also be present. Low growing shrubs include bog bilberry, arctic bearberry, crowberry and mountain cranberry. Graminoid species are present in the ground cover along with various lichen species (*Cladina* spp., *Stereocolun* spp., and *Peltigera* spp.).

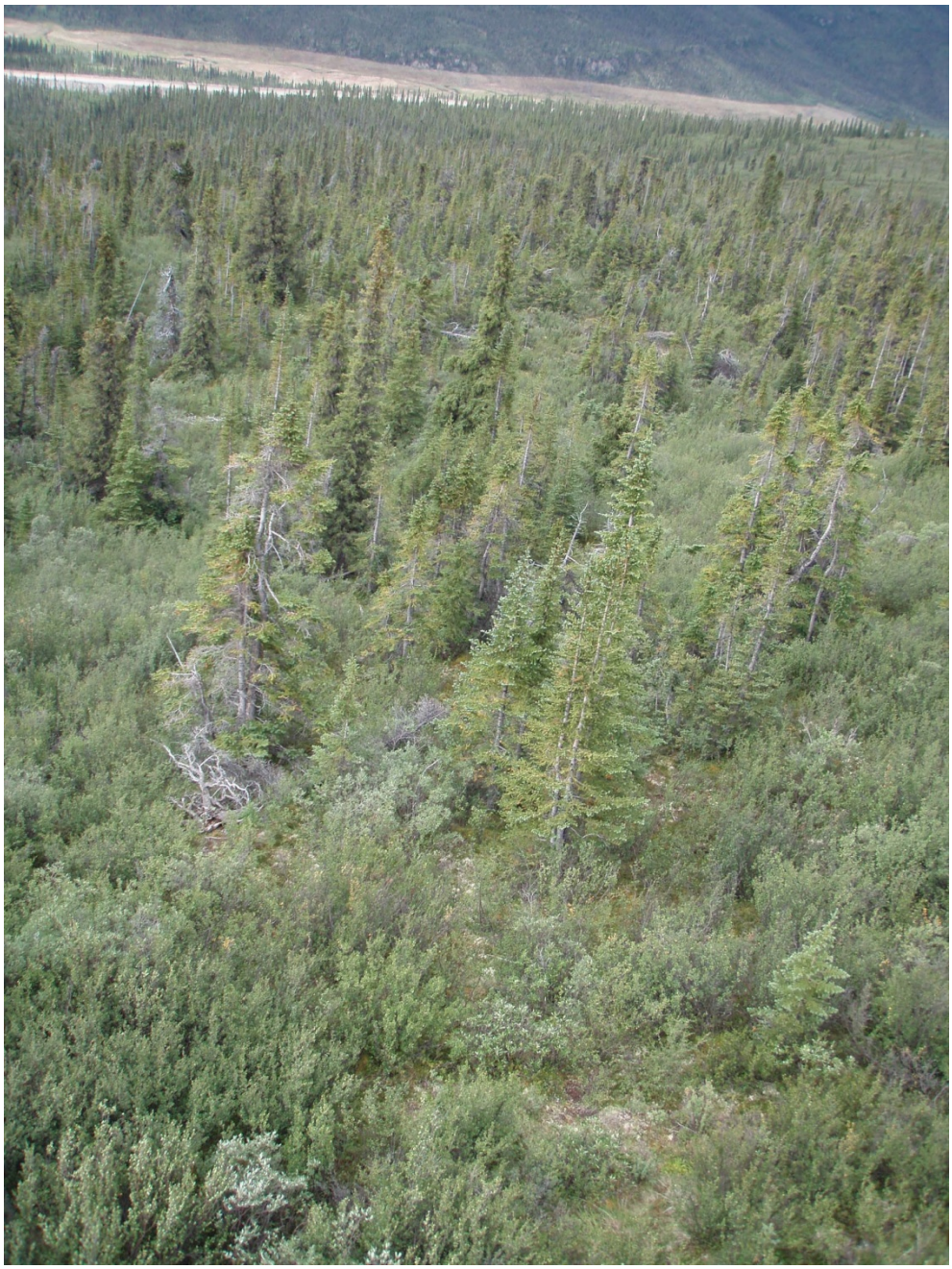

Figure 6I-2-7: Dwarf birch/subalpine fir vegetation community

8) White Spruce/Willow (Sw/W)

The white spruce/willow association is the most frequent vegetation association within the study area, occurring in both the boreal and the subalpine zones on various upland and lowland slopes. White spruce dominates the tree canopy, though subalpine fir may also be present. A well-developed shrub layer is dominated by a high cover of 1 m tall willow species, along with a lower percent of dwarf birch, Labrador tea and shrubby cinquefoil. Dwarf shrubs in the ground cover layer include bog billberry, common bearberry (*Arctostaphylos uva-ursi*), net-veined

willow and crowberry. Common horsetail and bluegrass species are also frequent. Stair step moss (*Hylocomium splendens*), reindeer lichens (*Cladina rangifera*) and pelt lichens (*Peltigera* spp.) are common throughout the vegetation association.



Figure 6I-2-8: White spruce/willow vegetation association

9) White Spruce/Feather moss (Sw/Fm)

This vegetation association occurs most frequently on well-drained alluvial flats as well as on mesic sites in lowland areas throughout the boreal zone. The tree canopy is comprised of dense white spruce trees with a sparse shrub understory. Tall shrubs consist of willow species, dwarf birch and shrubby cinquefoil whereas low growing shrubs consist of mountain cranberry, bog bilberry, alpine bearberry and crowberry. Vegetation in the herbaceous layer includes arctic lupine (*Lupinus arcticus*), alpine sweet vetch (*Hedysarum alpinum*), purple-leaved willow-herb (*Epilobium ciliatum*) and bluegrass species. A thick carpet of feathermosses such as stair step moss is also present.

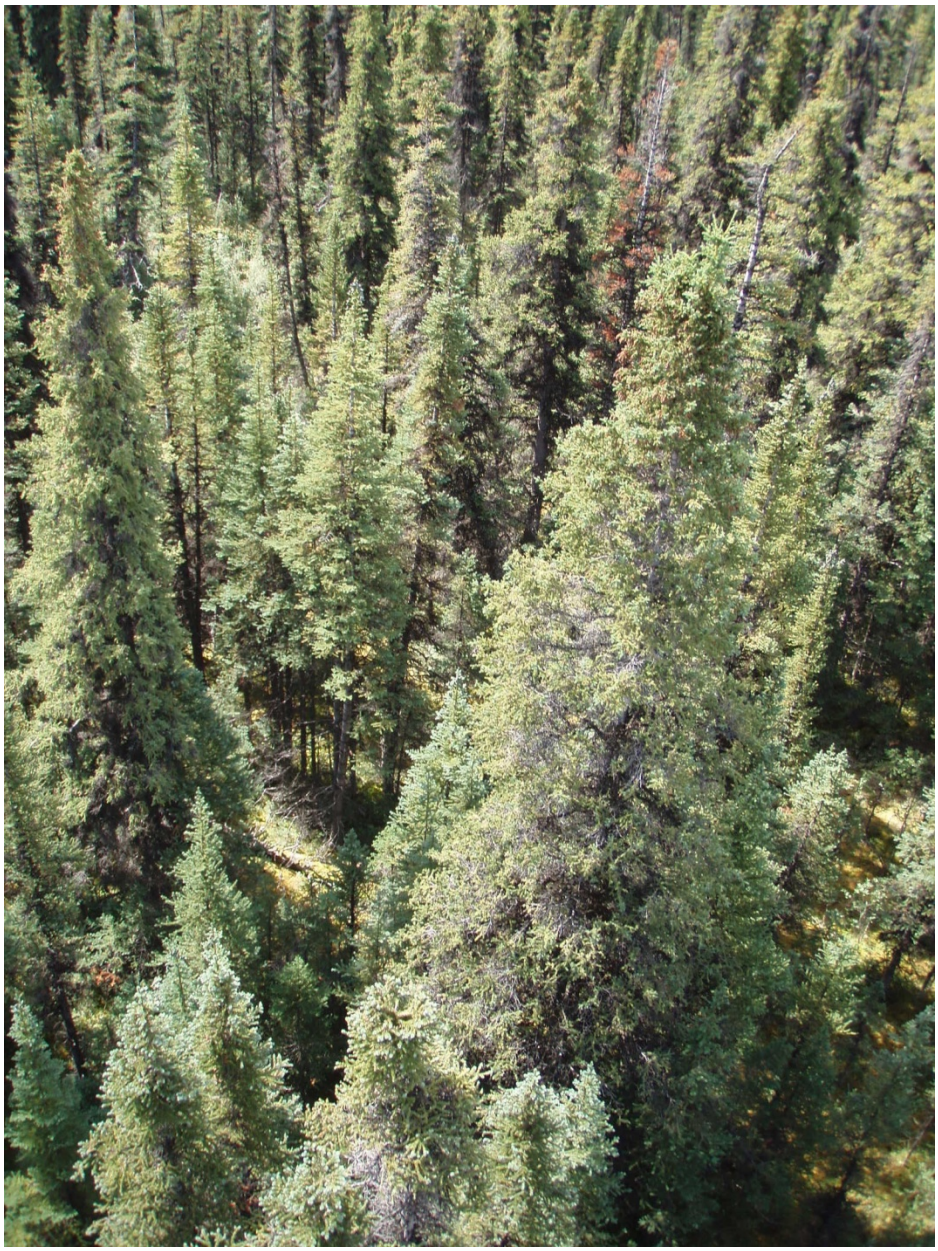

Figure 6I-2-9: White spruce/feather moss vegetation association

10) Pine (Pl)

The Pine vegetation association is as its name suggests a dominant tree canopy of lodgepole pine (*Pinus contorta*). It is found mostly on upland areas around the Grum and Vangorda pit at the SE end of the LSA in the boreal zone. The average tree canopy height is 16 m, with a few white spruce trees scattered throughout the subcanopy. A tall shrub layer of Sitka alder (*Alnus crispa* ssp. Sinuate) and Scouler's willow (*Salix scouleriana*) is common and followed by a lower shrub layer of Labrador tea, prickly rose (*Rosa acicularis*) and buffaloberry (*Shepherdia canadensis*). Ground cover consisting of bog bilberry, crowberry, bunchberry (*Cornus canadensis*), common bearberry and twinflower (*Linnaea borealis*) are noted at lower cover

values. Feathermosses are also a common ground cover. This vegetation association is a typical mid-successional forest following fire.



Figure 6I-2-10: Pine vegetation association

11) Mixed Coniferous-Deciduous (Mx)

This vegetation association establishes on well drained sites over a broad elevation range. It consists of a mixture of coniferous and deciduous trees including white spruce, trembling aspen, balsam poplar (*Populus balsamifera*), lodgepole pine. Depending on moisture and nutrients, subalpine fir and/or black spruce (*Picea mariana*) may also be present. This is often a young forest or "mid-seral community following fire" (Staniforth, 1998) whereby trees are in both the tree canopy and shrub layer. Additional shrubs include dwarf birch, willow species and Labrador tea. Bog bilberry, crowberry and mountain cranberry comprise the layer of low growing shrubs whereby stair step moss, green reindeer lichen and pelt lichens moderately cover the remainder of the ground.



Figure 6I-2-11: Mixed Coniferous-Deciduous vegetation association

12) Deciduous (Dd)

The deciduous vegetation association often establishes on sites regenerating from a disturbance, whether it be fire or human development. Sites tend to be located on well-drained slopes and are rich in diversity. Most often located in the boreal zone, trembling aspen is the dominant tree species ranging in height from 2 to 8 m tall, followed by balsam poplar on moister sites. Tall shrubs include willow species, Sitka alder, shrubby cinquefoil, Labrador tea, dwarf birch, buffaloberry and prickly rose. White spruce may also be visible in the understory. Low growing shrubs include arctic bearberry, common bearberry, mountain cranberry and blueberry willow (*Salix myrtilifolia*). The herbaceous layer consists of bunchberry, bastard toad-flax (*Geocaulon lividum*), fireweed (*Epilobium angustiflolium*), northern grass-of–parnassus (*Parnassia palustris*) and twin flower.



Figure 6I-2-12: Deciduous vegetation association

13) Graminoid (Gr)

The graminoid vegetation association is found in lowland areas on and around the project footprint in the boreal zone. It generally comprises an area re-established from seed mixtures of grasses and low growing forbs such as the freshwater reservoir located SE of the tailings pond along the access road. Grasses such as brome (*Bromus* spp.), reedgrass species (*Calamagrostis* spp.) and fescue species (*Festuca* spp.) dominate this vegetation association. Sedge species can occur as well as various forbs such as fireweed and wormwood (*Artemisia* spp.).



Figure 6I-2-13: Graminoid vegetation association

Appendix 6J
Environmental Baseline Report: Terrestrial Wildlife

Draft

Environmental Baseline Report: Terrestrial Wildlife Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon Y1A 2J9

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Acronyms and Abbreviations

µg/L	micrograms per litre
AAM	Government of Yukon, Assessment and Abandoned Mines Branch
C&M	care and maintenance
CCME	Canadian Council of Ministers of the Environment
CDC	Conservation Data Centre
CH2M HILL	CH2M HILL Canada Ltd.
CVD	Cross Valley Dam
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
EBA	EBA Engineering Consultants Ltd.
ELC	ecological land classification
ELR	Ecological Logistics & Research Ltd.
EY	Environment Yukon
ETA	Emergency Tailings Area
FMC	Faro Mine Complex
GIS	Geographic Information System
GMS	Game Management Subzone
ID Pond	Intermediate Dam Pond
ISQG	Interim Sediment Quality Guidelines
km	kilometre
km^2	kilometre square
LCP	Little Creek Pond
LSA	local study area
m	metre
masl	metres above sea level
MELP	Ministry of Environment, Lands, and Parks
mg/kg	milligrams per kilogram
PEL	Probable Effects Level
RCD	Rose Creek Diversion
RSA	regional study area
SAR	Species at Risk
SARA	*Species at Risk Act*
SCF	sightability correction factor
RIC	Resources Inventory Committee

SPP	Sheep Pad Ponds
SRK	SRK Consulting Engineers and Scientists
TKD	tracks/kilometre/day
USGS	United States Geological Survey
VHF	Very High Frequency
WKA	Wildlife Key Area
WTP	Water Treatment Plant
YESAB	Yukon Environmental and Socio-Economic Assessment Board
YG	Government of Yukon

SECTION 1

Introduction

Ecological Logistics & Research Ltd. (ELR) was retained by CH2M HILL Canada Ltd. (CH2M HILL), on behalf of Government of Yukon (YG), Assessment and Abandoned Mines Branch (AAM) to prepare a wildlife baseline report to support the upcoming Project Proposal submission to the Yukon Environmental and Socio-economic Assessment Board (YESAB) as part of the Faro Mine Interim Works for the Faro Mine Complex (FMC).

The FMC is located 15 kilometres (km) north of the Town of Faro and is comprised of two former mine components, the Faro Mine Area and the Vangorda/Grum Area. These two components are separated by a 14-km haul road (Figure 6J-1). The FMC operated as an open-pit lead and zinc mine extracting concentrates that also produced silver and gold between 1969 to 1998. In 1998, the operating company went into receivership and the mine subsequently went into a care and maintenance (C&M) phase. AAM assumed management responsibilities of the FMC in 2009.

1.1 Objectives and Scope

The primary objective of this wildlife baseline report is to describe terrestrial wildlife resources at the FMC and surrounding area, to support an assessment under the Yukon Environmental and Socio-economic Assessment Act. The report forms part of a multidisciplinary program prepared to describe current conditions at the FMC.

The scope of baseline information presented in this report represents a collection of efforts dating back to the 1970s; a number of which were conducted prior to when AAM assumed responsibility for the site in 2009. More recent regional and local studies have been completed by Environment Yukon (EY) or on behalf of AAM, respectively.

Information collected from available sources was compiled, reviewed, and summarized, and is organized into three key sections: (1) Introduction, providing historical and geographical context to the information presented, (2) Methods, describing methodologies used for each baseline component, and (3) Results, presenting a synthesis of the findings from each baseline component and integrated into species-specific sections.

1.2 Environmental Setting

The FMC is located within the Yukon Plateau-North Ecoregion of the Boreal Cordillera Ecozone, a region characterized by rolling uplands, small mountain groups, and plateaus dissected by glaciated valleys (Smith et al., 2004). The FMC occurs on the Vangorda Plateau, with elevations ranging from 1,000 to 1,400 metres (m) above sea level (masl). The Anvil Range Mountains rise up immediately north of the Vangorda Plateau, with major summits exceeding 2,000 masl, including Mount Mye and Mount Aho. Drainage of the FMC is via Rose Creek and Vangorda Creek, both of which flow from the FMC to the Pelly River. The Pelly River flows northwest in the wide valley of the Tintina Trench, which is located south of the Vangorda Plateau at an approximate elevation of 600 masl. The Tintina Trench is a fault that traverses the territory from the southeast corner toward the City of Dawson in west central Yukon.

The FMC occurs primarily within mid-elevation boreal forest, dominated by white spruce and occasional lodgepole pine with willow, dwarf birch, and ericaceous shrubs in the understory. Poorly drained sites consist of black spruce, willow, birch, and mosses. Subalpine vegetation communities are dominated by scrub birch, subalpine fir, white spruce, some lodgepole pine, and lichen. Above the treeline, alpine areas are characterized by rock and bluffs, low ericaceous and willow shrubs, and an abundance of terrestrial lichen (Smith et al., 2004).

SECTION 2

Methods

2.1 Wildlife Study Areas

2.1.1 Wildlife Local Study Area

The FMC is spatially defined by the extent of the existing disturbance footprint; this area represents an immediate zone of project effects. A local study area (LSA), encompassing the area with reasonable potential for project-related effects, includes the FMC and a 1-km buffer, creating a total area of 81.2 kilometres square (km^2) (Figure 6J-2). A similar LSA was used in a 2008 wildlife baseline report, which included a description of conditions at the FMC (Gartner Lee Limited, 2008a).

2.1.2 Wildlife Regional Study Area

For some wide ranging wildlife species (e.g., moose, caribou, grizzly bears, and some raptors) the assessment requires an understanding of abundance and distribution in areas extending beyond the LSA. Accordingly, a wildlife regional study area (RSA) was used to describe wildlife populations and to assess effects at a broader geographical scale (Figure 6J-2). The RSA was defined as an area extending 15 km beyond the FMC footprint, resulting in a total area of 1,530 km^2.

2.2 Existing Wildlife Information Datasets

Several sources of existing wildlife data were reviewed to characterize baseline conditions for wildlife and wildlife habitat at the FMC. These sources include:

- YG Wildlife Key Area (WKA) datasets
- Yukon hunting regulations and EY database for harvested big game species
- Breeding bird survey data
- Species at Risk (SAR) resources including the Yukon Conservation Data Centre, the *Species at Risk Act* (SARA) Registry, and NatureServe Canada
- Previous reports and summaries prepared for the FMC

2.2.1 Wildlife Key Area Datasets

WKAs are geographic locations or areas in the Yukon that have been identified as important habitat areas used by wildlife for critical and seasonal life functions. WKA delineations are based primarily on regional surveys conducted by EY but also on local area knowledge or anecdotal information (EY, 2009). WKAs are important as they help identify the habitat requirements for key life functions (e.g., winter feeding, rutting, and calving).

The YG WKA database was spatially queried to determine the presence of WKAs within the RSA and LSA. WKAs found within the RSA are summarized within the corresponding species sections herein.

2.2.2 Hunting Regulations and Harvest Database

Hunting in the Yukon is regulated under the Yukon *Wildlife Act.* Regulations and guidelines for hunters are published annually in the Yukon Hunting Regulations Summary (EY, 2013a). Information relating to species harvest in the Faro region was compiled for each of the large mammal species sections in this report.

EY provided harvest data for moose, caribou, grizzly bear, and thinhorn sheep in the Game Management Subzones (GMSs) that overlap or occur in the vicinity of the FMC. EY compiles the data from records submitted by hunters every year. Wildlife manager typically use a 5-year period to assess and determine trends that occur in a wildlife population (Alain Fontaine, Liard Area Regional Biologist; personal communication). A 10-year period of harvest data was requested from EY for the FMC area GMS, to characterize potential trends in hunting pressures and in wildlife populations that occur in the area.

2.2.3 Breeding Bird Surveys

Breeding bird survey data for the Town of Faro was accessed, as this data can provide a valuable indication of avian species that may potentially be present in the FMC area. Two breeding bird survey databases were queried to compile a list of species that have been reported to have been observed near Faro, as follows:

- Birds of the Yukon Database - Map sheets 105K3 and 105K6 (Canadian Wildlife Service [CWS], 2007)
- North American Breeding Bird Survey Database - Faro Route (United States Geological Survey [USGS], 2013)

Species were summarized according to those most commonly observed and those being of conservation concern, and were grouped into water and land bird species in Table 6J-7 and 6J-8, respectively, for reference.

2.2.4 Species At Risk

Several resources were examined to identify potentially occurring SAR within and around the project LSA and RSA:

- Species for which WKAs were identified within the RSA were cross-referenced with federal and territorial SAR listings.
- The YESAB Geolocator was employed to spatially evaluate the RSA for the presence of important habitat for species of conservation concern. For any Conservation Data Centre (CDC) Species of Conservation Concern polygons that occurred within the RSA, an information request was submitted to the Yukon Conservation Data Centre for additional information.
- The Yukon *Wildlife Act,* the federal SARA registry, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and NatureServe Canada were queried to determine the conservation status for species occurring or potentially occurring in the project area.

2.2.5 Previous Wildlife Reports and Studies

Three existing reports describing wildlife and wildlife habitat conditions at the FMC were reviewed for inclusion in this baseline document. The methods used to collect or compile information in these reports are summarized in the following sections.

2.2.5.1 Wildlife Habitat Local Study Area Baseline Report

A wildlife baseline study report was developed on behalf of AAM in 2008, in support of the development of a preliminary closure and remediation plan for the FMC (Gartner Lee Limited, 2008a). The objective of the document was to provide wildlife information relevant to those issues identified as important during community meetings and during consultation with First Nations (Selkirk First Nation and Ross River Dena Council), the Town of Faro, YG biologists, local residents and project scientists in the study area at that time, as well as to issues that may be associated with project effects. The geographic scope of that report was limited to the LSA; however, due to the limited wildlife and wildlife habitat information available for the mine area, regional data were used to infer conditions at the local level. Data collection methods were limited to incidental sightings during a vegetation classification survey conducted in August 2007. Information was also compiled from previous reports and available community and traditional knowledge reports. Gartner Lee Limited reviewed the data and information, and integrated it into species or functional group accounts including descriptions of species populations, movements, distribution, harvest, habitat use, and diet.

The 2008 baseline report provided a compilation of existing information. Data and observations from that report have been integrated into this baseline report document, and have been updated where possible to reflect baseline conditions at the FMC.

2.2.5.2 Faro Area Thinhorn Sheep Summary

Following the development of the Wildlife Habitat Local Study Area Baseline Report by Gartner Lee Limited in 2008, an additional report was developed by Gartner Lee Limited as a complementary component to the wildlife baseline document. Gartner Lee Limited (2008b) digitized archived sheep data that had been collected over a period of 18 years (1981 to 1999) in the FMC area by YG. The archived data included observational records logged on paper maps and in field notes taken during aerial and ground surveys. In addition, radio telemetry locations of

ewes that were collected during a sheep monitoring program that ran from November 1989 and May 1990, were also digitized. During this program, nine ewes were captured and fitted with very high frequency (VHF) radio collars (Schweinsburg, 1990). Gartner Lee Limited (2008b) also digitized sighting records logged during two additional studies: (1) an investigation conducted by McLeod (1981) of the Mount Mye sheep population, and (2) an impact assessment targeting stone sheep in the Grum and Vangorda pit areas conducted by Horejsi (1998).

Gartner Lee Limited (2008b) digitized point locations on-screen at a scale of 1:10,000 using a geographic information system (GIS) and subsequently logged location-specific attribute data into a database; only records with specific geographic reference information were digitized. The locations were spatially compiled to produce seasonal use maps and migratory movement maps. The spatial information resulting from the digitizing efforts in 2008 was summarized into the Faro Area Thinhorn Sheep - Additional Baseline Data Summary report (Gartner Lee Limited, 2008b) and is integrated into the current baseline report document to help characterize sheep distribution and use of the FMC and surrounding area.

2.2.5.3 Current Environmental Conditions Supporting Document

The Faro Mine Complex Closure and Reclamation: Current Environmental Conditions Supporting Document (AECOM Canada Ltd., 2009) reported on current environmental conditions at the FMC including climate and atmospheric environment, geology, and water resources, as well as aquatic and terrestrial resources. Wildlife baseline conditions were described as a terrestrial resource; supporting information was drawn from the Local Study Area Baseline Report (Gartner Lee Limited, 2008a), as described in Section 2.2.4.1.

2.3 Recent Regional Studies

Two regional studies have recently been conducted by EY: an early-winter moose survey and a thinhorn sheep lambing survey. EY periodically conducts such ungulate studies to monitor population trends and to inform land and harvest management decisions. Methods from these regional studies are summarized in the next section.

2.3.1 2011 Faro Region Early-Winter Moose Survey

EY conducted an early-winter moose survey of the Faro region in 2011 to estimate the abundance, distribution and composition (i.e., sex and age class) of the local moose population (Clarke et al., 2012). By comparing the 2011 survey data with data collected during previous surveys, EY also evaluated recent population trends. The survey included 10 GMS of which one (i.e., 4-40) was only partially surveyed (Figure 6J-3). Additional analytical effort was expended on GMS 4-45 to evaluate the population trends in that unit due to recently increased access and resulting heavy hunting pressure in the area. The Faro Mine Area of the FMC overlaps the southwestern portion of GMS 4-45, as well as GMS 4-44, 4-46, and 4-51 (Figure 6J-3).

The survey was conducted according to the geospatial survey methods of Kellie and Delong (2006) and included two main components: (1) an intensive stratification and (2) a population census. The survey was performed over a total survey area of 6,470 km^2 which was divided into 405 survey blocks with 4 km by 4 km dimensions (16 km^2 each). The first step in the survey was to stratify (i.e., classify) blocks using a fixed-wing aircraft. At this stage, blocks were classified according to the expected density of moose (e.g., high or low) based on observations of moose, moose tracks, and habitat characteristics, as well as local knowledge. This step helps to extrapolate field results more accurately to a population estimate. Next, 30 percent of all blocks were randomly sampled to include in the population census component. During the census, blocks were flown using helicopters and moose were enumerated and classified to sex and age class (adult or calf). Due to the difficulty in differentiating between yearling and adult cows, they were grouped as one age class. A sightability correction factor (SCF) was calculated to estimate and correct for the number of moose that were missed during the census. Clarke et al. (2012) calculated abundance ratios of adult bulls to cows, calf survival, and yearling recruitment. Statistical comparisons were made between data collected in 1997, 2004, and 2011 for the Faro study area population.

2.3.2 2011 Faro Region Lambing Sheep Survey

EY conducted lambing surveys in June and July of 2011 throughout the Anvil Range mountains (EY, 2011; unpublished data) (Figure 6J-5). EY's purpose for conducting the surveys was to collect current demographic and distribution data for the Faro area thinhorn sheep (Dall's subspecies; *Ovis dalli dalli*) population in response to

increased mineral exploration activities in the area. Furthermore, EY indicated that WKAs identified for lambing in the study area were outdated (i.e., based on lambing data from the late 1980s) and were assumed to under represent important areas that are used by ewes during the lambing season, which ranges from May to June annually (Ministry of Environment, Lands, and Parks [MELP], 2000).

The lambing surveys were conducted using a Robinson R44 helicopter to systematically search alpine habitats for cliffs in use by ewes with newborn lambs. Two surveys were conducted; the first was performed in June to count newly born lambs, and the second was performed in July to determine the survival rate of lambs approximately one month later. To minimize disturbance to nursing sheep, sheep were observed and counted from a distance using binoculars or a spotting scope. Ewes with new lambs were differentiated from nursery groups with mobile lambs by observing those that did not flee (i.e., new lambs) with those that did (i.e., mobile lambs).

2.4 Recent Field Programs

Recent onsite field programs include a 2012 winter snow tracking survey and a 2013 waterfowl study. In addition, a log of wildlife observations at the FMC has been maintained by site C&M contractors, and has been included herein to augment local species occurrence information.

2.4.1 Waterfowl Surveys and Habitat Assessment

In September of 2013 a study was conducted to collect data on the usage of pits and ponds in the FMC area by waterfowl and waterbirds, and to characterize the habitat provided by those pits and ponds as they relate to waterfowl and waterbird use. These data were collected with the intent of characterizing the potential risks to those wildlife. The study was conducted in 2013 as only anecdotal or incidental data regarding waterfowl use of the aquatic areas in the FMC previously existed. Study sites included FMC pits and ponds in the Faro Mine Area (Figure 6J-8a) and in the Vangorda/Grum Area (Figure 6J-8b). The study was limited to the fall migratory period, and was conducted by ELR biologists who employed a combination of observational and field sampling methods to better understand the contributions of the aquatic areas to waterfowl habitat, and the potential for exposure pathways.

2.4.1.1 Observational Study

ELR conducted observational surveys following protocols outlined by the British Columbia Resources Inventory Committee (RIC) protocol for presence/non-detected surveys for waterfowl (MELP, 1999a). When waterfowl were observed, behaviors such as feeding, diving, resting or drinking were also noted.

2.4.1.2 Habitat Assessment

A qualitative approach was used to describe habitat characteristics at the pits and ponds in order to characterize habitat value based on the presence of available riparian vegetation, presence and abundance of aquatic vegetation, and presence and abundance of benthic macroinvertebrates.

Benthic sediment and aquatic and riparian vegetation tissue samples were collected when present in the ponds and analyzed for total metals concentration. Laboratory results for sediment were compared to Canadian Council of Ministers on the Environment Sediment Quality Guidelines for the Protection of Aquatic Life (Canadian Council of Ministers of the Environment [CCME], 1995), including Interim Sediment Quality Guidelines (ISQG) and Probable Effects Level (PEL) guidelines to determine potential risk levels. Vegetation metals concentrations were compared to corresponding sediment metals concentrations to determine whether metals levels were elevated, and whether metals were being magnified in relation to sediment levels.

In conjunction with sediment collection for metals analysis, sediment was also assessed for the presence of benthic macroinvertebrates. Twenty litre composite samples were collected from ponds and were field sieved using a 400 micrometre sieve. Benthic invertebrates captured by the sieve were assessed visually, and were field preserved prior to being sent to an invertebrate taxonomic laboratory for identification.

2.4.1.3 Assessment of Habitat Potential

Observational and habitat data for the FMC pits and ponds were assessed to determine habitat potential for each area surveyed, which was described in terms of either stop-over or feeding habitat. The presence of stop-over

habitat potential was identified in areas where surface water was consistently present in an area large enough to be used for resting by waterfowl, and where waterfowl were previously observed. Feeding habitat potential was described as where benthic macroinvertebrates, aquatic vegetation, and riparian vegetation were observed, and where waterfowl have been observed.

2.4.2 2012 Winter Tracking Survey

ELR was retained by CH2M HILL on behalf of AAM to conduct a winter tracking survey in March 2012 to collect data on the relative abundance, diversity and habitat use of furbearers and other wildlife species at the FMC during late winter (ELR, 2012). The survey was conducted according to RIC protocols for marten and weasels, and for medium-sized territorial carnivores and selected ungulates (MELP, 1998a; 1998b; 1999b).

The tracking survey employed a ground-based track count method in the LSA, using transects based on equilateral triangles of three 1-km lengths (Figure 6J-7), distributed among 14 ecological land classification (ELC) units described by AECOM (2009; unpublished data). Biologists followed transects between 24 and 72 hours after the last snowfall, and recorded tracks as either active detections (created since the last snowfall) or incidental tracking detections (older tracks of unknown age). Sightings or other wildlife sign were also recorded as incidental observations.

Data were analyzed by overlaying Geographic Positioning System track files over the ELC polygons using GIS software, where track segments were classified according to a functional habitat type. For this analysis, the 14 ELC ecosystem units identified by AECOM (2009) were grouped into eight functional habitat groups in order to reduce the number of habitat categories and thereby minimize the effect of small sample sizes in uncommon habitats. Tracking effort (km x days) was calculated for the entire LSA and for particular habitats, while track density (tracks/km/day; TKD) was calculated for species within each of eight functional habitat types. The tracking data was also analyzed to assess effort and track density for the entire LSA. Incidental observations were also discussed.

2.4.3 FMC Incidental Wildlife Log

An incidental wildlife log has been maintained by FMC C&M staff since 2009 (AAM, 2013, unpublished data), and is currently maintained by Tlicho Engineering and Environmental Services. Log records include wildlife observations reported by C&M staff, AAM staff, onsite contractors and visitors. Each record consists of the observation date, a specific or general description of the animal (e.g., grizzly bear or bear), and most records include a reference to sighting location. The wildlife incidental reporting program has resulted in a 5-year record of nearly daily wildlife observations. The observations were made incidentally while conducting C&M activities, and were not part of a structured wildlife monitoring program. As such, the resulting dataset has some inherent limitations. Factors affecting this dataset include the variation in detectability of wildlife species, the seasonality of onsite activities (and therefore detection ability), the observers' species identification skills, and the likelihood of multiple observers reporting a single species occurrence (resulting in an overrepresentation of the number of occurrences). Although the resulting inferences from the data are limited, the records provide a list of species that have been observed onsite as well as a general indication about what seasons wildlife have been observed in the area. ELR compiled the observation records to sort and tabulate data according to species and season; species summaries are detailed in the corresponding results sections.

SECTION 3

Results

The results and information presented in the following sections have been drawn from a variety of sources; some of which pertain to more than one species or species group. As such, results for this report were synthesized into species-specific sections to provide an integrated summary of existing conditions for the FMC area. These species, listed by species group, include:

- Ungulates (Including moose, caribou, and thinhorn sheep)
- Carnivores (Including grizzly bear and furbearer species)
- Avian species (Including waterfowl and waterbirds, passerines, raptors, and upland game birds)
- Small mammals and amphibians
- Invertebrates

3.1 Ungulates

3.1.1 Moose (*Alces alces*)

Moose are distributed across the Yukon and are most concentrated in the Faro region with average population densities among the highest in the territory (Clarke et al., 2012). Moose are ranked as secure in Canada (except in Nova Scotia where they are listed as threatened) by the National General Status Working Group (Canadian Endangered Species Conservation Council, 2011). Moose are an important prey species, and maintaining healthy populations is key to ensuring biological diversity. Moose are valued as a big game species and are relied upon by First Nation and Yukon residents for subsistence.

3.1.1.1 Existing Information

Yukon hunting regulations restrict the moose harvest to one bull per year per licensed hunter (EY, 2013a). EY implements a voluntary no-hunting request each year for GMS 4-42 to 4-46, in which hunters are requested to cease moose harvest once the allowable harvest quota for these areas has been reached. Portions of GMS 4-44, 4-45, 4-46, 4-47, and 4-51 occur within the RSA; however, GMS 4-51 is closed to all big game hunting. The western portion of GMS 4-45 can be accessed through the FMC main access road and consequently this GMS sees significant hunting pressure and subsequently high harvest rates as described in Section 3.1.1.3. below.

Moose harvest data provided by EY (2013b) indicates a total of 394 moose harvested in the last decade (2003 to 2012) from the GMS surrounding the FMC, including 4-41 to 4-47 and 4-51 (Table 6J-1; Figure 6J-3). GMS 4-45 had the highest harvest rate of moose for every year in the ten-year period, providing evidence for the hunting pressures occurring in that area. The EY data includes harvests from resident, non-resident (i.e., outfitter guided) and special guided[1] hunters and does not include First Nation harvest. Resident, non-resident, and special guided hunters harvested 80 percent (n= 313), 15 percent (n = 60), and 5 percent (n = 21), respectively, of all moose reported here.

TABLE 6J-1

Total Moose Harvest In Game Management Subzones Near the Faro Mine Complex

Faro Mine Remediation Project

GMS	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	GMS Total
4-41	3	1	5	4	6	1	4	4	3	4	35
4-42	5	6	7	4	2	5	2	2	0	1	34
4-43	1	2	0	0	2	1	3	1	1	0	11

[1] Non-resident hunts guided by a Yukon resident holding a valid big game hunting license.

TABLE 6J-1
Total Moose Harvest In Game Management Subzones Near the Faro Mine Complex
Faro Mine Remediation Project

GMS	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	GMS Total
4-44	1	3	3	2	2	0	0	1	1	2	15
4-45	20	16	24	36	12	21	27	23	26	15	220
4-46	6	6	7	3	5	9	2	7	1	4	50
4-47	2	4	4	3	4	4	1	0	1	4	27
4-51	0	0	1	0	0	0	1	0	0	0	2
Yearly Total	38	38	51	52	33	41	40	38	33	30	394

EY, 2013b, unpublished data.

Moose were the second most frequently observed species recorded in the FMC Incidental Wildlife Log, having 263 observation records of a total of 842 over the 5-year incidental wildlife reporting period (i.e., 2009 to 2013) (AAM, 2013, unpublished data). Seasonally, moose were observed in all months (except November) with the most observations occurring during the summer months. Over 70 percent of observations occurred in the Faro Mine Area, including areas in the vicinity of the parking lot and guardhouse, the Emergency Tailings Area (ETA), Cross Valley Dam (CVD) Pond, Intermediate Dam Pond (ID Pond), Rose Creek, Rose Creek Diversion (RCD), Faro Diversion area and generally in the Down Valley area. Approximately 15 percent of moose observations occurred in the Vangorda/Grum Area, including those in proximity to the Grum Pit, Vangorda Flume, Little Creek Dam and Vangorda Water Treatment Plant (WTP). The remaining 15 percent of observations of moose occurred on the Haul Road, with only a few recorded from along the Access Road. There are no moose WKAs in the FMC LSA or RSA; the nearest moose WKA lies in the Ross River valley 45 km^2 east of the Vangorda/Grum Area.

3.1.1.2 2011 Early Winter Regional Moose Survey

The early winter moose survey was conducted by EY in November 2011 and spanned across 10 GMS (Figure 6J-3). The survey covered an area of 6,470 km^2 from the Pelly River valley, northeast across the Anvil and South Fork mountain ranges to the Riddell River (Clarke et al., 2012), including the Town of Faro and the FMC. Moose were observed primarily in high elevation subalpine habitats in the Anvil and South Fork mountain ranges within the Mount Connolly and Mount Kulan areas. The intensive stratification component of the survey classified 405 survey blocks into those with a high expected moose density (n = 201) and those with a low expected moose density (n = 204). 30 percent (n = 127) of the total of 405 blocks were then randomly sampled to be included in the census component of the survey, and included 90 high strata and 37 low strata blocks (Clarke et al., 2012).

A total of 866 moose were observed during the census, including 522 cows (yearlings and adult cows combined), 210 adult bulls, 37 yearling bulls, and 97 calves. An average of 570 moose per every 1,000 km^2 were observed in high strata blocks, while an average of 80 moose per 1,000 km^2 were observed in the low strata blocks. Factoring in the SCF, Clarke et al. (2012) estimated that 12 percent and 4 percent of moose were missed from high and low strata blocks, respectively, while conducting the census survey. The total moose population within the Faro survey area was estimated to be 2,352 ±23 percent individuals and was lower than the 2004 estimate of 2,450 ±27 percent.

Clarke et al. (2012) estimate that the majority of the survey area (6,084 km^2) is considered to have high quality moose habitat, while the remaining 386 km^2 is characterized primarily by alpine habitats or large water bodies and is of limited value to moose. High moose densities in the survey area are believed to reflect the availability of high quality habitat. The average moose density was estimated at 364 moose per 1,000 km^2 of total area and 387 moose per 1,000 km^2 in suitable moose habitat (areas with shrubby browse, including subalpine and creek draws that offer willow browse)(Clarke et al., 2012). These densities exceed Yukon-wide averages of 157 and 209 moose per 1,000 km^2 in total and in suitable habitats, respectively, but were lower than the 2004 Faro area survey

densities of 379 moose per 1,000 km^2 of the total area surveyed and 403 moose per 1,000 km^2 in suitable moose habitat.

From the 2004 to 2011 surveys, the adult bull to cow ratio dropped from 53 adult bulls to every 100 cows to 42 bulls to every 100 cows in 2011. In both years; however, the ratio exceeded the Yukon average and the minimum management guideline of 30 adults bulls to every 100 adult cows. Calf survival (i.e., number of calves per 100 cows) increased from 19 in 2004 to 36 in 2011 and exceeded the Yukon average of 33, as well as the minimum management target for calf survival (i.e., 25 calves per 100 cows) to sustain a stable population. Recruitment (i.e., number of yearlings per 100 adult moose) was estimated at 10 and remained the same between the 2004 and 2011 survey events. Clarke et al. (2012) report that this recruitment value occurs within the management target of eight to 15 yearlings per 100 adult moose for ensuring a stable population increase over time.

Survey data analyzed for GMS 4-45 (which overlaps with the LSA) indicates that it has the highest average moose harvest rate of all the Yukon. Comparing the 2011 survey data with data collected in 2004 and 1997, the moose population within GMS 4-45 has declined at an annual rate of 2 percent and a total of 28 percent since 1997. The 2011 data indicate the harvest rates may be exceeding the recommended 4 percent threshold for sustaining a healthy population. Management of the area moose population has relied on the voluntary harvest restriction program; however, as quotas have been reached or exceeded in recent years, it has not been an effective management tool to limit additional moose harvest.

3.1.1.3 2012 Winter Tracking Survey

Moose were the only ungulate detected in the LSA during the 2012 winter tracking survey (ELR, 2012). Moose tracks were detected at an overall density of 0.04 TKD on active transects, and were detected incidentally (i.e., observed on transect but were older tracks of unknown age) throughout the site. The overall moose track density recorded was lower than expected for the site as suitable habitats occur within the FMC, and incidental observations were recorded across nearly all habitats types found in the LSA. The result was also lower than those of comparable studies. For example, an overall track density for moose of 0.16 TKD was recorded at the Ketza River Mine site, which is located approximately 90 km southeast of the FMC (EBA Engineering Consultants Ltd. [EBA], 2008). Several factors may have attributed to the low observed moose track density at the FMC at the time of the survey, including sub-optimal late-winter conditions such as a deep snow pack, or simply a sampling effect of the short duration of tracking surveys.

At the FMC, recent moose tracks were only detected in riparian shrub and mixed wood habitats at the time of the study, while incidental observations were more widespread (as noted above). Incidental observations from the site suggested that the majority of moose habitat use is centred around riparian areas of Rose Creek and other riparian draws.

3.1.2 Thinhorn Sheep (*Ovis dalli*)

Two subspecies of thinhorn sheep occur in the Yukon, Dall's (*Ovis dalli dalli*) and Stone's (*Ovis dalli stonei*), although southern Yukon is the northern extent for the latter. Sheep occurring in the FMC area are referred to as 'fannin', have an intermediate pelage colour between the darker Stone's sheep and the lighter Dall's sheep, and may be the result of crossbreeding (Worley et al., 2004). Fannin sheep are reported to range only in the Pelly and Ogilvie mountains. Neither Stone's nor Dall's sheep have been listed by COSEWIC.

3.1.2.1 Existing Information

Yukon hunting regulations restrict the harvest of sheep to a single full curl ram and in most of the RSA GMS harvest is managed by lottery (i.e., permit hunt authorization). EY compiles harvest information for thinhorn sheep.

Thinhorn sheep harvest data provided by EY (2013b) for five GMS surrounding the FMC (including 4-41 to 4-45) indicates a total of 56 individual sheep have been harvested in the last decade (2003 to 2012) (Table 6J-2). There were no sheep harvested from GMS 4-46, 4-47, and 4-51 during this period. GMS 4-45 had the highest number of sheep harvested overall (i.e., pooled years) followed by 4-44 and 4-41. The sheep harvest data represents

harvests by licensed resident and non-resident hunters; the harvest data does not include First Nation sheep harvest. Resident and non-resident hunters harvested 37.5 percent (n = 21) and 62.5 percent (n = 35), respectively, of all sheep reported here.

TABLE 6J-2
Total Sheep Harvest In Game Management Subzones Near the Faro Mine Complex
Faro Mine Remediation Project

GMS	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	GMS Total
4-41	0	0	1	0	0	2	3	2	2	4	14
4-42	1	0	0	0	0	0	0	0	0	0	1
4-43	0	0	2	0	0	0	0	1	0	2	5
4-44	0	0	0	2	4	0	1	0	1	3	11
4-45	1	2	2	7	1	2	4	1	2	3	25
4-46	0	0	0	0	0	0	0	0	0	0	0
4-47	0	0	0	0	0	0	0	0	0	0	0
4-51	0	0	0	0	0	0	0	0	0	0	0
Year Total	2	2	5	9	5	4	8	4	5	12	56

EY, 2013b, unpublished data.

Fannin sheep have been observed in the FMC in all months from May to November (AAM, 2013, unpublished data). Observation data pooled across the 5-year period from 2009 to 2013 includes observations in May (n = 495), June (n = 522), and September (n = 518) in all five years. Sheep were less frequently observed in July (n = 18), August (n = 37), October (n = 106), and November (n = 1) and were not consistently observed in all of these months in all five years. The majority of these sightings were concentrated in the Vangorda/Grum Area. Several sheep were incidentally observed during the waterfowl surveys conducted by ELR in September 2013. A large group of rams, ewes, yearlings, and lambs were observed resting at the base of the remediated slopes below the Grum Sulphide Cell. In addition, several sheep were observed along the north wall of the Grum Pit; they were variably observed to be resting or licking the exposed minerals along the north wall.

Thirty-one thinhorn sheep WKAs occur within the RSA, indicating that there are important habitats for the thinhorn sheep population in the area. The WKAs include mineral licks, seasonal ranges, and migration corridors (Figure 6J-4). Of these, four occur within the immediate FMC LSA, including portions of three migration corridors that traverse the FMC site between Mount Mye and Rose Mountain. Additionally, a portion of one winter range extends down from a southern slope of Mount Mye into the LSA.

3.1.2.2 2008 Thinhorn Sheep Summary

A total of 1,427 individual sheep locations were digitized from archived data observations that had been compiled from three sources that documented sheep occurrences over an 18-year period (1981 to 1999; Gartner Lee 2008b). Of these, rams (n = 327), ewes (n = 765), yearlings (n = 26), lambs (n = 199), and unclassified individuals (n = 110) were observed. Most observations were recorded during the summer months with few recorded during the fall and winter. The majority of individuals were observed on Mount Mye, Sheep Mountain, and Rose Mountain, with some individuals observed on Mount Kulan and the Yukon Plateau; mountain locations are indicated in Figure 6J-5. The sheep were observed to be concentrated primarily on Sheep Mountain during spring months, and were dispersed across on Mount Mye and Rose Mountain during the summer. During the fall months, sheep were observed moving along migration routes from Mount Mye to Sheep Mountain. Although few observations were recorded during the winter months, sheep were again observed to be dispersed on Mount Mye and Rose and Sheep Mountains, as well as lower elevations in these areas.

Gartner Lee Limited (2008b) reported that during the YG telemetry program, a total of nine ewes were collared and monitored during a 7-month period from November 1989 to May 1999. A total of 118 telemetry locations were collected among the nine animals during this time and only five ewes were collared and monitored for the full 7-month period. One ewe was collared and monitored only during the winter months and the remaining four ewes were collared and monitored only in the spring months. Telemetry locations for all individuals during the winter and spring months were clumped on the southern slopes of Sheep Mountain. During spring months, locations for two ewes were recorded on the western slopes on Sheep Mountain, followed by movement to higher elevations during the lambing season.

Gartner Lee Limited (2008b) synthesized data from all archived data sources to summarize seasonal range use by thinhorn sheep in the Faro area. Data indicate that while ewes, yearlings, and lambs spent winter months in groups on the south slopes of Sheep Mountain, rams were observed on the western slopes indicating these areas are important winter range. From their wintering and early spring areas on the lower slopes of Sheep Mountain, ewes were observed to move to higher elevations to lamb. During summer months, all age classes were observed to disperse to more general habitats including areas of Mount Mye, Rose Mountain, Blind Creek and Swim Lakes, Sheep Mountain, and the FMC. Observations recorded during rutting season were very limited and rams were only observed during this period on Sheep Mountain.

One additional sheep winter range occurs on the southern slopes of Mount Mye within 1 km of Grum Pit. Additional wintering areas were also identified but do not fall within the LSA; these include Blind and Swim Lakes, Pelly River Bluff, Rose Mountain, and areas along Vangorda Creek.

3.1.2.3 2011 Anvil Range Lambing Survey

During the lambing survey in June, a total of 192 sheep were observed in five mountain blocks in GMS 4-41, 4-45 and 4-46 (EY, 2011, unpublished data) (Figure 6J-5); the latter two of which overlap the northern boundary of the LSA. Of the total number of sheep observed, 12 percent were lambs (n = 23), 10 percent were ewes (n = 20), 12 percent were rams (n = 23) and 66 percent were unclassified (i.e., unknown sex) adults (n = 126). As a result of the large proportion of unclassified individuals during the June survey, EY was not able to calculate sex ratios (2011, unpublished data). Furthermore, due to survey conditions that likely resulted in missed observations, it was not possible to compare lamb data between the two surveys to determine lamb survival during their first month of life.

During the post-lambing survey conducted in July of 2011, EY surveyed eight GMS (4-17, 4-41, 4-43 to 4-46, 4-48, and 4-51) (Figure 6J-5). Combined productivity was estimated to be 27 lambs per 100 nursery sheep for all surveyed GMS, which suggests a stable population (EY, 2011, unpublished data). The combined ram to ewe ratio was estimated at 61 rams per 100 nursery sheep. EY (2011, unpublished data) cautions that while the observed proportion of rams is higher than average for a hunted population, that hunting pressures have increased in the area, particularly in GMS 4-45, because of an increase in access. EY (2011, unpublished data) reports that the primary management concern for the surveyed population at this time is an increase in mineral exploration activities in the area.

Although there were no observations of sheep in the FMC during the 2011 survey, there was a report of a nursery group observed along the Grum Pit edge in early June. It was suggested that these sheep may have been en route from their winter to summer range along a migration corridor between Sheep Mountain and Mount Mye (EY, 2011, unpublished data).

3.1.3 Caribou (*Rangifer tarandus caribou*)

The annual ranges of four woodland caribou (Northern Mountain population; *Rangifer tarandus caribou*) herds, occur in the Faro region and include the Tay River, Finlayson, Moose Lake, and Pelly herds (EY, 2012). Only the annual range of the Tay River caribou herd overlaps the project RSA. The Tay River herd annual range extends from the Pelly River in the south to the upper Stewart River in the north, east to the Ross River and west to Moose Lake. The Tay River herd overlaps with the Moose Lake caribou herd in the west, shares a boundary with the Pelly herd in the south and roughly meets the western extent of the Finlayson herd in the Ross River valley. Caribou observed within the FMC LSA therefore most likely belong to the Tay River herd, with limited potential for

observing individuals from the Pelly herds (Alain Fontaine, Liard Area Regional Biologist, personal communication). There are no caribou WKAs within the project LSA or RSA.

All woodland caribou of the Northern Mountain population are ranked by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and are listed under Schedule 1 of SARA as a species of special concern. Caribou are traditionally hunted for food and have a high local value for both First Nations and Yukon residents. EY hunting regulations limit licensed hunters to one bull caribou per year in the Faro region; however, GMS 4-51 is closed to all big game hunting (EY, 2013a). A Department of Renewable Resources report stated that the annual harvest from the Tay River herd was estimated to be approximately 1 percent of the population in 1996 and was considered to be a sustainable amount at that time (Gartner Lee Limited, 2008a).

3.1.3.1 Existing Information

Caribou have infrequently been observed in the FMC according to the FMC Incidental Wildlife Log records (AAM, 2013, unpublished data). Over the five years of wildlife reporting, there have been 13 recorded caribou observations onsite. Observations have occurred in the months of May, June, or July only, in 2010 (n = 1), 2011 (n = 4), 2012 (n = 6) and 2013 (n = 2). Caribou were observed in several locations including on the haul road, near Rose Creek, in the area of the Faro diversion, near the Grum Dump meteorological station, and near the ETA.

EY (2013b) provided caribou harvest data for GMS in the FMC RSA for the 10-year period from 2003 to 2012 (Table 6J-3). During this period, 119 caribou were harvested from GMS 4-41 to 47; however, no caribou were harvested from GMS 4-51. When considering 2003 to 2012 data, caribou harvest was highest in GMS 4-45 (n = 83), and next highest in GMS 4-46 (n = 19). The majority (72 percent) of all caribou were harvested between 2005 and 2009, with notably lower harvest number in recent years. The EY data includes harvests from resident, non-resident (i.e., outfitter guided), and special guided hunters and does not include First Nation harvest. Resident, non-resident, and special guided hunters harvested 75 percent (n = 89), 19 percent (n = 23), and 6 percent (n = 7), respectively, of all caribou reported here.

TABLE 6J-3
Total Caribou Harvest In Game Management Subzones Near the Faro Mine Complex
Faro Mine Remediation Project

GMS	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	GMS Total
4-41	0	0	1	0	1	2	0	0	2	0	6
4-42	1	0	2	1	0	1	1	1	0	0	7
4-43	0	0	0	0	0	0	1	0	0	0	1
4-44	0	0	1	0	1	0	0	0	0	0	2
4-45	5	7	13	11	7	10	19	4	3	4	83
4-46	3	2	0	5	2	1	4	1	1	0	19
4-47	0	0	0	0	0	1	0	0	0	0	1
4-51	0	0	0	0	0	0	0	0	0	0	0
Year Total	9	9	17	17	11	15	25	6	6	4	119

EY, 2013b, unpublished data.

3.2 Carnivores

Several carnivore species occur in the FMC area and are discussed according to species group or family below. Although both grizzly and black bears are known to occur in the area, only grizzly bears are discussed here to due to their conservation status and the ecological and socio-economic value of the species. Furbearer information is summarized according to mustelid, canid, and felid family groups. Although considered a furbearer, red squirrels are discussed with small mammals in Section 3.4.

3.2.1 Grizzly Bear (*Ursus arctos*)

Grizzly bear (*Ursus arctos*) are often considered to be a keystone species and referred to as ecological indicators, as they are critical components to ensuring ecosystem diversity and integrity. Grizzly bears range across the entire territory, with the exception of the southwestern limit of the Yukon (which is characterized by the largely uninhabitable Icefield Ranges of the St. Elias Mountain Range). The western population of grizzly bears is listed by COSEWIC as a species of special concern but currently has no protection status under SARA.

Resource development activities are a limiting factor for grizzly bears and can result in habitat loss or fragmentation and an increased potential for mortalities due to human-bear encounters. In addition to this, the species has a naturally low, reproductive rate reproducing once every six to seven years. EY is making efforts to reduce female grizzly bear harvest numbers to reduce the impact of removing reproductive females from the population. Hunting regulations restrict bag limits to one bear every three license years (EY, 2013a). There are spring and fall hunts in the Faro area GMS, but GMS 4-51 (i.e., spans the Pelly River valley immediately to the southwest of the Town of Faro) is currently closed to all big game hunting (Figure 6J-6).

3.2.1.1 Existing Information

EY (2013) provided Grizzly bear harvest data for GMS in the FMC area for the ten-year period from 2003 to 2012 (Table 6J-4). During this time, a total of 13 grizzly bears were harvested across GMSs 4-41 to 4-47 and 4-51 inclusive, ranging from 0 to 2 bears in any one year within individual GMSs. No Grizzly bear harvests were recorded for GMS 4-43 or 4-46, and no Grizzly bear harvests were recorded for any GMS in 2007, 2008, and 2010. When considering all 10 years, GMS 4-45 had the highest number of grizzly bear harvests (n = 4) among the data provided.

TABLE 6J-4
Total Grizzly Bear Harvest In Game Management Subzones Near the Faro Mine Complex
Faro Mine Remediation Project

GMS	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	GMS Total
4-41	1	0	0	0	0	0	0	0	1	0	2
4-42	0	0	1	1	0	0	1	0	0	0	3
4-43	0	0	0	0	0	0	0	0	0	0	0
4-44	0	0	0	0	0	0	0	0	2	0	2
4-45	1	1	0	0	0	0	1	0	0	1	4
4-46	0	0	0	0	0	0	0	0	0	0	0
4-47	0	0	0	0	0	0	0	0	0	1	1
4-51	0	0	0	1	0	0	0	0	0	0	1
Year Total	2	1	1	2	0	0	2	0	3	2	13

EY, 2013b, unpublished data.

The FMC Incidental Wildlife Log indicates a total of 60 grizzly bear sightings occurred from May 2009 to July 2013 (AAM, 2013; unpublished data). This is likely an underestimate, as bear sightings were classified in the records as either grizzly bear (n = 60), black bear (n = 58) or bear (n = 37). Thus, the 'bear' category would likely include bears of either species. Pooled for all years, grizzly bear sightings occurred during the period of April to October, with the most observations recorded each May (n = 21), followed by June (n = 17). Furthermore, grizzly bears were consistently observed during the month of May in all five years of observation records while the timing of sightings was not consistent across observation years. Of the 60 grizzly bear records, four observations were of sows with either one, two or three cubs, accounting for a total of 12 of the individual observation records. Approximately half of the grizzly bear observations occurred in the Faro Mine Area, including areas in proximity to the CVD and CVD Pond, RCD, ID Pond, Rose Creek Tailings Area and the Faro Pit and Diversion. A third of the

grizzly bear observations occurred in the Vangorda/Grum Area, including areas in the vicinity of the Grum Pit, Grum Sulphide Cell, Vangorda Flume and Sheep Pad Ponds (SPP). The remaining 20 percent of observations occurred along or near the Haul Road.

For comparison, black bear sightings were also the most abundant (n = 22) during the month of May, which was the only month during which sightings occurred during all five years of record. June (n = 11) and July (n = 12) were the next most common for black bear observations. While there was only one observation of a black bear sow with two cubs, there were another six sightings of a bear sow 'with two cubs' (n = 6) and 'with cubs' (n=9). Black bear and bear sightings occurred equally frequently, with approximately one third of observations occurring in each of the Faro Mine Area, Vangorda/Grum Area, and the area in between these (including the Haul Road, mine Access Road, and the Freshwater Dam area). Faro Mine Area sighting locations included the parking lot and guardhouse area, as well as areas in the vicinity of Rose Creek and the RCD, ID Pond, Rose Creek Tailings Area, ETA, S-Wells and Sludge Cells, as well as generally in the Down Valley area. In the Vangorda/Grum Area, observations were made near the SPP, Little Creek Dam, Grum Pit, Grum Sulphide Cell, Grum Haul Road, Vangorda Pit, and Vangorda WTP Sludge Pond.

The immediate project footprint has limited habitat that is suitable for grizzly bear life requisites due to the disturbed nature of most areas; however, reclaimed areas that support grass species growth, surrounding woodlands and shrubby subalpine hillsides likely provide vegetation species for foraging (e.g., berry-producing shrubs such as *Hedysarum* sp.) as well as potential prey items (e.g., ungulates and arctic ground squirrels).

3.2.2 Furbearers

Many furbearing species are common to the Yukon and include American marten (*Martes americana*), ermine (short-tailed weasel; *Mustela erminea*), mink (*Mustela vison*), fisher (*Pekania pennanti*), wolverine (*Gulo gulo*), otter (*Lontra canadensis*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), Canada lynx (*Lynx canadensis*), red squirrel (*Tamiasciurus hudsonicus*), as well as grey wolf (*Canis lupus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and arctic fox (*Vulpes lagopus*) (EY, 2013c). Among these species, COSEWIC has indicated that the Canada lynx is not at risk. The wolverine is listed as special concern by COSEWIC although is not currently listed under SARA; the wolverine is believed to be stable within the Yukon (Yukon Conservation Data Centre, 2011). The remaining species listed here have not been assessed by COSEWIC.

Trapper harvest of furbearers is an important economic activity in much of the Yukon. The FMC falls within a large group trapping concession that is approximately 35,400 km^2 in size.

The 2012 winter tracking survey provided local data set describing the presence and abundance of furbearers within the LSA (ELR, 2012). During this study, a total distance of 35.28 km was surveyed along tracking transects (Figure 6J-6), resulting in a total survey effort of 77.3 km days. Winter track study results for furbearers is presented below according to species and FMC Wildlife Incidental Log data is included where furbearing species data exists.

3.2.2.1 Mustelids

Five mustelid species were detected during the 2012 winter tracking survey (Table 6J-5). American marten and ermine were the most commonly detected mustelids, while one set of fisher tracks were observed. Mustelid species were detected in all functional habitat types occurring on the FMC but were highest in habitats having a conifer species component (i.e., mixed, pine, or conifer). The fewest mustelid detections were recorded in non-riparian shrub, deciduous and footprint habitat types (Table 6J-6).

TABLE 6J-5
Mustelid Species Observed During the March 2012 Faro Mine Track Survey
Faro Mine Remediation Project

Name	Latin Name	Detected on Track Transect	Incidental Winter Observation
Fisher	Martes pennanti	✓	✓
American Marten	Martes americana	✓	✓
Least Weasel	Mustela nivalis		✓
Ermine	Mustela erminea	✓	✓
Mink	Mustela vison	✓	

TABLE 6J-6
Mustelid Species Track Detection Densities (TKD) Organized by Functional Habitat Groupings as Observed During the 2012 Faro Mine Winter Track Study
Faro Mine Remediation Project

Functional Habitat Grouping	American Marten	Ermine	Fisher	Mink
Non-Riparian Shrub	0.33	0	0	0
Riparian Shrub	0.22	0.54	0	0
Graminoid/Sedge	0.58	0.29	0	0
Deciduous	0.42	0	0	0
Mixed	1.30	0.43	0	0.09
Pine	3.06	0.19	0	0
Conifer	0.87	1.24	0.05	0
Footprint	0.13	0.45	0	0

American Marten

A total of 60 marten observations were made during the 2012 winter tracking survey, with an overall track density of 0.77 TKD within the LSA (ELR, 2012). Marten were detected on active track transects in all habitat types within the LSA, with the highest density recorded in pine forest at 3.06 TKD. The next highest densities were recorded in mixed forest and mature conifer (i.e., spruce) at 1.30 and 0.87 TKD, respectively. While marten are reliant on complex habitats, mature forest cover, and a suitable prey base, they are sometimes generalist in nature. FMC observations across all habitats are likely the product of complex habitat, thermal and snow cover, and an abundance of prey items such as red squirrel and grouse.

Five marten observations were recorded in the FMC Incidental Wildlife Log (AAM, 2013, unpublished data). Observations were recorded near the gatehouse, the Down Valley Lower Gate, and the Faro Creek Diversion, and also on the haul road.

Fisher

Putative fisher tracks were detected once on active track transects (in conifer forest), resulting in an overall average track abundance of 0.01 TKD during the 2012 winter tracking survey (ELR, 2012). Three putative incidental observations of fisher tracks were also recorded in white spruce/willow and footprint habitats; they were identified primarily in mature conifer habitats (0.05 TKD) within the study area. Distinguishing fisher tracks from marten

tracks can be difficult; as there is an overlap in trail size between mature male marten and female fisher (there is a track width overlap between the species from approximately 3.5 inches wide to 4.25 inches wide). Track patterns tend to differ between the species, with fisher alternating between two, three, and four track patterns frequently, while marten tend to primarily use a two track bounding pattern. During the 2012 study, a combination of track size and pattern was used for identification; however tracks that could not be positively identified as fisher were classed as marten (if in the intermediate track width range). The identification of fisher tracks at the FMC is of interest, as this location is outside of the current known range of fisher in the Yukon Territory (Jung and Slough, 2011).

Fisher generally occur in mature forests with dense canopies and a high level of habitat complexity. Their detection in the LSA could suggest the presence of quality habitat (i.e., for reproductive denning) and a suitable abundance of prey items (also supported by the current study results). Fishers are also specialist predators on porcupine, which were detected in several habitats within the LSA.

Wolverine

While wolverines are expected to occur in the LSA, no signs of wolverine presence or activity were observed during the 2012 tracking survey (ELR, 2012). Wolverines have very large home ranges that can range from 100 to 500 km^2, and therefore the absence of track observations does not exclude their presence in or use of the LSA. Due to this large home range size, ground tracking surveys are not well suited to determining wolverine presence or density.

Over the 5-year record, two wolverine sightings were recorded in the FMC Incidental Wildlife Log (AAM, 2013, unpublished data). One individual was spotted along the haul road in June 2011 and the second individual was observed at the back of the mill in June 2012.

Ermine, least weasel and mink

Ermine (also known as short-tailed weasel) were detected during the 2012 winter track study on active track transects in six of the eight primary habitats, with the highest density being in coniferous forest at 1.24 TKD (ELR, 2012). The habitat type with the next highest density of ermine tracks was riparian shrub, with 0.54 TKD. Ermine were observed incidentally (i.e., observed during the study but not while on active tracking transects) ten times including a visual observation. Incidental observations were primarily made in white spruce/willow and non-riparian shrub habitats. Ermine were detected in six of the eight LSA habitat associations, with highest densities being in mature conifer and riparian shrub habitats and an overall track density for the site of 0.59 TKD. This figure again suggests the presence of suitable habitat and abundant prey species in the area.

Least weasel was detected only once as an incidental observation, in willow/dwarf birch shrub habitat.

Mink were detected only once on an active track transect and once incidentally, both occurring in mixed forest (Table 6J-6). The overall average track density recorded for mink was 0.01 TKD.

3.2.2.2 Canids

Grey wolf, coyote, and red fox were all detected during the 2012 winter tracking survey at low densities (ELR, 2012). Grey wolves were detected only once on an active track transect and four times as incidental observations. Collectively, these detections occurred in coniferous forest, in footprint areas, on the mine access road near the Vangorda Pit, and near the Grum waste rock piles. Grey wolves are known to utilize roads and linear corridors for movement through the landscape, and this behavior was observed at the Faro Mine site (tracks observed along the main haul road); however, wolf tracks were also observed in forested stands with pine and mature white spruce.

Neither foxes nor coyotes were detected on regular transects during the tracking survey. Coyotes were only detected four times as incidental observations; three times amongst waste rock piles near the mill site, and once near the prior freshwater reservoir. Red fox were only detected twice as incidental observations and both observations were made amongst the waste rock piles near the mill site. A low level of detection for these species was expected based on the level of tracking effort at the site. Incidental observations, primarily near disturbance areas, show that they are using the LSA area, although their movements and habitat use may be closely tied to

the existing footprint infrastructure. Coyotes and foxes are generalist feeders, and are likely taking advantage of prey species such as ptarmigan that were observed to be concentrated in areas of disturbance.

Wolf and fox sightings were the most common records among furbearer species in the FMC Incidental records. Of a total of 142 furbearer observations, 64 were wolf and 47 were fox observations (AAM, 2013, unpublished data). Wolves were observed in all months except February, but records were variable across the 5-year period. Red fox sightings occurred between February and November, and were variable among years. Both wolf and fox observations were from a range of locations at the FMC, including the haul and main access road, the pits and ponds, in the parking lot at the guard house, and in the Rose Creek diversion area. These furbearer species were the most commonly sighted but they are also the most conspicuous. Additionally, several observations occurred within a short period of time from each other suggesting multiple sightings of the same individual or individuals.

3.2.2.3 Felids

Four incidental Canada lynx observations were recorded during the 2012 winter tracking survey, however no detections were recorded on active track transects (ELR, 2012). Lynx tracks were observed in willow/dwarf birch, willow/white spruce, white spruce/willow, and footprint habitats. The incidental detections suggest that lynx are using the LSA area but at a relatively low density. Conversely, detections of hare tracks were relatively high, and suitable habitat was observed within the LSA area. During the 5-year period of FMC Incidental Wildlife reporting, lynx were observed four times; once in 2009 and three times in 2010.

3.3 Avian Species

Many areas surrounding the Town of Faro and the FMC offer suitable habitats for a wide range of avian species, including waterfowl, shorebirds, songbirds, upland game birds and raptors. EY (2003) estimates that approximately 160 avian species occur in the Faro and Ross River area out of the 279 species known to occur in the Yukon. CWS and USGS bird database queries produced a pooled list of 28 water bird and 39 land bird species (Tables 6J-6 and 6J-7, respectively) that have been observed in the Faro area (potentially within the FMC RSA). The most commonly observed species included white-winged crossbill, dark-eyed junco, common raven, Swainson's thrush, hermit thrush, gray jay and American robin. Lesser yellow legs and sandhill crane were also commonly sighted.

A total of 10 waterfowl species were observed during the 2013 waterfowl survey (Table 6J-7; ELR, 2013). Gartner Lee Limited (2008a) reported incidentally observing gulls near the tailings pond and as well as a Harlan's hawk (a dark morph of a red-tailed hawk; *Buteo jamaicensis harlani*) while conducting a vegetation classification study in 2007. Also incidentally observed during this study was a bank swallow colony, located along an exposed road cut on the access road to the CVD Pond water pump station. The FMC Incidental Wildlife Log records included several avian observations including bald eagle, swan, snowy owl, grouse, ptarmigan, common raven and sandhill crane (AAM, 2013, unpublished data).

Migratory species are protected under the *Migratory Birds Convention Act* and there are provisions in the Yukon *Wildlife Act* for non-migratory species; specifically Section 17 of the latter refers to the protection of non-migratory species eggs and nests. Four species observed onsite are considered to be of conservation concern:

- Bank swallow (*Riparia riparia*) - Threatened (COSEWIC)
- Harlequin duck (*Histrionicus histrionicus*) - Special Concern (COSEWIC and SARA Schedule 1)
- Horned grebe (*Podiceps auritus*)- Special Concern (COSEWIC)
- Trumpeter swan (*Cygnus buccinator*) - Specially Protected (Yukon *Wildlife Act*)

The olive-sided flycatcher (*Contopus cooperi*) has not been specifically observed onsite but has been recorded as occurring in the Faro area. It is listed by COSEWIC as a threatened species and is listed under Schedule 1 of SARA. The olive-sided flycatcher is associated with open areas containing or adjacent to mixed or coniferous mature forest with snags or tall live trees (COSEWIC, 2007). Open areas can include natural or anthropomorphic clearings, often near or adjacent to wetland areas. Tall trees are used for perching and coniferous trees are used for nesting.

Six avian species were observed during the winter tracking surveys conducted in March 2012, and included detections (i.e., signs or sightings) of common raven, boreal chickadee, common redpoll, gray jay, ptarmigan and

grouse (ELR, 2012). Ptarmigan and grouse were the second most abundant species group detected during the 2012 winter tracking survey, and were found among five of the eight primary FMC habitat types. Ptarmigan and grouse track density was highest in non-riparian shrub habitat at 10.56 TKD. Disturbance areas, mixed, and conifer forest habitats also had moderately high densities of 3.82, 2.43, and 2.25 TKD, respectively. Incidental observations were also made, including many visual observations. The majority of incidentals were observed in non-riparian shrub and footprint areas. Overall, 235 ptarmigan and grouse observations were made during the study (some of which were groups of several individuals), with the overall average density of tracks on transects being 3.00 TKD.

TABLE 6J-7
Waterbird Species Potentially Present or Previously Observed in the Faro Area
Faro Mine Remediation Project

Species	Scientific Name	Potentially Present [a]	Observed in Area [b]	Confirmed in LSA [c]	Conservation Status
American coot	Fulica americana	✓			Not at risk (COSEWIC)
American wigeon	Anas americana	✓		●	Not assessed
Arctic tern	Sterna paradisaea	✓			Not assessed
Barrow's goldeneye	Bucephala islandica	✓		●	Not assessed
Blue-winged teal	Anas discors	✓			Not assessed
Bonaparte's gull	Larus philadelphia	✓			Not assessed
Bufflehead	Bucephala albeola	✓			Not assessed
Common goldeneye	Bucephala clangula			●	Not assessed
Common loon	Gavia immer	✓			Not at risk (COSEWIC)
Glaucous gull	Larus glaucescens	✓			Not assessed
Green-winged teal	Anas crecca	✓			Not assessed
Harlequin	Histrionicus histrionicus			●	Special Concern (SARA Schedule 1)
Herring gull	Larus argentatus	✓		●	Not assessed
Hooded merganser	Lophodytes cucullatus	✓			Not assessed
Horned grebe	Podiceps auritus	✓		●	Special Concern (COSEWIC)
Lesser scaup	Aythya affinis	✓			Not assessed
Lesser yellowlegs	Tringa flavipes	✓			Not assessed
Mallard	Anas platyrhynchos	✓			Not assessed
Mew gull	Larus canus	✓	✓		Not assessed
Northern pintail	Anas acuta	✓			Not assessed
Northern shoveler	Anas clypeata	✓			Not assessed
Pacific loon	Gavia pacifica	✓			Not assessed
Red-breasted merganser	Mergus serrator			●	Not assessed
Redhead	Aythya americana	✓			Not assessed
Ring-necked duck	Aythya collaris	✓			Not assessed
Ruddy duck	Oxyura jamaicensis	✓			Not assessed
Sandhill crane	Grus canadensis	✓		●	Not assessed

TABLE 6J-7
Waterbird Species Potentially Present or Previously Observed in the Faro Area
Faro Mine Remediation Project

Species	Scientific Name	Potentially Present [a]	Observed in Area [b]	Confirmed in LSA[c]	Conservation Status
Semipalmated plover	Charadrius semipalmatus	✓			Not assessed
Solitary sandpiper	Tringa solitaria		✓		Not assessed
Sora	Porzana carolina	✓			Not assessed
Spotted sandpiper	Actitis macularius	✓		●	Not assessed
Surf scoter	Melanitta perspicillata			●	Not assessed
Tundra swan	Cygnus columbianus	✓			Not assessed
Trumpeter swan	Cygnus buccinator			★	Specially Protected (Yukon *Wildlife Act*)
Wilson's snipe	Gallinago delicata		✓		Not assessed

[a] CWS, 2007

[b] USGS, 2013

[c] ● ELR, 2013; ❄ ELR, 2012; ★Incidental Sighting (AAM, 2013, unpublished data or Gartner Lee Limited, 2008a).

TABLE 6J-8
Land Bird Species Potentially Present or Previously Observed in the Faro Area
Faro Mine Remediation Project

Species	Scientific Name	Potentially Present [a]	Observed in Area [b]	Confirmed in LSA	Conservation Status
Alder flycatcher	Empidonax alnorum	✓	✓		Not assessed
American pipit	Anthus rubescens	✓			Not assessed
American robin	Turdus migratorius	✓	✓		Not assessed
American three-toed woodpecker	Picoides dorsalis	✓			Not assessed
American tree sparrow	Spizella arborea	✓	✓		Not assessed
Bald eagle	Haliaeetus leucocephalus	✓		★	Not at risk (COSEWIC)
Bank swallow	Riparia riparia	✓		★	Threatened (COSEWIC)
Belted Kingfisher	Megaceryle alcyon	✓			Not assessed
Blackpoll Warbler	Setophaga striata		✓		Not assessed
Bohemian waxwing	Bombycilla garrulus	✓	✓		Not assessed
Boreal chickadee	Poecile hudsonica	✓	✓	❄	Not assessed
Chipping sparrow	Spizella passerina	✓	✓		Not assessed
Cliff swallow	Petrochelidon pyrrhonota	✓	✓		Not assessed
Common raven	Corvus corax	✓		❄ ●	Not assessed
Common redpoll	Acanthis flammea		✓	❄	Not assessed
Common yellowthroat	Geothlypis trichas	✓	✓		Not assessed
Dark-eyed junco	Junco hyemalis	✓	✓		Not assessed

TABLE 6J-8
Land Bird Species Potentially Present or Previously Observed in the Faro Area
Faro Mine Remediation Project

Species	Scientific Name	Potentially Present [a]	Observed in Area [b]	Confirmed in LSA	Conservation Status
Fox sparrow	Passerella iliaca		✓		Not assessed
Golden eagle	Aquila chrysaetos	✓			Not at risk (COSEWIC)
Gray jay	Perisoreus canadensis	✓	✓	❄ ●	Not assessed
Gray-cheeked thrush	Catharus minimus	✓	✓		Not assessed
Gray-crowned rosy finch	Leucosticte tephrocotis	✓			Not assessed
Great grey owl	Strix nebulosa	✓			Not at risk (COSEWIC)
Great horned owl	Bubo virginianus	✓			Not assessed
Hermit thrush	Catharus guttatus	✓	✓		Not assessed
Lapland longspur	Calcarius lapponicus	✓			Not assessed
Lesser yellowlegs	Tringa flavipes		✓		Not assessed
Lincoln's sparrow	Melospiza lincolnii	✓	✓		Not assessed
Northern flicker	Colaptes auratus	✓	✓		Not assessed
Northern shrike	Lanius excubitor	✓			Not assessed
Northern waterthrush	Seiurus noveboracensis	✓			Not assessed
Olive-sided flycatcher	Contopus cooperi		✓		Threatened (SARA Schedule 1)
Orange-crowned warbler	Oreothlypis celata		✓		Not assessed
Red-tailed hawk	Buteo jamaicensis		✓		Not at risk (COSEWIC)
Red-winged blackbird	Agelaius phoeniceus	✓	✓		Not assessed
Ruby-crowned kinglet	Regulus calendula	✓	✓		Not assessed
Rusty blackbird	Euphagus carolinus	✓			Special concern (SARA Schedule 1)
Savannah sparrow	Passerculus sandwichensis	✓			Not assessed
Snowy owl	Bubo scandiaca			★	Not at risk (COSEWIC)
Swainson's thrush	Catharus ustulatus	✓	✓		Not assessed
Tennessee warbler	Oreothlypis peregrina		✓		Not assessed
Townsend's solitaire	Myadestes townsendi	✓			Not assessed
Tree swallow	Tachycineta bicolor	✓			Not assessed
Violet-green swallow	Tachycineta thalassina	✓			Not assessed
Wilson's warbler	Cardellina pusilla		✓		Not assessed
White-crowned sparrow	Zonotrichia leucophrys	✓	✓		Not assessed
White-winged crossbill	Loxia leucoptera	✓	✓		Not assessed
Yellow warbler	Dendroica petechia	✓			Not assessed
Yellow-bellied flycatcher	Empidonax flaviventris		✓		Not assessed

TABLE 6J-8
Land Bird Species Potentially Present or Previously Observed in the Faro Area
Faro Mine Remediation Project

Species	Scientific Name	Potentially Present [a]	Observed in Area [b]	Confirmed in LSA	Conservation Status
Yellow-rumped warbler	Setophaga coronata	✓			Not assessed

[a] CWS, 2007

[b] USGS 2013

[c] ● ELR, 2013; ❄ ELR, 2012; ★Incidental Sighting (AAM, 2013, unpublished data or Gartner Lee Limited, 2008a).

3.3.1 Waterfowl Observational Survey Results

A total of 60 person hours of observation time was spent at the FMC pits and ponds during September of 2013 (ELR, 2013, unpublished data). During this time, observers recorded a number of sightings of waterfowl using the various pits and ponds. In summary, a total of 40 individuals representing nine species were observed at the 11 sites during the fall survey period (Table 6J-8). The type and number of species observed are summarized in Table 6J-8. The locations of the assessed sites and waterfowl observations in the Faro Mine and Vangorda/Grum Areas are provided in Figure 6J-7a and Figure 6J-7b, respectively. All species observed were in their non-breeding plumage, and were observed diving, foraging, dabbling, drinking and resting in the various habitats in the FMC.

TABLE 6J-9
Waterfowl Observations for Faro Mine Pits and Ponds
Faro Mine Remediation Project

Pond/Pit Name	Species Observed (Common Name)	Species Observed (Common Name)	Number	Comments
Intermediate Dam (ID) Pond	American wigeon	Anas americana	3	Drinking and preening.
Sheep Pad Ponds (SPP)	Common goldeneye	Bucephala clangula	2	Actively diving and foraging.
	Harlequin duck	Histrionicus histrionicus	4	Actively diving and foraging.
Slot Cut in Grum Pit	Spotted sandpiper	Actitis macularius	1	Actively foraging along muddy shore.
Ponded Water on Tailings Facility	Herring gull	Larus smithsonianus	6	Observed to be preening in wetted area.
Cross Valley Pond	Harlequin duck	Histrionicus histrionicus	1	Observed diving, foraging near pump at southeast corner of pond.
Slot Cut in Grum Pit	Harlequin duck	Histrionicus histrionicus	4	Same birds as from SPP, observed diving and foraging.
Faro Pit	Red-breasted merganser	Mergus serrator	5	Resting on water.
	Horned grebe	Podiceps auritus	5	
	Surf scoter	Melanitta perspicillata	9	
	Barrow's goldeneye	Bucephala islandica	4	

3.3.2 Waterfowl Habitat Assessment

3.3.2.1 Habitat Descriptions

Habitat structure was considered at each pit and pond as it relates to value for waterfowl. As each of the assessed pits and ponds have been altered or constructed for the purposes of water holding and treatment for mine operation, their respective structures and vegetation composition were found to reflect this heavily altered state.

Well-established vegetation was observed at the RCD, Slot Cut in Grum Pit, and SPP. Ponds in the North Fork of Rose Creek below the access road are largely naturalized, with significant riparian vegetation, aquatic vegetation including algae, horsetails, various shrubs and forbs along the shores. The diversion reach is armoured with large rip-rap, creating a straight channel, though some pooling is created above the diversion reach where remnants of the original channel are present. Numerous patches of horsetail, willow and various grasses and sedges were observed at Slot Cut in Grum Pit. In addition, some willow has established in the riparian areas, as have some moss species along the coarse slope material.

Areas of grass, sedge and some emergent and aquatic vegetation were observed along the shores of the CVD Pond and Grum Settling Pond. Both ponds are constructed with armoured sidewalls that drop steeply into the pond (i.e., Grum Settling Pond) or gradually slope into the water (i.e., CVD Pond). Where silt and sediment have entered GSP from the adjacent Vangorda WTP Sludge Pond, the accumulation of fine material has allowed the establishment of some grasses and sedges. Riparian vegetation is sparse in the CVD Pond, but there are patches of emergent and aquatic vegetation where the gently sloping shores support mud and silt substrate allowing common horsetail (*Equisetum arvense*), milfoil (*Myriophyllum sp.*) and a variety of grasses and sedges to become established.

Limited vegetation establishment was observed at the remaining ponds, including the ID Pond, the Faro, Grum and Vangorda Pits, the Slot Cut in Grum Pit and the Little Creek Pond (LCP). The ID Pond is highly contaminated, preventing the successful establishment of any aquatic vegetation and allowing only limited riparian vegetation. Vegetation that is able to grow around the perimeter shows significant signs of stress. Faro, Grum, and Vangorda Pits were not sampled, as it was assumed for the purpose of this study that the depth of the pits would prevent contact with any sediment on pit bottoms. These pits were created as a by-product of mining extraction and their steep walls prevent vegetation establishment.

The Vangorda Water Treatment Plant (WTP) Sludge Pond is a constructed feature used for the storage of treated water from the Vangorda/Grum Area. This pond is heavily altered annually with the complete draining and dredging of sludge preventing the establishment of any riparian or aquatic vegetation. The LCP receives water from the Vangorda Waste Rock Dump and significant blackened vegetation exists around the entire perimeter of the pond. No aquatic vegetation exists, and the sparse horsetails present above the water line appear highly stressed.

3.3.2.2 Benthic Invertebrates

Based on preliminary invertebrate data available at the time of this report, benthic invertebrate diversity was markedly different between the ponds, and appears to relate to the degree of local disturbance. No invertebrates were found in the sediments from the ID Pond and LCP. Sampling results from the CVD Pond and the Grum Settling Pond yielded relatively low abundance and diversity when compared to what would be expected in natural unaffected wetlands. Samples from the SPP and the Slot Cut in Grum Pit did yield relatively higher abundance of invertebrates relative to the other sites sampled in the FMC, but still significantly lower in abundance compared to that which would be expected in an unaffected wetland or pond habitat.

3.3.3 Results of Metals Analyses

3.3.3.1 Sediment

Metals levels in sediment samples collected in the FMC Ponds in 2013 were compared to CCME Sediment Quality Guidelines for the Protection of Aquatic Life (CCME, 1995; ISQG and PEL, as described in Section 2.4.1, above). A summary of data for seven key metals (copper, chromium, cadmium, mercury, lead, arsenic, and zinc) is provided in Table 6J-9, including a comparison of metals levels with CCME guidelines. Bold text indicates those results that exceed the ISQG, while shaded results indicate that the detected level also exceeded the PEL.

Sediment samples from each of the ponds sampled exceeded the CCME ISQG or PEL sediment guideline levels for at least one metal. Sediment from the CVD Pond exceeded the ISQG limits for cadmium, chromium, copper, and mercury, and exceeded the PEL for lead, arsenic, and zinc. Sediment from the LCP exceeded the ISQG for chromium, cadmium and pH, the PEL for lead, arsenic, and zinc. Sediment from the ID Pond exceeded the PEL for copper, mercury, lead, arsenic and zinc, and exceeded the ISQG for pH. Sediment from the SPP exceeded the PEL

for lead, arsenic and zinc; and exceeded the ISQG for mercury and cadmium. Sediment from the Grum Settling Pond exceeded the ISQG for cadmium, lead, arsenic, and zinc. Sediment from the Slot Cut in Grum Pit exceeded the ISQG for lead, zinc and cadmium, and the PEL for arsenic. While not exceeded, chromium levels in the Slot Cut in Grum Pit were measured to be 36.4 milligrams per kilogram (mg/kg), with the ISQG being 37.3 mg/kg.

TABLE 6J-10
Results of Benthic Sediment Total Metals Analysis [a]
Faro Mine Remediation Project

	Detected Levels (mg/kg)									CCME Guideline Levels	
Element	CVD Pond 1	CVD Pond 2	CVD Pond 3	LCP	ID Pond 1	ID Pond 2	SPP	Grum Settling Pond	Slot Cut in Grum Pit	ISQG (mg/kg)	PEL (mg/kg)
Cu	46.8	48.8	106	33.8	381	276	35.4	31.7	28.0	35.7	197
Cr	82.4	48.0	22.4	57.6	35.6	22.5	34.1	24.4	36.4	37.3	90
Cd	0.539	2.2	0.969	1.14	0.479	0.374	2.59	1.22	0.650	0.6	3.5
Hg	<0.050	0.123	0.211	0.089	4.41	5.34	0.186	0.054	0.078	0.17	0.48
Pb	45.7	159	565	121	3,940	2,830	137	45.3	50.8	35	91.3
As	22.9	26.6	34.6	31.6	764	589	20.9	11.9	21.2	5.9	17
Zn	307	2,640	1,340	1,690	1,980	1,550	653	204	176	123	315
pH	8.18	8.05	7.79	3.20	2.90	2.94	8.18	7.870	8.35	7.0 – 9.0[a]	-

[a] Results in bold text indicate that the detected level exceeds the ISQG, and shaded results indicate that the detected level also exceeded the PEL.

[b] The pH range has been taken from the Water Quality Guidelines for the Protection of Aquatic Life as no guidelines for pH currently exist for sediment levels.

3.3.3.2 Vegetation

A summary of metals levels in aquatic and riparian vegetation collected at FMC ponds in 2013 is provided in Table 6J-10. Metal levels in the vegetation tissue samples were compared to sediment metals levels from the same pond to assess whether accumulation in aquatic and riparian plants may be occurring. Results where vegetation metals concentrations exceeded corresponding sediment metals levels are shaded in the table.

Copper and chromium levels were found to be elevated at the LCP. Elevated levels of cadmium were detected in vegetation from the CVD Pond, LCP, ID Pond, SPP, and Slot Cut in Grum Pit. Elevated levels of mercury in vegetation were only detected from the third sample location in the CVD Pond. Elevated lead concentrations in vegetation samples were detected at CVD Pond, ID Pond, LCP and SPP. Arsenic vegetation levels were elevated in samples from the CVD Pond, LCP, ID Pond, and the SPP. Zinc concentrations were elevated in vegetation samples from all ponds except the Grum Settling Pond and the Slot Cut in Grum Pit.

TABLE 6J-11
Results of Vegetation Total Metals Analysis [a]
Faro Mine Remediation Project

	Detected Levels (mg/kg)									
Element	CVD Pond 1	CVD Pond 2	CVD Pond 3	CVD Pond 4	LCP	ID Pond 1	ID Pond 2	SPP	Grum Settling Pond	Slot Cut in Grum Pit
Cu	41.6	24.2	90.1	28.5	54.1	52.5	133	22.8	17.0	7.54

	Detected Levels (mg/kg)									
Element	**CVD Pond 1**	**CVD Pond 2**	**CVD Pond 3**	**CVD Pond 4**	**LCP**	**ID Pond 1**	**ID Pond 2**	**SPP**	**Grum Settling Pond**	**Slot Cut in Grum Pit**
Cr	64.5	32.5	24.1	16.1	38.3	33.0	23.3	17.3	4.33	6.49
Cd	0.893	1.66	0.864	1.68	8.78	4.07	8.53	3.43	1.01	0.701
Hg	0.035	0.044	0.289	0.046	0.071	0.151	0.570	0.075	0.010	0.021
Pb	59.8	69.1	606	63.0	107	326	632	168	6.89	4.73
As	13.0	13.8	34.0	9.23	25.2	23.3	84.4	29.9	2.02	3.05
Zn	580	1,460	856	646	5,950	2,010	1,600	784	75.8	127
Zone Sampled	Littoral Riparian	Benthic Littoral	Littoral Benthic Riparian	Littoral Benthic	Riparian	Riparian	Riparian	Littoral Benthic Riparian	Riparian	Littoral Riparian
Vegetation Type Sampled	Milfoil Horsetail Willow	Milfoil Pond-weed Horsetail	Pond-weed Grass Willow	Pond-weed Milfoil Horsetail	Willow Horsetail	Willow Horsetail	Willow Horsetail	Pond-weed Grass Willow	Willow Sedge	Grass Willow Horsetail

[a] Shaded results indicate instances where the concentration of a particular metal in aquatic or riparian vegetation exceeded that of sediment in the same pond or area.

3.3.3.3 Habitat Potential

Based on an assessment of waterfowl observations at the studied pits and ponds of the FMC, five of the FMC ponds were considered to have stop-over and feeding potential (CVD Pond, Pumphouse Pond, Grum Settling Pond, Slot Cut in Grum Pit, and SPP). Six other pits and ponds were considered to likely only provide stop-over potential (ID Pond, Faro Pit, Grum Pit, Vangorda WTP Sludge Pond, Vangorda Pit, and LCP). Habitat characteristics and habitat potential for each pit and pond studied is provided in Table 6J-11, while a summary of habitat data, metals information and habitat potential for the pits and ponds studied is provided in Table 6J-12.

TABLE 6J-12
Summary of Habitat Characteristics and Habitat Potential for FMC Pit and Ponds Assessed During the 2013 Waterfowl Study
Faro Mine Remediation Project

Name	Habitat Characteristics	Suitability and Potential
Faro Pit	Water accumulation resulting from ore extraction. No riparian, aquatic or emergent vegetation. Steep slopes and hard rock banks.	**Stop-over**: open water provides suitable stop-over habitats for migrating waterfowl. No opportunities for foraging identified.
Grum Pit	Water accumulation resulting from ore extraction. No riparian, aquatic or emergent vegetation. Steep slopes and hard rock banks.	**Stop-over**: open water provides suitable stop-over habitats for migrating waterfowl. No opportunities for foraging identified.
Vangorda Pit	Water accumulation resulting from ore extraction. No riparian, aquatic or emergent vegetation. Steep slopes and hard rock banks.	**Stop-over**: open water provides suitable stop-over habitats for migrating waterfowl. No opportunities for foraging identified.
CVD Pond	Armoured sides, some deposition of sediment, steep slopes, emergent and aquatic vegetation, moderately developed riparian in isolated areas.	**Feeding/Stop-over**: some mud and sand areas, gently sloping allows easy access to emergent and aquatic vegetation by ducks and geese. Benthic invertebrates present.

TABLE 6J-12

Summary of Habitat Characteristics and Habitat Potential for FMC Pit and Ponds Assessed During the 2013 Waterfowl Study

Faro Mine Remediation Project

Name	Habitat Characteristics	Suitability and Potential
ID Pond	Sloping sides, minimal riparian area, minimal emergent or aquatic vegetation, water quality influenced by tailings and sludge.	**Feeding/Stop-over**: no aquatic vegetation is present and riparian vegetation is highly stressed, so offers limited foraging opportunities. Tailings sludge creates mud flat-like feature, potentially attracting migrating waterfowl.
Rose Creek and Rose Creek Diversion (Pumphouse Pond)	Natural watercourse with well-established riparian area in non-diverted channel areas, riffle-pool morphology, significant emergent and aquatic vegetation.	**Feeding/Stop-over**: well-established riparian, emergent and aquatic vegetation is this structurally diverse aquatic habitat.
Vangorda WTP Sludge Pond	Constructed pond used in collection of treated water. Pond water is drained each Fall, with accumulated sludge dredged and placed in a sludge storage facility. Steep sides and no aquatic vegetation exist. Riparian vegetation is heavily altered and managed in order to allow safe access and maintenance.	**Stop-over**: aquatic and riparian habitat is heavily modified through annual dredging of sludge from pond. No emergent or aquatic vegetation, benthic community poorly developed. Open treated water provides suitable stop-over habitat for migrating waterfowl.
Grum Settling Pond	Semi-natural dug-out pond receiving treated water from Vangorda WTP Sludge Pond. Riparian vegetation is poorly developed due to artificial nature of pond; however, emergent and aquatic vegetation present.	**Feeding/Stop-over**: benthic invertebrates present, some emergent vegetation becoming established. Open water suitable for stop-over of migrating waterfowl.
Slot Cut in Grum Pit	Resulting from waste rock piles, receiving runoff from Grum waste rock above. Shallow, muddy pond with significant emergent and aquatic vegetation to southeast end. Minimal riparian vegetation present due to disturbed nature of area.	**Feeding/Stop-over**: mud flat and open water with well-established emergent vegetation and benthic invertebrate communities provides potential habitat for resident or migratory waterfowl.
SPP	Water accumulation from small drainage collects in north pond, flows into south pond through above-ground metal culvert.	**Feeding/Stop-over**: significant riparian, emergent and aquatic vegetation with well-established benthic invertebrate community provides potential habitat for resident or migratory waterfowl.
LCP	Heavily contaminated resulting from runoff from Vangorda waste rock piles upslope. Blackened vegetation around perimeter and in path of runoff. Sparse riparian vegetation around perimeter.	**Stop-over**: no emergent or aquatic vegetation, and does not consistently hold water. Provides low-value habitat for migrating waterfowl and contaminant level likely contributes to lack of forage availability.

TABLE 6J-13
Summary of Observation Types, Sampling Conducted and Habitat Potential for Waterfowl at FMC Pits and Ponds Assessed During the 2013 Waterfowl Study
Faro Mine Remediation Project

					Elevated Metals		Habitat Potential	
Pond or Pit Name	Waterfowl Observations	Riparian Vegetation Observed [a]	Aquatic Vegetation [a]	Benthic Invertebrates [a]	Sediment/ Vegetation Sample Data [b]	Surface Water Data [c]	Feeding	Migratory Stop-over
CVD Pond	ELR, C&M	Yes	Present, Sampled	Present, Sampled	Yes	Yes	✓	✓
Grum Settling Pond	C&M	Yes	Present, Sampled	Present, Sampled	Yes	Yes	✓	✓
Slot Cut in Grum Pit	ELR, C&M	Yes	Present, Sampled	Present, Sampled	Yes	Yes	✓	✓
SPP	ELR, C&M	Yes	Present, Sampled	Present, Sampled	Yes	Yes	✓	✓
LCP	C&M	Yes	Not Present	Present, Sampled	Yes	Yes	-	✓
ID Pond	ELR, C&M	No	Not Present	Present, Sampled	Yes	Yes	-	✓
Pumphouse Pond	C&M	Yes	Likely Present [d]	Likely Present [d]	NA	Yes	✓	✓
Faro Pit	ELR, C&M	No	Likely Not Present [e]	Likely Not Present [e]	NA	Yes	-	✓
Grum Pit	C&M	No	Likely Not Present [e]	Likely Not Present [e]	NA	Yes	-	✓
Vangorda Pit	C&M	No	Likely Not Present [e]	Likely Not Present [e]	NA	Yes	-	✓
Vangorda WTP Sludge Pond	C&M	No	Likely Not Present [f]	Likely Not Present [f]	NA	Yes	-	✓

[a] Based on qualitative observations or field sampling, or both, by ELR field staff during field surveys in September 2013

[b] Based on analytical results from samples collected by ELR field staff during field surveys in September 2013

[c] Based on water quality sampling program data (C&M).

[d] Assumed to be present based on observations at site by ELR field staff during field surveys in September 2013.

[e] Not sampled; Assumed to be not present based on pit depth and composition of surrounding substrate (i.e., rock).

[f] Not sampled; Assumed to be not present due to annual dredging and composition of surrounding substrate (i.e., rock, gravel and sand).

3.4 Small Mammals

Small mammals are considered to be ecologically important as some species are considered furbearers (i.e., red squirrels) but most are prey species for land-based carnivores and raptors and support the basis for an ecosystem food web; small mammal species are defined accordingly within this report to include snowshoe hare and porcupine, in addition to species (e.g., small rodents, squirrels, and chipmunks) typically included within this group. Several small mammal species have been observed within the FMC LSA, none of which are listed by COSEWIC, and are discussed below.

A contaminant-related study that sampled from small mammal populations was conducted at the FMC between 2004 to 2005 and documented the presence of several small mammal species (Gartner Lee Limited, 2006). These species included northern red-backed vole (*Clethrionomys rutilus*), common shrew (*Sorex cinereus*), heather vole (*Phenacomys intermedius*), deer mouse (*Peromyscus maniculatus*), Siberian lemming (*Lemmus sibiricus helvolus*), and least chipmunk (*Tamias minimus*).

Both the 2012 winter tracking survey (ELR, 2012) and the FMC Incidental Wildlife Log (AAM, 2013, unpublished data) included observations (including signs or sightings) of snowshoe hare, porcupine, and red squirrel. Mice and vole sightings were also recorded in the log records. Small mammals (mice and voles) were detected in four of the eight primary habitat types during the winter tracking survey. They were most commonly observed in disturbance areas and in pine forest, with densities of 0.58 and 0.38 TKD, respectively. Small rodent tracks were also recorded twice during incidental observations, in non-riparian shrub and pine habitats.

The red squirrel was the most frequently detected species during the tracking survey, with an average track density of 6.15 TKD across all LSA habitats, and having particularly high densities in pine, mixed, deciduous, and riparian shrub habitats. Red squirrels generally have a preference for mature conifer forests (spruce and pine) as these habitats provide a more consistent supply of food (cones), thermal and visual cover, as well as a thick canopy for movement above ground. Their overall high population density is believed to be a factor of the abundance of pine forests within the LSA, and suggests that an excellent prey base is available for species groups such as raptors, mustelids, and canids.

The snowshoe hare was the third most abundant species group detected during the tracking survey with an overall average density of 2.90 TKD. Hare were detected most frequently in deciduous and pine forest habitats.

Four porcupine observations were made on active track transects, all of which were observed in non-riparian shrub, mixed, and coniferous forest habitats, with densities of 0.11, 0.09, and 0.09 TKD, respectively. Porcupine tracks were observed six times incidentally in non-riparian shrub, deciduous, riparian shrub, and pine habitats. Both tracks and feeding sign were observed.

3.5 Amphibians

Five species of amphibians are known to occur in the Yukon; however, based on the distribution of these species the wood frog (*Rana sylvatica*) is the only likely species to occur in the FMC area (EY, 2005). One wood frog was observed by a field crew in the Vangorda/Grum area while conducting a vegetation classification survey in July 2007 (Garner Lee Limited, 2008a). Wood frogs are not at risk at the territorial or federal level, and are not anticipated to be abundant at the FMC. There are no reptile species found within the Yukon (Canadian Amphibian and Reptile Conservation Network, 2012).

3.6 Invertebrates

One 'Species of Conservation Concern' polygon was found to occur within the FMC RSA using the YESAB Geolocator. The Yukon Conservation Data Centre results indicate that the polygon was established after a single specimen of a dragonfly species known as the Canada darner (*Aeshna canadensis*) was observed at this location. The Canada darner is ranked as critically imperiled in the Yukon by NatureServe (2013). The polygon is located in the Swim Lakes area, approximately 8.5 km east of the FMC LSA boundary. This species is ranked secure at the national level (NatureServe 2013) and is not listed by COSEWIC. Specimens of this species have not been observed in other habitats appropriate for the species elsewhere in southern Yukon (Randi Mulder, Yukon Conservation Data Centre; personal communication).

SECTION 4

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Figures



VICINITY MAP



LEGEND

Base Layers

- Major Road
- Watercourses
- Waterbodies
- Wetlands

Topographic Contours (30 m Interval)

- Boreal Zone (< 1450 masl)
- Subalpine Zone (1450 - 1550 masl)
- Alpine Zone (> 1550 masl)

Notes:

1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheets:105K3-105K6
4. Imagery provided by CH2M HILL Canada Ltd.
5. m - metres
6. masl - metres above sea level
7. National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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FIGURE 6J-1

Faro Mine Complex Location Overview Map

Faro Mine Remediation Project

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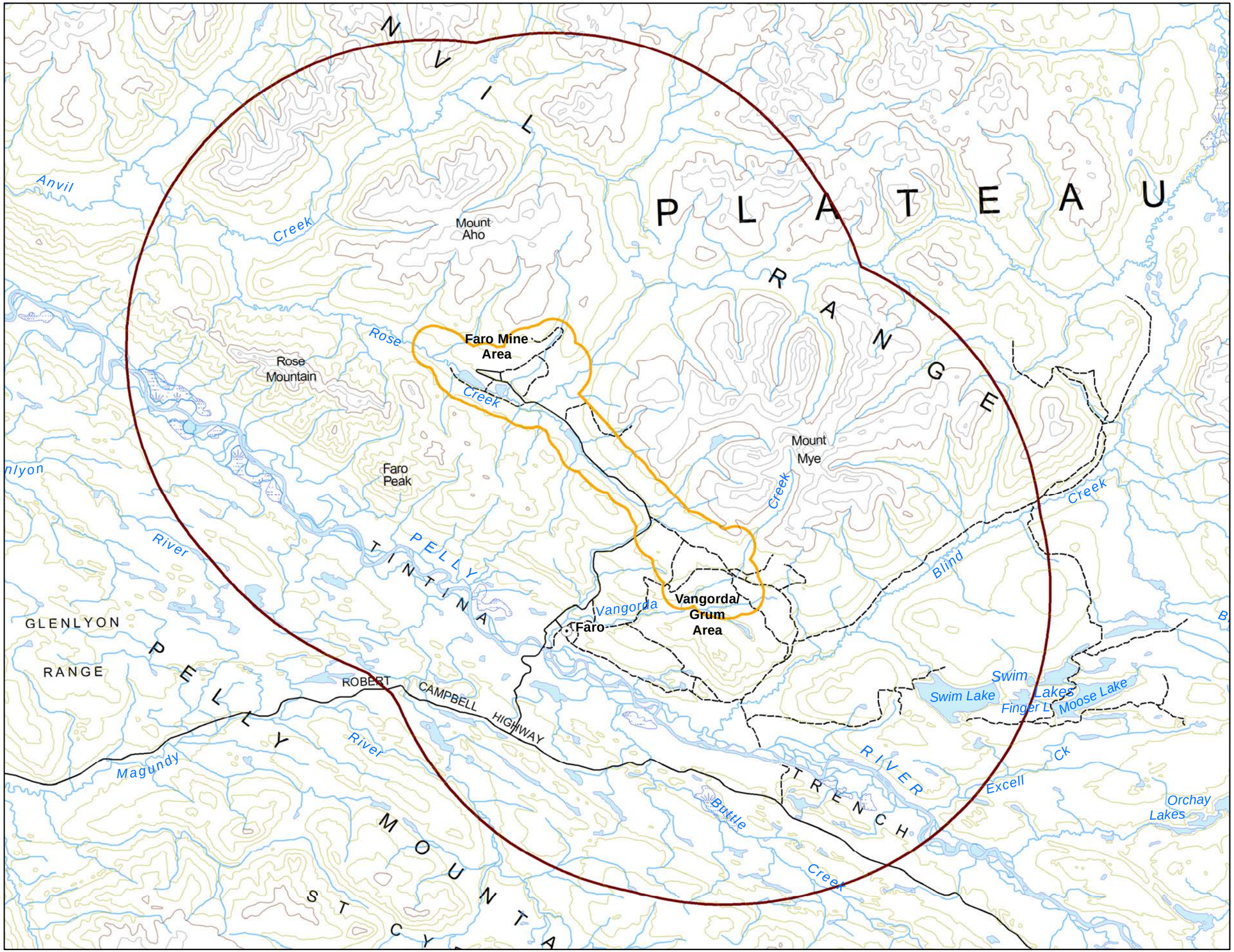

VICINITY MAP



LEGEND

Base Layers
- Major Road
- Limited Use Roads
- Watercourses
- Waterbodies
- Wetlands

Topographical Contours (150 m interval)
- Boreal Zone (< 1450 masl)
- Supalpine Zone (1450 - 1550 masl)
- Alpine Zone (> 1550 masl)

Project Layers
- Wildllife Local Study Area
- Wildlife Regional Study Area

Notes:
1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheet:105K
4. m - metres
5. masl - metres above sea level
6. National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:250,000. Cadastral data compiled by Natural Resources Canada. Reproduced under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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FIGURE 6J-2
Faro Mine Complex Wildlife Baseline Study Areas
Faro Mine Remediation Project

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VICINITY MAP



LEGEND

Base Layers

- Major Road
- Limited Use Roads
- Watercourses
- Waterbodies
- Game Management Subzones
- Moose WKA - Late Winter Range

Topographical Contours (150 m interval)

- Boreal Zone (< 1450 masl)
- Supalpine Zone (1450 - 1550 masl)
- Alpine Zone (> 1550 masl)

Project Layers

- Wildlife Local Study Area
- Late-Winter Moose Survey Area (Clarke et al., 2012)

Notes:

1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheet:105K and 105L
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5. masl - metres above sea level
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FIGURE 6J-3

2011 Early Winter Moose Survey Area

Faro Mine Remediation Project

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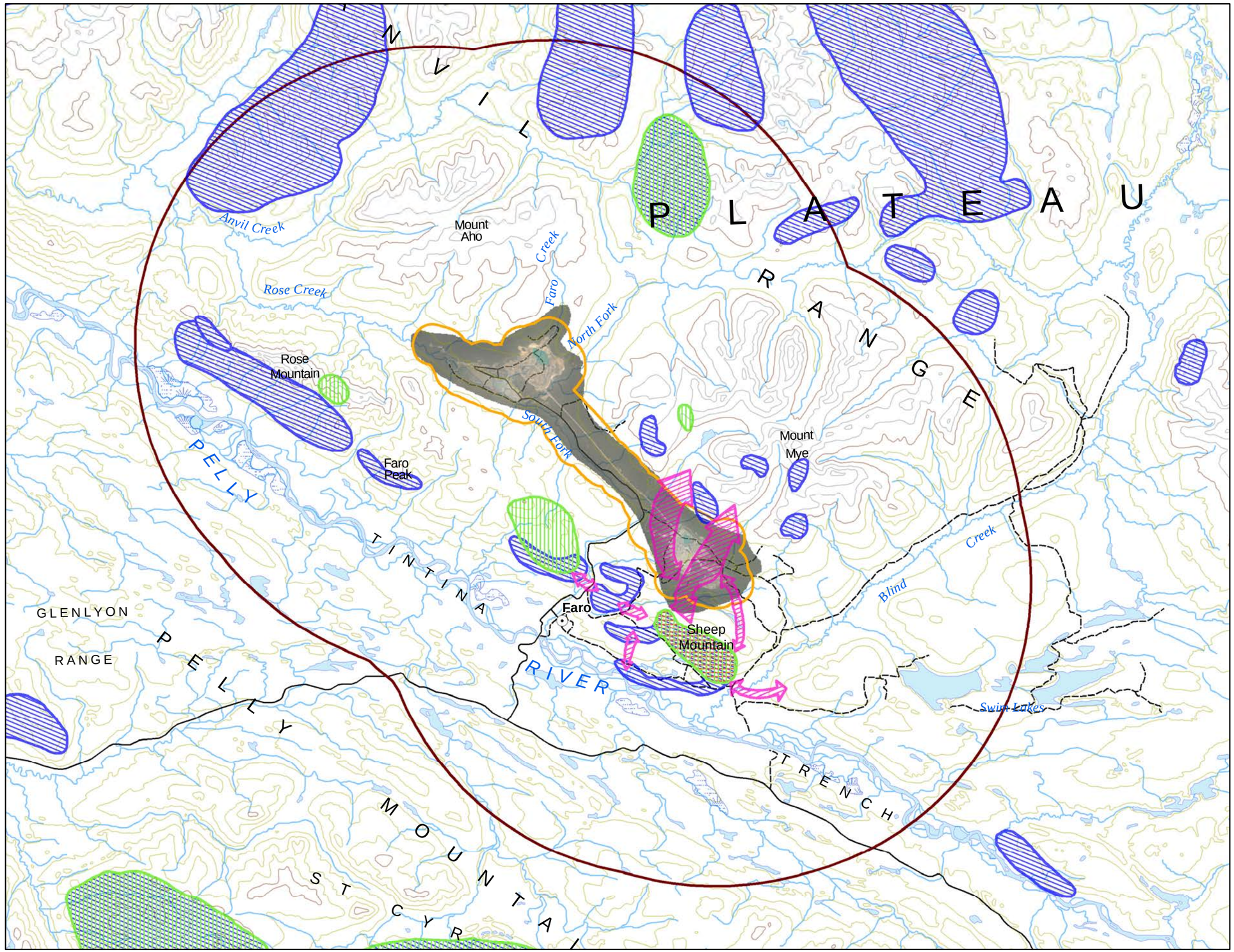
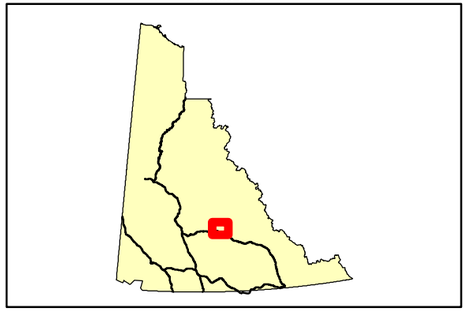


VICINITY MAP



LEGEND

Base Layers
- Major Road
- Limited Use Roads
- Watercourses
- Waterbodies

Topographical Contours (150 m interval)
- Boreal Zone (< 1450 masl)
- Supalpine Zone (1450 - 1550 masl)
- Alpine Zone (> 1550 masl)

Thinhorn Sheep Wildlife Key Areas
- Spring Lambing
- Early Winter Rut
- Winter Range
- Movement Corridor

Project Layers
- Wildlife Local Study Area
- Wildlife Regional Study Area

Notes:
1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheets:105K
4. m - metres
5. masl - metres above sea level
6. National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:250,000. Cadastral data compiled by Natural Resources Canada. Reproduced under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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FIGURE 6J-4
Thinhorn Sheep Wildlife Key Areas Occurring in the Faro Mine Complex Wildlife Regional Study Area
Faro Mine Remediation Project

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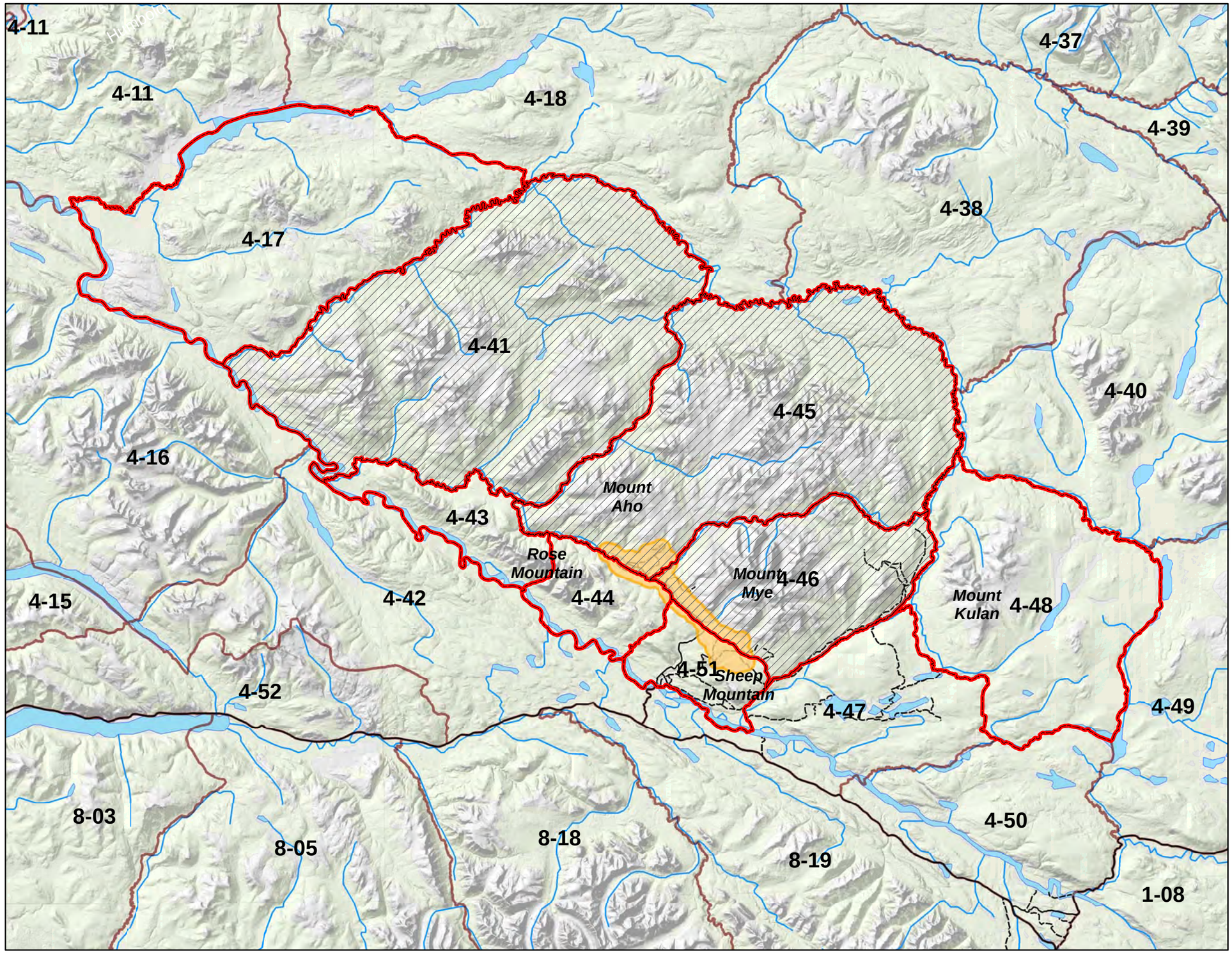

VICINITY MAP



LEGEND

Base Layers

- Major Road
- Limited Use Roads
- Watercourses
- Waterbodies
- Game Management Subzones

Project Layers

- Wildlife Local Study Area
- 2011 Lamb Survey Area - June (Environment Yukon, 2011)
- 2011 Lamb Survey Area - July (Environment Yukon, 2011)

Notes:

1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheet:105E, F, K, L
4. National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:1,000,000 (water data) and 1:250,000 (road data). Cadastral data compiled by Natural Resources Canada. Reproduced under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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FIGURE 6J-5

2011 Thinhorn Sheep Lambing Survey Area

Faro Mine Remediation Project

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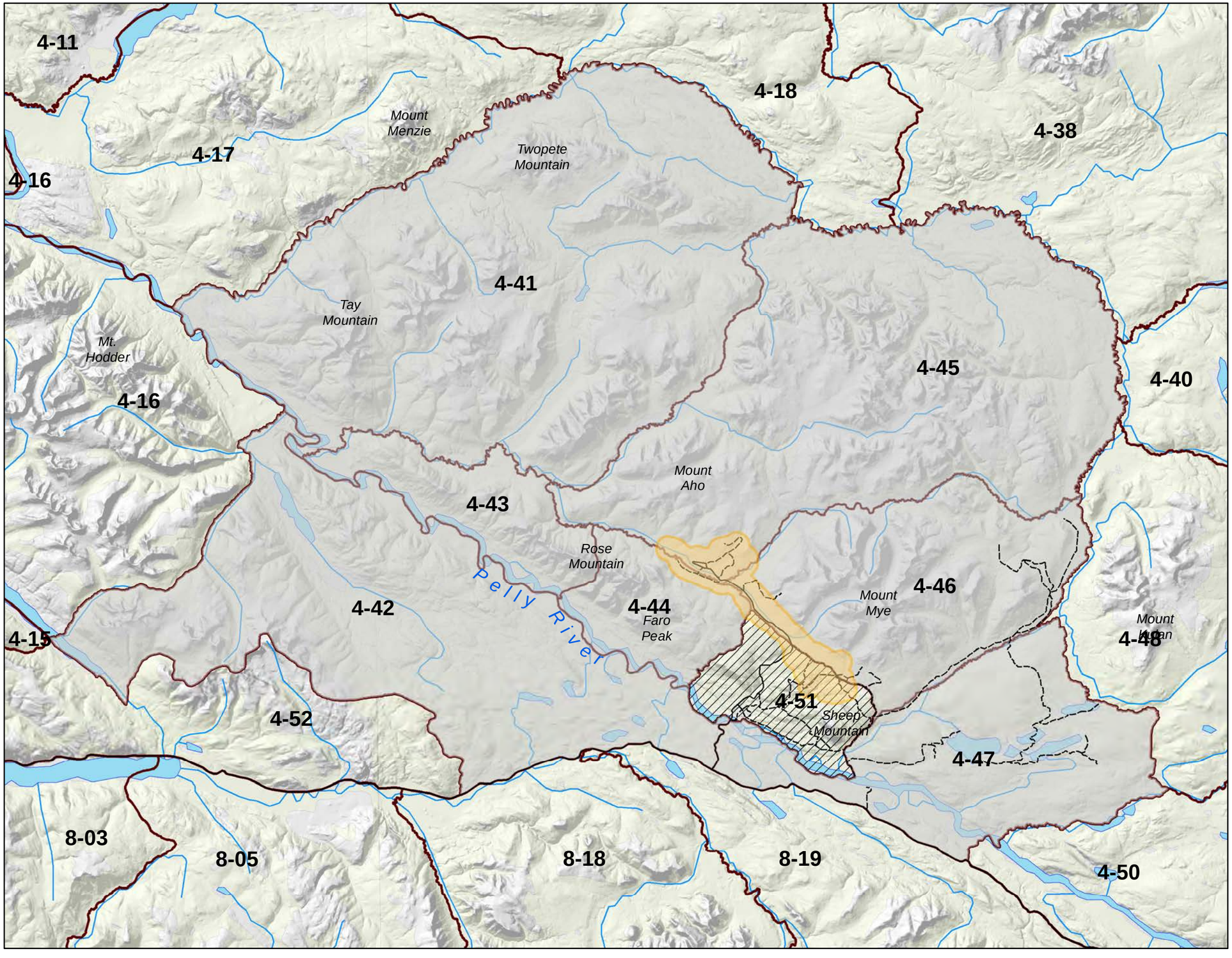

VICINITY MAP



LEGEND

Base Layers

- Major Road
- Limited Use Roads
- Watercourses
- Waterbodies

Project Layers

- Wildlife Local Study Area
- Game Management Subzones
- Extent of Harvest Data Provided
- Game Management Subzone Closed to Big Game Hunting

Notes:

1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheet:105E, F, K, L
4. National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:1,000,000 (water data) and 1:250,000 (road data). Cadastral data compiled by Natural Resources Canada. Reproduced under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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FIGURE 6J-6

Spatial Extent of Harvest Data Provided by Environment Yukon

Faro Mine Remediation Project

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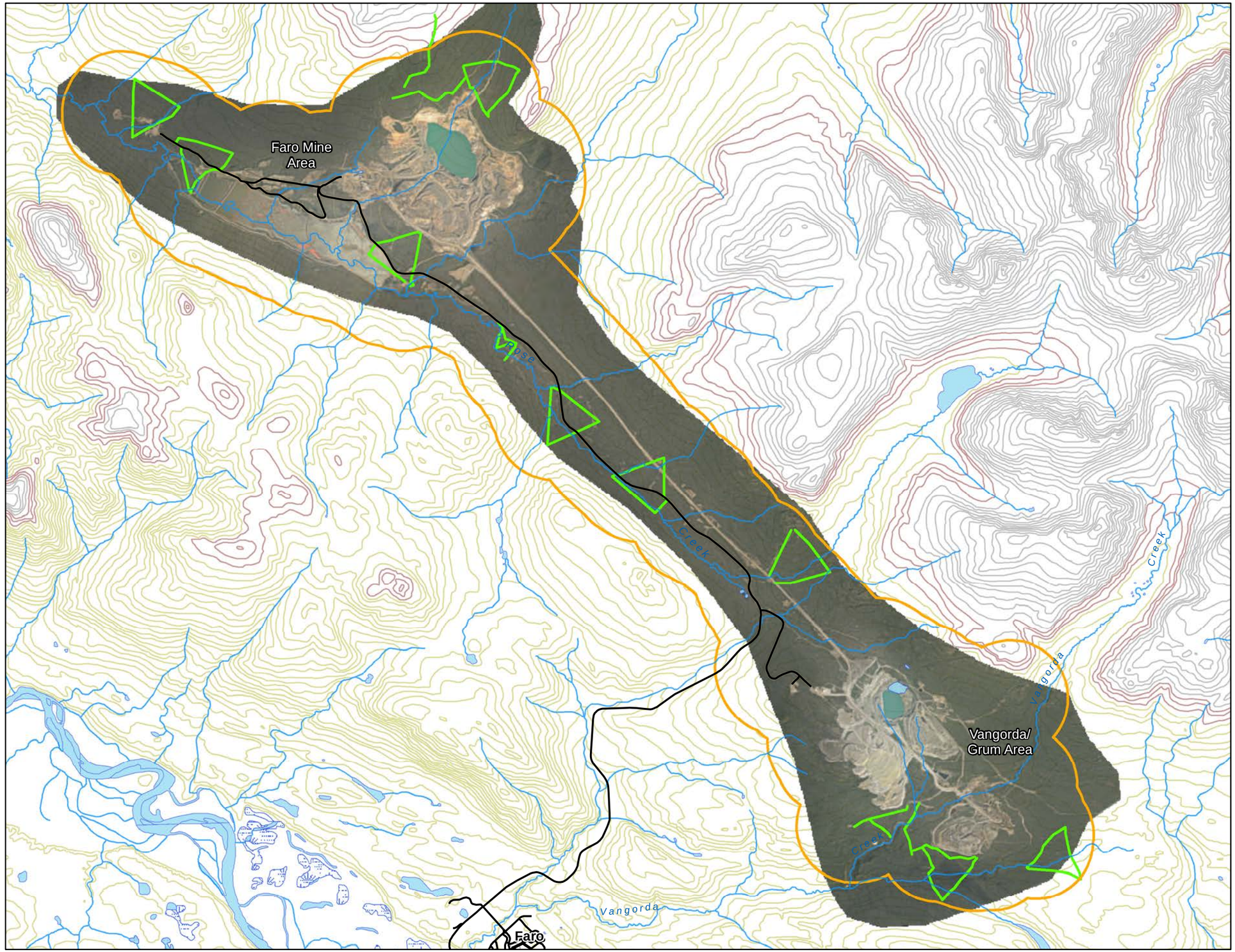

VICINITY MAP



LEGEND

Base Layers
- Major Road
- Watercourses
- Waterbodies
- Wetlands

Topographic Contours (30 m Interval)
- Boreal Zone (< 1450 masl)
- Supalpine Zone (1450 - 1550 masl)
- Alpine Zone (> 1550 masl)

Project Layers
- Winter Tracking Survey Transects
- Wildlife Local Study Area

Notes:
1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheets:105K3-105K6
4. Imagery provided by CH2M HILL Canada Ltd.
5. m - metres
6. masl - metres above sea level
7. National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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FIGURE 6J-7
Location of 2012 Winter Tracking Transects
Faro Mine Remediation Project

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VICINITY MAP



LEGEND

Project Layers

Waterfowl Observations

Assessed Sites

Notes:

1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheets:105K06
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Metres

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FIGURE 6J-8a

Waterfowl Survey Sites - Faro Mine Area

Faro Mine Remediation Project

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VICINITY MAP



LEGEND

Project Layers

- Waterfowl Observations
- Assessed Sites

Notes:

1. Projection: UTM Zone 8N
2. Horizontal Geodetic Datum: NAD 83 CSRS
3. NTS Mapsheets:105K06
4. National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada.

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Metres

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FIGURE 6J-8b

Waterfowl Survey Sites - Vangorda/Grum Area

Faro Mine Remediation Project

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Appendix 6K
Heritage Resource Impact Assessment of the Proposed Faro Mine Interim Works Proposed Borrow Areas (Ecofor)

ECOFOR
natural and cultural resource consultants

FINAL REPORT

Historic Resource Impact Assessment of the Proposed Faro Mine Interim Works Borrow Areas

(TO BE INCLUDED IN YESAA MATERIALS – NO SITE SENSITIVE DATA)

Permit 13-26ASR

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February 4, 2014

Historic Resource Impact Assessment of the Proposed Faro Mine Interim Works Borrow Areas

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ACKNOWLEDGMENTS

Ecofor Consulting Ltd. (Ecofor) prepared this report on behalf of the Government of Yukon, Energy Mines & Resources, Assessment and Abandoned Mines.

James Mooney and Kevin Wilson (Owner) would like to thank Assessment and Abandoned Mines for the opportunity to conduct this project and for providing us with assistance. We would also like to thank the Ross River Dena Council field participants Dean Bolton and Ashley "AJ" Charlie.

Finally, we would like to thank the Ecofor staff and the Ross River Dena Council for their high quality of work.

Ecofor is solely responsible for any errors evident in this report. The opinions and/or recommendations presented herein are ours and do not necessarily reflect those held by the Heritage Branch of the Yukon Government.

MANAGEMENT SUMMARY

Cultural resources staff of Ecofor Consulting Ltd., (Ecofor) completed the fieldwork for this project between September 24th and September 26th, 2013 on behalf of the Government of Yukon Energy, Mines and Resources, Assessment and Abandoned Mines (AAM). Field staff included James Mooney and Holly Smith from Ecofor Consulting Ltd., and Dean Bolton and Ashley "AJ" Charlie of the Ross River Dena Council. Previous heritage overview assessment work for the Faro Mine Complex was completed by Ecofor (Mooney and Smith 2012). The purpose of the current project was to assess potential impacts to heritage resources through reconnaissance survey and selected shovel testing across the proposed borrow areas.

Eight areas were proposed for ground disturbing impacts associated with the Faro Mine Interim Works. These areas had been previously identified in the overview assessment to possess potential for heritage resources. The current field team conducted the Heritage Resources Impact Assessment and found seven (7) areas assessed in the field to contain significant potential for buried heritage resources. Each of these areas was shovel tested. One of these areas contained an isolated prehistoric lithic surface find (KcTq-1), and three contained prehistoric lithic scatters (KcTq-2, KcTq-3, and KcTq-4). Site KcTq-2 contained two lithic materials which were collected from the first 10 cm of soil and most likely from above the White River ash layer (or Tephra) (WRT). Site KcTqu-3 contained two lithic materials in the top 10 cm of soil. Site KcTq-4 consisted of lithic materials found directly under the WRT, and may present the Little Arm Phase. These three sites were flagged with a 30 m buffer of yellow "No Work Zone" flagging tape. The location of the single surface isolated find was marked by a single strand of yellow "No Work Zone" flagging tape. A modern horse corral and cabin were identified and recorded. A single log privy was also identified and recorded. Two isolated game hanging racks were noted in and near the current borrow pit edges.

No further heritage resources work is recommended for site KcTq-1. Impacts to the remaining three lithic sites (KcTq-2, KcTq-3, and KcTq-4) are recommended to be avoided. If avoidance is not possible then data recovery work is recommended. Data recovery should include limited shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 6 square meters of excavation would be recommended for each site.

Impacts to the horse corral and cabin are recommended to be avoided. If the impacts to the horse corral and cabin cannot be avoided then consultation with owner(s) and/or trapline holder or big game outfitter is recommended. No further heritage resources work is recommended for the game hanging racks or the single log privy.

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1.0 INTRODUCTION

1.1 Scope of Project

The proposed ground disturbing impacts are associated with the Faro Interim Mine Works. This proposed project is located within the Faro Mine Complex which is located approximately 22 km north of the community of Faro and 360 km northeast of Whitehorse and is located within the traditional territory of the Ross River Dena Council (RRDC) and the Liard First Nation (LFN) which are both members of the Kaska Nation. This general project area is within N.T.S. map sheets 105K/6 and very near the boundary to 105K/5. The property is accessible by road from Faro.

The intent of the Faro Mine Remediation Project is to remediate the land that is currently disturbed by the mine site. There are basically two areas of previous open pit operations consisting of the Faro Mine Area and the Vangorda Plateau Area (which included the Vangorda Pit and the Grum Pit). There is also one large tailings area known as the Rose Creek Tailing Area.

The current project proposes to assess possible impacts to heritage resources associated with eight areas proposed as borrow source locations, or proposed to have ground disturbing impacts. Impacts to heritage resources could include ground disturbances such as earth moving, borrow pit operations and disturbance of the area.

No previous heritage impact assessment fieldwork was conducted within this area however a heritage resources overview assessment was conducted for the larger project area in 2012 (Mooney and Smith 2012). Due to the relatively small size of the project the current fieldwork was completed in September 24th to 26th, 2013. The project incorporated First Nation participant throughout the fieldwork. The study areas of the past overview assessment and the current impact assessment are shown in Figure 1.

1.2 Personnel

Field crews consisted of Ecofor employees James Mooney and Holly Smith with field assistance provided by Dean Bolton and Ashley "AJ" Charlie of the Ross River Dena Council.

1.3 Report Format

Section 2 provides environmental setting of the project area. Section 3 discusses the culture history of the project area. Section 4 presents the methodology employed, including the inventory, site evaluation, and impact identification and assessment. Section 5 presents the results of the resource inventory conducted and recommendations. Section 6 summarizes the conclusions and recommendations for the project. Section 7 lists the references cited.

Five appendices are included at the end of this report. Appendix I contains the project mapping, Appendix II contains newly recorded archaeological site forms, Appendix III contains the artifact catalogues, Appendix IV contains copies of field notes, and Appendix V contains selected photo documents.

Yukon
Energy, Mines and Resources

FARO HERITAGE ASSESSMENT

Figure 1. Faro Heritage Resource Impact Assessment Overview Map

Map Projection: NAD 83, UTM Zone 8
Date: October 30, 2013

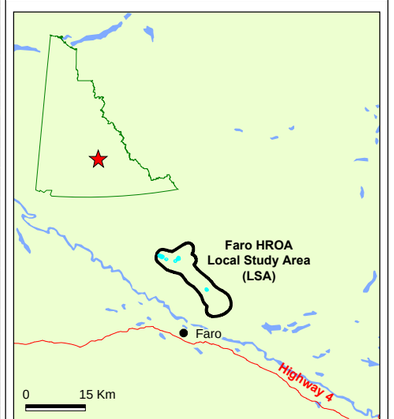
N
W E
S

750 0 750 1500 2250
Meters
Scale: 1:75,000

L E G E N D

- Faro HROA Local Study Area (LSA)
- Waterbody
- Wetland
- Order In Council
- Previously Disturbed Area
- Archaeological Potential
- Stream
- Contour
- Road
- Trail
- Faro HRIA Study Areas

Disclaimer:
This product is for informational purposes only and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. The base data layers have been obtained from the National Topographic Database (NTDB) and its features may display the data with +/- 30m accuracy.



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2.0 ENVIRONMENTAL SETTING

The target assessment areas fall within the Yukon Plateau North Ecoregion which is part of the Boreal Cordillera Ecozone (Smith, Meikle and Roots 2004).

2.1 The Yukon Plateau - North Ecoregion

This is the largest ecoregion entirely inside the Yukon and contains a large portion of the Tintina Trench. The ecoregion generally consists of relatively rolling highlands on an east-west orientation.

Mean annual temperatures are near -5°C. Mean temperatures for January range from below -30°C in the lower valleys to above -20°C over the higher terrain. This is drastically different by July as mean temperatures in the lower valleys are 15°C and drop to close to 8°C in higher terrain. Frost can occur at any time of the year but is less likely from mid-June to late July.

Precipitation is moderate with an increase in eastern higher elevation sections. Annual precipitation amounts range from 300 to 600 mm. The winter months have mean amounts of 20 to 30 mm while the summer months can expect rainfall amounts of 40 to 80 mm (Smith, Meikle and Roots 2004). Winds are generally light however may increase to moderate/high during unusually active weather systems or thunderstorms.

The vegetation of the Yukon Plateau–North ranges from boreal to alpine. Northern boreal forest exists at elevations up to 1,500 m (Smith, Meikle and Roots 2004). Open black spruce with a moist moss, or drier lichen understory is the dominant forest type in the boreal zone. Shrub and lichen tundra dominate the higher elevations. The alpine vegetation is characterized by low ericaceous shrubs, prostrate willows and lichens. In the subalpine areas, shrub birch, with scattered pine, white spruce, subalpine fir and a lichen understory, is extensive. Extensive shrub lands exist on valley bottoms subject to cold air drainage and at mid-elevations. Black spruce is the dominate tree type in the ecoregion however white spruce, occasionally with aspen or lodgepole pine, occur in warmer, better-drained areas and in forest fire burn areas.

The Yukon Plateau–North Ecoregion supports wildlife populations typical of Yukon's boreal forest mammals. Moose, woodland caribou, Stone sheep, Dall Sheep, grizzly bear, black bear, wolverine, and marten are all abundant. This ecoregion supports the greatest proportion of brown-coloured black bears in the Yukon, occurring between the Stewart and Pelly rivers. Lynx, beaver, chestnut cheeked vole, mule deer, coyotes, and red fox are also present in some sections of the Yukon Plateau-North (Smith, Meikle and Roots 2004). Of particular interest in the larger area are the Tay River Caribou herd, and an overlap of Stone and Dall Sheep, while Mountain goats are uncommon.

The glacial history of the Yukon Plateau North Ecoregion was dominated by the actions of the Cordilleran Ice sheet and local glaciers, while more recent glaciations were less extensive, and most current glacial features were left from the McConnell glaciation (Smith, Meikle and Roots 2004). However, some older features and glacial erratics are present from the older Reid and pre-Reid glaciations. Some uplands and valley floors were extensively eroded into "whalebacks" or rock drumlins by the glacial flow. The western edge of the ecoregion was approximately the terminus for the

ice sheet of the McConnell glaciation. As the ice retreated through regional stagnation and wasting it left behind kame and kettle topography and glacial lake deposits in many valleys (Smith, Meikle and Roots 2004).

Elevation within the overall mine site ranges from 1645 m Above Sea Level (ASL) in the northeast to roughly 915 m ASL in the lower valleys. The current main road in the project area follows the access road that was built to service the mine when it was in development. This road follows roughly both the Vangorda and Rose Creek drainages on its way out of Faro.

As noted above, the soils in the valleys of this ecoregion tend to be underlain by glacial parent materials. Soil development also reflects the presence of extensive discontinuous permafrost and a strong continental climate (Smith, Meikle and Roots 2004). Of interest is the presence of the Wounded Moose and the Diversion Creek paleosols. These two paleosols are buried soils formed a great deal of time before the current environmental conditions and may reflect past stable ground surfaces. The Wounded Moose paleosol developed on glacial surfaces of pre-Reid age and the Diversion Creek paleosol developed between the Reid and the McConnell glaciations. Both of these paleosols would predate the known cultural history in the Yukon.

Water availability is the one overwhelming environmental predictor of archaeological site potential. Proximity to water sources is an important indicator of archaeological potential as water is essential for survival. People normally live close to sources of water and will often use watercourses as travel routes.

A narrow drainage divide denotes the approximate boundary between the southeast quarter of the larger study area which is drained by Vangorda Creek and the northwestern three quarters which is drained by Rose Creek. Vangorda Creek flows generally southwest while Rose Creek flows to the northwest while most of its tributaries flow into it from the north east. The previously disturbed mine consist of the Faro open pit in the northwest, the Vangorda Plateau in the southeast (with the Vangorda and Grum pits) and the Rose Creek tailings storage facilities along the northwest valley floor of Rose Creek.

The bedrock geology of this ecoregion includes sections of two geological provinces of metamorphosed sedimentary rock. In the northern half of the ecoregion, variably deformed sedimentary rocks have been deposited on the outer continental shelf of ancestral North America, the Selwyn Basin.

The bedrock geology in the southeast part of the ecoregion includes siliceous sedimentary and volcanic rocks of the Yukon-Tanana terrane and metabasaltic flows of the Slide Mountain terrane but the origin of these materials is not as well known due to deformation before and during transportation onto the Selwyn Basin strate (Smith, Meikle and Roots 2004).

The southeast section of the ecoregion between Faro and Ross River also includes exposed river and stream cutbanks along the Tintina Trench (a 450 km fault) that contains rhyolite and olivine basalt which may have provided materials for prehistoric stone tool making. Also of interest in the northern Anvil Range are jet-black or gunsteel-blue weathering siliceous siltstone and conglomerate containing chert pebbles. These materials may also have been used for making stone tools.

The larger study area has been disturbed by a variety of actions. These previous disturbances can be grouped into four main categories: Faro Mine Area in the north; Rose Creek Tailing Area in the northwest; Vangorda Plateau (containing both Vangorda and Grum) in the southeast; and lastly the access roads between the pits and mine components. The Faro Pit is 1,675 m long, 975 m wide, and 335 m deep. The Vangorda Plateau consists of the Vangorda Pit which is 1,150 m long, 350 m wide, and 150 m deep, and the Grum Pit which is 1,100 m long, 700 m wide, and 200 m deep. The Rose Creek Tailings Area is approximately 4 km long, and up to 1 km wide with approximately 55 million tonnes of tailings. The access roads between the Vangorda Plateau and the Faro Mine Area consist of a heavier haul road just east of a lighter access road to the west. The mill and other infrastructure were located between the Faro Pit and the Rose Creek Tailings Area.

3.0 CULTURAL HISTORY

This study area has not been the subject of many cultural resource studies or investigations prior to the current efforts. Therefore, in order to build a context for the area's likely cultural resources, the prehistoric, proto-historic, and historic past land use of a larger area is summarized. While a good deal is known about the historic period, less is known of the prehistoric and proto-historic periods. The following is an overview of the culture history for the broader region including south-central and southwest Yukon and northern BC. Many researchers have reviewed the culture history of this broader area and presented the information using a variety of terms and temporal ranges (Clark 1981; West 1996; Workman 1978, Wright 1995, 1999).

3.1 Prehistoric Period (pre ca 11,000 B.C. to ca A.D. 1840s)

The earliest prehistoric occupation, which dates to early post-glacial times, is known as the Northern Cordilleran tradition (Clark 1983; Hare 1995). The earliest Northern Cordilleran tradition occupation known at present is a site located near Beaver Creek, dated to 10,670 radiocarbon years before present (B.P.)(Heffner 2002). The majority of sites appear to date older than 7,000 to 8,000 B.P. The Northern Cordilleran tradition, with some overlap, predates the introduction of microlithic technology from Alaska into the interior of the central and southern Yukon (Clark 1983; Hare 1995).

Little Arm Phase dates from 7,000 to approximately 4,500 B.P. (Clark and Gotthardt 1999; Workman 1978) and can be defined by the use of microlithic technologies. After about 4,500 B.P., there is less evidence of microblade use in the Yukon, and an increase in the use of notched projectile points and a variety of scraping and carving tools, labeled the Taye Lake phase in southwest Yukon, or more broadly in Yukon and Alaska, the Northern Archaic tradition (Hare 1995; Workman 1978). The most recent archaeological culture of southern Yukon is that of the Aishihik phase (Workman 1978). This phase is thought to be a cultural development from the earlier Taye Lake culture, although there are some significant differences in technology. The most notable is the introduction of the bow and arrow, replacing a type of throwing spear known as an atlatl (Hare, et al. 2004). These Aishihik Phase sites are found above the White River Volcanic ash layer (also known as Tephra) that is dated to about 1,250 radiocarbon years BP (Clague, et al. 1995).

3.2 Athabaskan Period (ca A.D. 500 to 1840s)

In the Athabaskan Period the project area is thought to have been populated by ancestors of the current Ross River Dena Council which may have been comprised of the Shu-tah Dene, Northern Tuchone and Kaska. A great deal of information concerning the Northern Tutchone people was recorded in oral traditions passed on through generations and recorded by various researchers (Dobrowolsky 1987, Gotthardt 1987, Legros 1999; McClellan 1981, McClellan et al., 1987). More information regarding the Kaska is presented below.

From a tool kit perspective, the Athabaskan period has been identified as a shift to stemmed projectile points, the increased use of bone and antler projectile points, and the use of the bow and arrow.

This late prehistoric period is defined by those archaeological components dating after the fall of the White River ash or Tephra (WRT). The Aishihik Phase has been evaluated as ranging from approximately A.D. 750 to A.D. 1750 and also includes the use of native copper tools, stemmed projectile points, and gorges. Also indicative of the Aishihik Phase are small stemmed Kavik points, end and side scrapers, and ground adzes (Hare 1995). The poor preservation of organic materials makes the task of diet reconstruction more difficult than at the coastal sites, but there is evidence of continued use of a variety of large and small mammals, fish, and birds. In the high elevations of the southern Yukon ice patches, examples of the transition from the older atlatl technology to the bow and arrow use has been clearly documented by recent finds (Hare at al. 2004). The shift to the new technology was a rather abrupt one at roughly A.D. 750 based on a good sample of dated atlatl dart shafts and bow and arrow remains.

3.3 Proto-historic Period (A.D. 1700s to ca A.D. 1840s)

The Proto-historic period, as presented here, also overlaps with late Athabaskan Period and can be defined by the appearance of non-native goods, other early trade items, and foreign (western or eastern) influences, but not the documented accounts of westerners themselves. Other indicators of the proto-historic period are the arrival of the first non-native diseases and information concerning non-natives. This period spans the time between the first introduction of non-native influences or artifacts, and the recording of first hand or primary written accounts. Unlike other cultural periods with more specific temporal ranges it is difficult and perhaps impossible to determine when the first ‘outside’ influences of Russian, Asian, European or other cultures began to impact First Nations people in the Yukon interior.

Some of these far reaching effects may have been passed along from Russian exploration in the early and mid 1700s (Veniaminov 1984) and other Asian and European (Andreev 1944, Quimby 1985) exploration and contact with coastal communities. The Chilkat Tlingit from the Northwest Coast travelled and traded with many interior First Nation peoples throughout this proto-historic period including the Kaska and the Northern Tutchone from the Dawson and Mayo areas and occasionally the Mountain Dene people from as far away as Fort Norman on the Mackenzie River. The Tlingit protected and controlled the trading routes into the interior and fiercely defended those routes when they were threatened. News of early non-native explorers and traders would have travelled inland along with foreign items such as metals, cloths, glass beads, and later tobacco and other goods.

In some of the earliest cases the impacts of these foreign cultures could have had significant impacts even without the presence of the foreigners themselves. Such is the case for what is called ‘drift-iron’ whereby metals and other materials from Asian or European shipwreck wash ashore. Historical accounts of shipwrecks have been reported in the mid 1700s but much earlier wrecks were possible. Metals and other foreign trade items have been derived from ship wrecks off what is now British Columbia, Southeast Alaska, and perhaps the Northwest Alaska as well. Of particular interest is the extent that Chinese exploration reached under the direction of Emperor Cheng Zu in the early 1400s.

3.4 Historic Period (ca A.D. 1840s to the Present)

During the early years of this period the Russians were expanding their exploration and trade network along the Pacific coast and up the major rivers of the Alaskan interior, while the British were exploring

eastward into what would become Canada's Northwest and Yukon Territories, as well as Alaska. In the 1840s, representatives of the Hudson Bay Company established trading posts near the study area. Frances Lake Post was established by the narrows of Frances Lake in 1840 while Fort Pelly Banks was constructed in the winter of 1842-43 on the Pelly River at the mouth of Campbell Creek. Fort Yukon was established by John Bell at the confluence of the Yukon and the Porcupine Rivers in 1847. The next year Robert Campbell established Fort Selkirk on the upper Yukon River and then relocated to an improved location in 1851. The Frances Lake post functioned primarily as a meat post and then as a staging post enroute to Fort Selkirk. These posts were plagued by starvation, poor supply and poor trade due to hostilities and feuding.

The location of Fort Selkirk was known to upset the Chilkat Tlingit who controlled the trade routes from the coast to the central Yukon. In 1852, a Chilkat Tlingit raiding party travelled inland and forced Robert Campbell and his crew to leave the trading post, which was consequently burned by the Northern Tutchone (Castillo 2012). The posts at Frances Lake and the Fort at Pelly Banks were abandoned by the Hudson's Bay Company by 1851-1852, while Fort Halkett remained open until 1865.

In 1867, US Secretary of State William Seward was able to focus increasing American interests, and he convinced the United States Senate to purchase Alaska from Russia. Soon after the purchase, the US Army sent Captain Raymond up the Yukon River on the first stern-wheel steamer to reach Fort Yukon (Grauman 1977). Raymond surveyed the location of Fort Yukon and proved that it was within US territory. The British sold the Fort to the US Government and relocated east across the 141st Meridian.

The inland fur industry continued to drive exploration and settlement into the late 1800s, but mining would shift the focus to the placer gold found in streams and alluvial deposits. Mining in the second half of the nineteenth century was a risky but often very lucrative enterprise. The impacts of mining would spread quickly and drastically change the project area.

Mineral prospecting and mining efforts in the second half of the nineteenth century were in some ways very dependent on the existing infrastructure of the fur trading and missionary efforts. As the competition for the inland fur trade grew, so would the number of stern-wheelers on the Yukon River. These steamers could better supply the small number of trading posts along the Yukon and its tributaries and reduce the risk of prospectors running short of supplies. Therefore more of the fur traders and other explorers turned their attention to search for gold and other minerals. Three key prospectors to the north were L.S. (Jack) McQueston, Al Mayo, and Arthur Harper. They wrote to miners in the United States to encourage them to come north. They also established outposts along the Yukon River, including Fort Reliance, established in 1874 near the confluence of the Klondike River (what would become Dawson City) (Wright 1976).

Harper and another man may have been the first to travel up the Fortymile in search of gold in 1881 (Buzzell 2003). They collected a very rich sample, but were unable to relocate the exact location. In 1886, McQueston, Harper, and Mayo built a post on the confluence of the Stewart and Yukon Rivers which provided supplies for additional prospectors. Also in 1886 Howard Franklin made a richer find on the Fortymile River. Others rushed in and these claims along the Fortymile River attracted miners from across Central and Eastern Alaska, and even Southeast Alaska. Fortymile was the first town to grow to over a thousand people by the mid 1890s (Buzzell 2003), and in 1887 the Stewart River post was deserted. Some prospectors that did not find easy success in Fortymile returned to the Stewart and

continued work in the area. In 1890, Harper re-established a trading post at the site of the old HBC post at Selkirk as interest in the area grows. This was followed by Jack Dalton who developed a series of existing First Nation trails from tide water at Haines Alaska, into Fort Selkirk.

Then, on August 16, 1896, George Carmack, Skookum Jim, and Tagish Charlie discovered a very rich claim on Bonanza Creek, a tributary to the Klondike River near Dawson. This discovery sparked one of the largest gold rushes in history.

It would take almost a year for the news of the Klondike gold fields to spread south, even to places relatively close by in southeast Alaska. Most of the prospectors and traders in the Alaskan and Yukon interior had already converged on the Dawson area during the winter and spring, and supplies ran dangerously low. That would quickly change in the summer of 1897 and spring of 1898 as new towns and supply posts sprang up along the Gold Rush routes to cash in on the increased demand.

The population of Dawson City grew very fast and in 1898 reached a peak of over 30,000. However the boom period did not last long and the vast majority of population moved on very quickly with the news of other discoveries and hopes of other bonanzas. The Gold Rush period saw greatly increased steamer traffic on the entire Yukon River drainage basin and across the interior. Just prior to the Gold Rush there were only a few steamers, while at its peak there would be hundreds of vessels working the rivers. These shallow draft steamers were supported by a network of wood camps, shipyards, and a large workforce which kept the river traffic moving. This network provided the infrastructure backbone for trading posts, fish camps, missionaries, and mail routes, while meeting the needs of the growing number of prospectors and traders.

As the world's attention was drawn to growing concerns in Europe in 1939, the Canadian Government began building a chain of airfields across the northwest under the Northwest Staging Route Program. Following the bombing of Pearl Harbor there was no doubt that Alaska and the Yukon would play a key role in the war, and a road needed to be built to link Alaska to the contiguous United States. It was quickly decided that the "Prairie Route" would be used, whereby key airfields would be linked from Great Falls, Montana to Fairbanks, Alaska. As part of the agreement Canada agreed to build and improve airstrips along the way including Watson Lake. In February 1942, the US War Department issued the directive to begin construction. These actions spurred on the building of approximately 2,446 km (1,520 mi) of new road through British Columbia and the Yukon Territory. Following the completion of the Alaska Highway the Canol Pipeline and Canol Road (North and South) were completed to allow the flow of oil from Norman Wells, NWT to Whitehorse in 1944. These two events increased access to the Traditional Territory of the Ross River Dean Council and were largely responsible for commercial and mining/industrial activities in recent decades, including construction of the Robert Campbell Highway (Tungsten Road) in 1961.

3.4 The Faro Mine

In the 1880's there was placer mining along the Pelly River however, there was never adequate amounts to trigger a Gold Rush in the area. Small amounts are taken from the creeks and sandbars along the Pelly River to this day, but most are hobby claims or small operations. However, the area around Faro is very rich in other ores and minerals. In 1953, prospector Al Kulan staked the Vangorda

Creek lead-zinc deposit with the assistance of Kaska prospectors Jack Ladue, Robert Etzel, Joe Etzel, Art John, and Jack Sterriah. At that time the deposit was considered too small and too remote to be mined (Town of Faro 2012).

When exploration of the ore body around Faro was conducted a few years later, it was realized they had hit upon a world class deposit of lead/zinc ore (galena). The Vangorda deposit was purchased by Kerr-Addison Mines Ltd. while Dynasty Explorations staked the Faro deposit in 1965. In the late 1960s preparations for full mine production began on the Faro deposit and the Town of Faro was established along the Pelly River, approximately 5 km from the LSA, in 1968. Faro Mine production began in 1969 and the mine was officially opened in 1970. There were over 100 people working in the area, and Dynasty had even built an airstrip on the claim site. Dynasty Explorations later joined forces with Cyprus Mines from Los Angeles to create Cyprus Anvil Mining Corp in 1975 (Faro Mine Remediation Project 2011).

Meanwhile the Kerr-Addison Mine Ltd. discovered the Grum deposit in 1973 and decided to sell both the Vangorda and Grum claims to Cyprus Anvil Mining Corp. in 1978. This collection of the Faro, Vangorda and Grum deposits benefitted Cyprus Anvil greatly. They quickly became the largest private sector employer in the Territory. In the 1970's the Faro Mine could produce up to 10,000 tonnes of ore per day. By the mid 1970's Faro was the largest lead/zinc mine in Canada (Faro Mine Remediation Project 2011); produced approximately 15% of the world's zinc/lead output; and, represented 20% of the Yukon's economy.

Mining continued intermittently between the Faro deposit and the Vangorda Plateau (the Vangorda and Grum deposits). The property changed hands multiple times and went through periods of operation and closure due to fluctuating metal prices. Until finally in 1998 the Anvil Range Mining Corp. declared bankruptcy and sought protection under Companies' Creditors Arrangement Act. The courts appointed an interim company to manage the environmental care and general maintenance of the property. In 2003, the territorial and federal governments officially stated the Faro Mine Complex will not reopen and entered into a joint agreement with the RRDC (on behalf of the Kaska Nation) and Selkirk First Nation to work together on developing a closure plan (Faro Mine Remediation Project 2011).

3.5 The Kaska Nation

The project falls within the traditional territories of the Ross River Dena Council (RRDC) and the Liard First Nation (LFN). Both first nations are part of the Kaska Nation. The Kaska Nation's traditional territory covers a large area of northwestern BC, southeastern Yukon and southern NWT. Within the Kaska traditional territory there are five First Nations communities: Dease River First Nation; Kwadacha Nation; Ross River Dena Council; Liard First Nation; and Daylu Dena Council. Each Kaska First Nation is represented by an elected Chief and Council as well as a Hereditary Chief.

Prior to European contact, traditional subsistence activities typically featured a seasonal round of winter hunting and summer fishing covering vast areas. In summer, families congregated at lakes and rivers, where fish and plants were collected, dried and stored. In late summer, small groups dispersed throughout the uplands and higher valley systems to hunt in clan-owned territories. Temporary camp sites, situated within a variety of ecological zones, were often reoccupied year after year in order to

exploit seasonally available resources (Honingmann 1981).

Contact with neighbouring Nations was vital to First Nations economies. Interior bands traded hides, furs and obsidian to coastal groups for fish oil, dentalium, woodwork and blankets. Trails were an intrinsic part of this economy and traditional subsistence as a whole. The principal ethnographic descriptions of the Kaska Dena are available in Black (1955), Jenness (1937) and Morice (1893, 1903, 1905). Additional information on past lifeways can be found in Honigmann (1981).

Ross River, near the confluence of the Ross and Pelly Rivers, is the modern focal point of the Ross River Dena Council. Originally First Nations people used the area as a seasonal camp and gathering place. By 1903, a trading post was established nearby and later when the American army completed the Canol Pipeline and Canol Road in 1944, they connected Ross River by road to the rest of the Yukon (Cohen 1992). In 1962, Ross River was relocated to its current site close to the Campbell Highway (Yukon Community Profiles 2012).

Watson Lake, Upper Liard and the adjoining settlements are home to the Liard First Nation. The amount of activity near Watson Lake was greatly increased when its airfield was established in 1939. This was part of the Canadian government's construction a chain of airports across north-eastern British Columbia and the Yukon as part of the lend-lease program. The new community was soon after used as a supply centre for the construction of the Alaska Highway in 1942.

3.6 Previous Heritage Investigations

In this case there are no previously recorded sites within or near the assessment areas, and no others recorded in the larger vicinity. The majority of archaeological investigations carried out in the broader area have been motivated by development activities, including mining/mineral exploration and road construction.

Ruth Gotthardt conducted heritage resource inventory in the upper Liard drainage including portions of the Robert Campbell Highway (1987) and also conducted work in the Francis Lake area (1993). Greg Hare conducted an overview assessment along a portion of the southern Robert Campbell Highway (1998). Christian Thomas conducted an assessment for proposed borrow pits for the Robert Campbell Highway (2007) and conducted an impact assessment for the same highway from km 10 - km 140 (2008).

A Preliminary Field Reconnaissance (PFR) was conducted by Ecofor in May 2012 for 28 proposed borrow pits along the Robert Campbell Highway. The focus of the PFR was to identify areas of heritage resource potential within these proposed borrow pits. Prior to fieldwork, previously identified archaeology sites and heritage resources location data were collected and included in field mapping. Field crew attempted to assess each block from the ground. Of the 28 targets, 15 were found to contain archaeology potential, 2 were inaccessible, and 11 were found to contain no heritage resource potential (Smith 2012). This assessment was used to recommend high potential areas for shovel testing that were used in a follow-up HRIA of Pit #7 also in 2012 (Mooney 2012).

In 2012, Ecofor Consulting Ltd. completed a Heritage Resources Overview Assessment for the Proposed Faro Mine Remediation Project (Mooney and Smith 2012) which identified likely resources to be found in the area and areas evaluated to contain potential for heritage resources.

4.0 METHODS

Field efforts were separated into two main tasks consisting of pedestrian transect survey to assess in-field potential, and sub-surface testing - where potential was rated as moderate to high.

Due to the relatively small size of the assessment areas each proposed target area was walked in relatively tight transect intervals of approximately 5 to 15 m apart. When areas or landforms were assessed in the field to posses moderate to high potential shovel testing was conducted. Shovel tests were located approximately 5 to 10 m apart. Shovel tests were a minimum of approximately 30 by 30 cm and were be excavated with shovel and trowel as needed into sterile sub soils. All soil matrix were screened though ¼" mesh. Artifacts identified were collected and bagged according to the shovel test unit and stratum, or arbitrary 5 cm vertical interval. The profile of positive shovel tests were recorded by depth below surface and natural and cultural soil strata. All shovel tests were backfilled and returned to as close to natural conditions as possible. If surface finds or subsurface cultural materials were identified additional shovel testing was conducted to assess the vertical and horizontal limits of the site, and to recover a sample of the material culture to assist in the assessment of the site use and cultural affiliation. All sites, isolates, and heritage resources were photographed and the site location will be recorded using a hand-held GPS unit, and a sketch map was prepared in the field. Sites were recorded using temporary site numbers and site data was recorded. Data included setting, access, vegetation, water system information, elevation, soils data including number of cultural strata, features present, and other comments. This information was submitted to Yukon Heritage Branch for site inventory and return of Borden Site number. The condition of sites was also assessed based on the amount of disturbance ranging from relatively intact to destroyed.

Historic and prehistoric sites were recorded and flagged in the field. Field work was completed by crews of three to four individuals (principal investigator, archaeological field technician, and First Nation Participants). A buffer area of 30 m around known historic and prehistoric sites was flagged with yellow "no work zone" ribbon as well as flagging at the centre of the site.

Interim and final reports, site forms, and artifact curation preparations met the Yukon Archaeological Sites Regulations Guidelines for Permit Holders.

If mummified or skeletal palaeontological remains were exposed, Yukon Palaeontology would have been contacted before disturbing them further.

If human remains were identified during operations, all work would have ceased in the area immediately and the R.C.M.P, First Nations, and Yukon Heritage Resources would have been notified.

4.1 Curation of Materials Collected

The Yukon Heritage Resources Unit will serve as the repository for the materials collected. Contact information of the Heritage Resources Unit is provided below.

Heritage Resources Unit
Department of Tourism and Culture
Government of Yukon
P.O. Box 2703, Whitehorse, Yukon Y1A 2C6

Contact: Ruth Gotthardt
Phone: (867) 667-5983
Fax: (867) 667-5377
Ruth.Gotthardt@gov.yk.ca

4.2 Resource Definitions

A *Site* is an area or a place, or; a parcel of land which contains heritage resources or objects.

Historic Sites contain heritage resources that are greater than 45 years in age and posses significant heritage value. By convention, historic sites date to the period for which written records are available; in this case, the historic period commences with the arrival of the Hudson's Bay Company in the early-mid 19th century. Historic sites may include cabins, caches, camps, brush camps, and any other man-made structures, features or objects that date between about the 1960's and 1830-50.

Archaeological or Prehistoric Sites generally represent use before European contact and are found on or under the ground surface, and may consist of the remains of ancient camps, including hearths, animal bone and stone tools and debris. In this usage, an Archaeological Site equates to a Prehistoric Site (a site that dates to the period before written history). Note, however, that in heritage resource management usage, archaeological resources are viewed as resources that are in subsurface context (buried) and may also include historic period objects and features.

Proto-historic Sites can be viewed as basically prehistoric sites from a time period which includes the effects of foreign historic cultures but lacks the first hand written descriptions of that area. For example, in the Yukon the proto-historic period ends with the appearance of first hand written descriptions in the mid 1800s. However the proto-historic time period extends back thru time when foreign materials such as "drift-iron" from ship wrecks on the west coast, or foreign trade items were carried into the Yukon. Examples of foreign historic materials which predate the mid 1800s found in prehistoric contexts usually represent this proto-historic period.

5.0 RESULTS AND RECOMMENDATIONS

Field work was completed across the eight proposed areas of ground disturbance in one fieldwork session from September 24th to 26th, 2013. The field crew were accommodated at the Faro Studio Hotel.

These eight areas of planned disturbance within the Faro Mine Interim Works had been previously identified in the overview assessment to posses potential for heritage resources. The current field team conducted the Heritage Resources Impact Assessment and found seven (7) areas or landforms assessed in the field to contain significant potential for buried heritage resources. Each of these areas was shovel tested. One of these areas contained an isolated prehistoric lithic surface find (KcTq-1), and three contained prehistoric lithic scatters (KcTq-2, KcTq-3, and KcTq-4).

A modern horse corral and cabin were identified and recorded. A single log privy was also identified and recorded. Two isolated game hanging racks were noted near the current borrow pit edges. None of these historic resources were assessed to be over 45 or 50 years of age and therefore they were not recorded with the Yukon Historic Site Inventory. These resources were noted here since they are within and near possible impact areas and would be of concern to stakeholders.

No paleontological remains, grave sites or human remains were identified. All of the newly identified prehistoric sites were flagged with a 30 m buffer of yellow and black "No Work Zone" tape except the isolate from disturbed context KcTq-1.

Overall results mapping are augmented with shovel test location sketch maps is in Appendix I while site forms for archaeological sites are in Appendix II. Appendix III contains detailed artifact catalogues, while Appendix IV presents field notes. Appendix V presents selected images of each shovel test location and representative images of sample artifacts and historic resources. The results of these efforts are presented below in prehistoric as well as modern use areas that may be of concern to related stakeholders.

5.1 Prehistoric Resources

The current 2013 fieldwork focused on assessing eight areas proposed for borrow pit areas or ground disturbing activities. Most of the ground surface in these areas consisted of side slope, covered in black spruce with little to no potential for buried heritage resources. As noted above seven (7) smaller areas or landforms within the proposed target areas were assessed in the field to possess moderate to high potential for buried cultural resources. Each of these landforms were the subject of sub-surface shovel testing. The results of this testing is presented in Table 1 below as an overview (which also includes areas of negative testing) and secondly in a more detailed site by site description.

Table 1. Shovel Test Location Results.

STL #	Borden #	Total (+) Tests	Total (-) Tests	Archaeological Potential	Landform	Landform Size	Site Size
1	KcTq-2	2	15	High	Esker Ridge	5 x 70 m	5 x 15 m
2	KcTq-1	0	4	Low	N/A disturbed	5 x 5 m	surface find
3		0	5	Moderate - High	Small Knoll	5 x 20 m	-
4	KcTq-3	2	7	High	Esker/Bench	5 x 40 m	5 x 18 m
5		0	6	Moderate - High	Ridge	50 x 10m	-
6	KcTq-4	1	9	Moderate - High	Esker Ridge	5 x 30 m	5 x 10 m
7		0	5	Moderate	Rock Bench	5 x 10 m	-

Borden #: KcTq-2
STL #, Temporary Site #, and name: STL J1, Site J2, Seklla Site
Location: See Map 1 – Appendix I
Landform: Esker Ridge
Number of Negative and Positive Shovel Tests: 15 negative and 2 positive
Total Number of Lithic Materials: STP #1: 2 interior flakes and 1 modified flake; STP #8: 1 interior flake
Diagnostic Materials/Possible Cultural Affiliation: Prehistoric – Likely Post White River Tephra (possible Aishihik Phase)

Assessment: There was evidence of the White River ash or tephra (WRT) in the shovel tests and it appears this site may have been used after the fall of the WRT. The lithic materials identified were found in STP #1 near the high spot of the lower southern end of the ridge, and in STP #8 in the middle of the ridge. This narrow and relatively low ridge runs roughly north to south and overlooks the Rose Creek drainage to the west. This drainage flows northwest and then west into the Pelly River. Cultural materials were found between 0-10 cm below surface and likely found above the WRT in the first 5 cm of soil. The lithic remains identified likely represent a small, low to moderate density, scatter remaining from a temporary campsite or lithic reduction workshop which may reflect the post WRT and use in the Athabaskan Period and perhaps the Aishihik Phase.

Soil Description: STP #8 Organic Layer/I 0-5 cm rich organic and thin black loam, II = 5-10 cm of White River Tephra, III = 10-20 cm reddish brown to brown coarse sandy loam with approximately 25% gravel and cobbles.

Recommendations: The site is located just west of the edge of a proposed borrow pit but the 30 m buffer flagged around the site (as per direction from Yukon Heritage) is within the proposed pit and may be impacted by the proposed developments. Avoidance of the site is recommended. If avoidance of this site and its 30 m buffer is not possible then data recovery work is recommended. Data recovery

should include additional shovel testing to determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 5 square meters of excavation would be recommended.

Borden #: KcTq-1
STL #, Temporary Site #, and name: STL J2, Site J1, Rose Creek Site
Location: See Map 1 – Appendix I
Landform: N/A disturbed
Number of Negative and Positive Shovel Tests: 4 negative and 0 positive (only a surface find)
Total Number of Lithic Materials: Surface Find: utilized flake
Diagnostic Materials/Possible Cultural Affiliation: Prehistoric – undetermined

Assessment: This single isolated find was found in a disturbed push area from heavy equipment workings on the edge of an existing borrow area on a southwest facing slope. The remaining surface of the disturbed area and undisturbed ground surface around it were inspected but no additional materials were identified. The crew also opened four shovel tests in the most level closely related ground surface adjacent to the disturbed area but no additional materials were identified. The single lithic isolate may have been moved downslope from higher ground to the northeast. This isolate likely represents a small low density scatter remaining from a temporary campsite or lithic reduction workshop. No culturally diagnostic materials were identified and it is uncertain when these materials were deposited. The isolate was found on a disturbed surface which consisted of gravel and cobbles and coarse sandy materials.

Soil Description: The intact soils at this location were very similar to those at STL #1 and the WRT was present. Although no cultural materials were found in-situ a representative soil profile was made at STP #2. This consisted of organic Layer/I 0-5 cm rich organic and thin black loam, II = 5-10 cm of White River Tephra, III = 10-20 cm reddish brown to brown coarse sandy loam with approximately 25% gravel and cobbles.

Recommendations: The isolate was located within a proposed borrow pit, and on the edge of an existing borrow pit, and would be directly impacted by the proposed developments. The likelihood that this sloped landform would contain significant cultural materials is assessed as low to none. No further heritage resources management work is recommended.

Borden #: KcTq-3
STL #, Temporary Site #, and name: STL J4, Site J3, Keda Look Out Site
Location: See Map 1 – Appendix I
Landform: Esker Bench
Number of Negative and Positive Shovel Tests: 7 negative and 2 positive
Total Number of Lithic Materials: STP #1: 1 interior flake; and STP #4: 1 modified flake
Diagnostic Materials/Possible Cultural Affiliation: Prehistoric –Post White River Tephra (probable Aishihik Phase)

Assessment: This small landform consists of a bench at the southeast end of ridge line that overlooks Rose Creek. These lithic materials likely represent a low to moderate lithic scatter reflecting a temporary campsite or lithic reduction workshop. Cultural materials were found between 0-10 cm

below surface and above the WRT which supports an Athabaskan Period use and probable association with the Aishihik Phase.

Soil Description: STP #4 Organic Layer 0-5 cm scattered and thin rich organic duff, II = 5-19 cm White River Tephra, III = 19-25 cm reddish brown coarse sand with approximately 20% gravel.

Recommendations: This site is located on the west edge of a planned borrow pit area and would be impacted by proposed activities. Avoidance of the site is recommended. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 6 square meters of excavation would be recommended.

Borden #: KcTq-4
STL #, Temporary Site #, and name: STL J6, Site J4, Whiskey Jack Site
Location: See Map 1 – Appendix I
Landform: Esker Ridge
Number of Negative and Positive Shovel Tests: 9 negative and 1 positive
Total Number of Lithic Materials: STP #5: 2 interior flakes
Diagnostic Materials/Possible Cultural Affiliation: Prehistoric – Little Arm Phase

Assessment: These materials were all found on the west facing side of a north-south ridge overlooking a tributary to Rose Creek. This ridge landform begins narrow in the north and widens in the south and only the northeast side is within the proposed borrow pit area. The lithic materials identified likely represent a small low density lithic scatter reflecting a temporary campsite or lithic reduction workshop. No culturally diagnostic materials were identified. However these materials were found between 10-15 cm below surface and 0-5 cm under the WRT which likely represent the Little Arm Phase.

Soil Description: STP #5 Organic Layer/I 0-3 cm, II = 3-12 cm of White River Tephra, III = 12-18 cm reddish brown coarse sandy loam, IV = 18-25 cm olive brown coarse sandy loam.

Recommendations: This site is located on the west edge of a planned borrow pit area and would be impacted by proposed activities. Avoidance of the site is recommended. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 5 square meters of excavation would be recommended.

5.2 Modern Use Areas and Resources

The field crew also recorded a modern horse corral and cabin, a single log privy, and two game hanging racks. These modern resources are noted here due to expected interests of current stakeholders. The modern corral and cabin are located on the north side of an existing access road within a planned borrow pit area. The single log privy is also within a proposed borrow pit area. One of the game racks

is within a proposed borrow pit while the second is between them on the edge of an existing road (see Map 1 of Appendix I). Due to the relatively modern age of these resources they were not recorded with Yukon Historic Sites Inventory.

The modern cabin was constructed of milled lumber with a plywood exterior and an ashpalt shingle roof and the corral was built with rough cut round logs and spikes. This cabin and corral area appears to have been used for big game guiding and/or hunting in the late 1900s and early 2000s and would be impacted by borrow pit development. Impacts to the horse corral and cabin are recommended to be avoided. If the impacts to the horse corral and cabin cannot be avoided then consultation with owner(s) and/or trapline holder or big game outfitter is recommended.

The single log privy was constructed with a rough cut log and plywood and likely represents late 1900s and early 2000s construction and use. The single log privy would be impacted by borrow pit development. No further work is recommended for the single log privy.

The game hanging racks consist of rough cut round logs suspended in trees and fixed with nylon rope and spikes which likely reflect late 1900s and early 2000s construction and use. No further heritage work is recommended for these game racks.

6.0 CONCLUSIONS

The current field work was completed between September 24th and 26th, 2013. A total of eight areas were proposed for ground disturbing impacts associated with the Faro Mine Interim Works. These areas had been previously identified in the overview assessment to possess potential for heritage resources. The current field team conducted the Heritage Resources Impact Assessment and found seven (7) landforms assessed in the field to contain significant potential for buried heritage resources. Each of these areas was shovel tested. One of these areas contained an isolated prehistoric lithic surface find (KcTq-1), and three contained prehistoric lithic scatters (KcTq-2, KcTq-3, and KcTq-4). Site KcTq-2 contained two lithic materials which were collected from the first 10 cm of soil and most likely from above the White River ash layer (or Tephra) (WRT). Site KcTqu-3 contained two lithic materials in the top 10 cm of soil. Site KcTq-4 consisted of lithic materials found directly under the WRT, and may present the Little Arm Phase. These three sites were flagged with a 30 m buffer of yellow "No Work Zone" flagging tape. The location of the single surface isolated find was marked by a single strand of yellow "No Work Zone" flagging tape. A modern horse corral and cabin, and a single log privy were also identified and recorded. Two isolated game hanging racks were noted near the current borrow pit edges.

No further heritage resources work is recommended for site KcTq-1. Impacts to the remaining three lithic sites (KcTq-2, KcTq-3, and KcTq-4) are recommended to be avoided. If avoidance is not possible then data recovery work is recommended. Data recovery should include limited shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 6 square meters of excavation would be recommended for each site.

Impacts to the horse corral and cabin are recommended to be avoided. If the impacts to the horse corral and cabin can't be avoided then consultation with owner(s) and/or trapline holder and big game outfitter is recommended. No further heritage resources work is recommended for the single log privy or the game hanging racks.

No paleontological remains, grave sites or human remains were identified. All of the newly identified prehistoric sites were flagged with a 30 m buffer of yellow and black "No Work Zone" tape. The location of the prehistoric isolate was marked with a single strand of "No Work Zone" tape but the area around it was not delineated.

If this project moves forward it is possible that further revisions in the proposed borrow pits may change. It is recommended that any areas of potential impact not previously assessed, are reviewed and assessed in the field prior to future impact. Impacts to recorded historic and prehistoric resources should be avoided were possible, or mitigation efforts should be completed prior to construction impacts.

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APPENDIX I: PROJECT MAPPING

APPENDIX II: SITE FORMS

APPENDIX III: ARTIFACT CATALOGUE

APPENDIX IV: FIELD NOTES

APPENDIX V: PHOTODOCUMENTATION

Appendix 6L
Socio-economic Baseline Conditions Report

Draft

Socio-economic Baseline Conditions Report Faro Mine Interim Works Project

Prepared for

Government of Yukon and the
Government of Canada
as represented by Aboriginal Affairs and
Northern Development Canada

March 14, 2014

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Acronyms and Abbreviations

AANDC	Aboriginal Affairs and Northern Development Canada
CH2M HILL	CH2M HILL Canada Limited
EI	employment insurance
Faro	Town of Faro
FMC	Faro Mine Complex
GMS	Game Management Subzones
IW	Interim Works
IWPP	Interim Works Project Proposal
KDC	Kaska Dena Council
km	Kilometre
LFN	Liard First Nation
m	Metre
RRDC	Ross River Dena Council
SFN	Selkirk First Nation
VC	valued component
YG	Government of Yukon
YESAB	Yukon Environmental and Socio-economic Assessment Board

SECTION 1

Report Goals and Introduction

The Faro Mine Complex (FMC) started operations in 1969 and mining continued under various owners until the late 1990s, with the last owners declaring bankruptcy. At that time, the management of the FMC was assigned to an interim receiver. In 2003, the Government of Canada and the Government of Yukon (YG) determined the FMC would not be reopened and planning for its permanent closure and remediation was initiated. This process is still underway. However, there are activities that need to be carried out over the next 10 years prior to the remediation and closure of the FMC so that human health and the environment continue to be protected. These Interim Works are to undergo an assessment by the Yukon Environmental and Socio-economic Assessment Board (YESAB). The YG and the Government of Canada ("co-proponents") are in the process of developing an Interim Works Project Proposal (IWPP), which describes the environmental and socio-economic effects of the interim works, for submission to the Watson Lake Designated Office of YESAB in early 2014.

CH2M HILL Canada Limited (CH2M HILL) is leading and coordinating the development of this project proposal. Hemmera Envirochem Inc., along with our team of subconsultants, has been retained by CH2M HILL to prepare the socio-economic baseline and a socio-economic effects assessment for the IWPP. This report forms the former of those two documents. A summary of this baseline is also included in Section 6.3 of the IWPP.

A socio-economic effects assessment provides estimates of potential changes a project may have on demographics, housing, public services, and even community well-being, and can thereby help proponents and communities avoid or mitigate potential negative project effects and identify potential positive outcomes of projects and related activities.

The first step towards completing a socio-economic effects assessment is to capture the conditions in the communities, or study areas, in a baseline report. The baseline conditions serve as a benchmark for measurement of potential changes in valued components (VCs) predicted to occur as a result of the project. For the purposes of this assessment, baseline conditions are considered to be the conditions in 2009 as this is the year that the co-proponents took over the day-to-day operational responsibility of the FMC from the receivers.

This report identifies the baseline conditions of the communities in the FMC study area. Further detail on the effects assessment methodology and the effects assessment itself are found in Section 7 of the IWPP.

SECTION 2

Faro Mine Context

2.1 Location

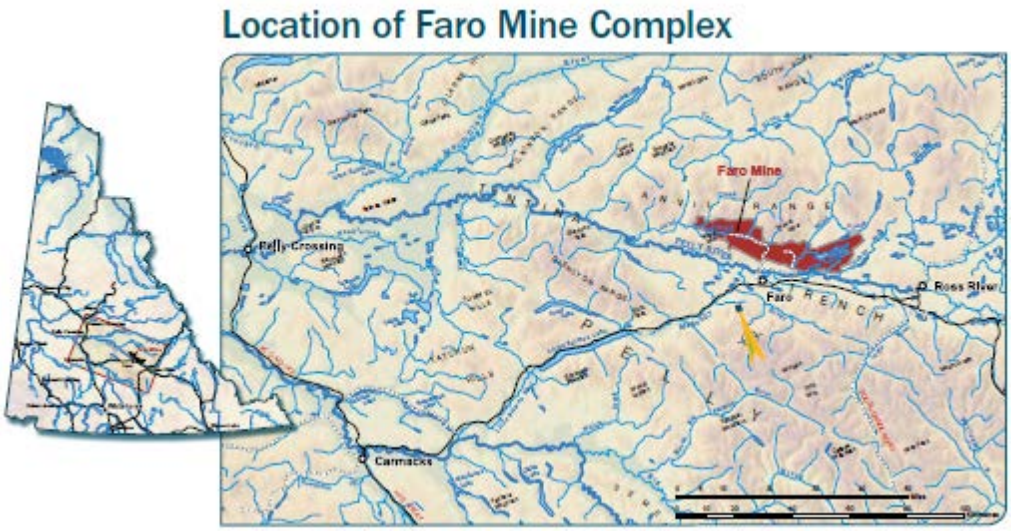
The location of the FMC is approximately 15 kilometres (km) north of Faro, located in south–central Yukon. The FMC is in the traditional territory of the Ross River Dena Council (RRDC), Liard First Nation (LFN), and Kaska Dena Council (KDC), and upstream from the traditional territory of the Selkirk First Nation (SFN) (YG, 2010a). See Figures 6L-1 and 6L-2 for maps showing the location of the FMC.

FIGURE 6L-1
Faro Mine Complex Location
Faro Mine Interim Works



Source: YG (2011); reproduced with YG's permission

FIGURE 6L-2
Faro Mine Location
Faro Mine Interim Works



Source: YG (2010); reproduced with YG's permission

The FMC is geographically bound to the north by the Anvil Range and lies directly along the Tintina Trench, in the Pelly River watershed.

The FMC comprises three key areas (YG, 2010a):

1. Tailings Area: This area is at the base of Rose Creek Valley and consists of 55 million tonnes of tailings deposited between 1969 and 1992. Three dams hold the tailings and a fourth dam stores water. The Rose Creek is diverted around this area.
2. Faro Mine Area: The mine area consists of a large (1,675 metres [m] by 975 m) open pit surrounded by approximately 250 million tonnes of waste rock. The Faro Creek is diverted around this facility.
3. Vangorda/Grum Area: Two additional large open pits (Vangorda and Grum) are surrounded by another 116 million tonnes of waste rock and overburden. Vangorda Creek is diverted around the Vangorda Pit.

The detailed layout of these three areas is shown in Figure 6L-3.

FIGURE 6L-3
Faro Mine Complex Layout
Faro Mine Interim Works



Source: YG (no date); reproduced with YG's permission

2.2 Local History

2.2.1 Pre-mining

The Faro Mine area was first prospected in 1953 by Al Kulan. He staked the Vangorda lead-zinc deposit and some drilling was carried out between 1953 and 1955, but little happened in the area until the early 1960s when the area was the subject of a detailed exploration program led by Dr. Aaro Aho. By 1965, the Faro Mine Area had clearly become an economical deposit, and in January 1970, the mine was officially opened by the Cyprus Anvil Mining Corporation (Macpherson, 1978).

2.2.2 Mining

From the original opening in 1970, the FMC operated until 1982, when production stopped because of low metal prices and high operating costs. Stripping carried on for a short time, but then all operations halted by the end of 1984. Near the end of 1985, the assets of Cyprus Anvil were purchased by Curragh Inc., who re-commenced operations at the FMC in spring of 1986. Mining continued until 1993 when it stopped again because of low metal prices, and Curragh entered into receivership. Anvil Range Mining purchased the assets of Curragh in order to re-open the FMC in 1995. Anvil Range Mining operated for a brief time, but ultimately the resource was effectively at the end of life. In early 1998, Anvil Range applied for creditor protection, and in April 1998, an interim receiver was appointed to maintain the site (YG, no date).

The FMC processed between 5,000 and 9,300 tonnes of ore per day (YG, 2010b). In 1989, the FMC was the sixth largest zinc producer in the world, supplying 3 percent of the western world's zinc and 5 percent of its lead concentrates. The FMC accounted for 20 percent of the Yukon's economy during its peak production (YG, no date).

2.2.3 Site Maintenance and Remediation Planning

From 1998 to 2008, care and maintenance work was carried out by the court-appointed interim receiver, Deloitte and Touche. In March 2009, YG took over this responsibility.

In January 2003, the federal and territorial governments agreed that the FMC would not reopen and planning for a permanent closure plan would need to occur. At that point, the two governments entered into an agreement with the RRDC and the SFN to jointly develop closure objectives for the site. These closure objectives define the intended outcomes of the remediation plan and guide the closure planning process. The closure objectives for the FMC are (YG, 2010):

1. Protect human health and safety.
2. Protect and, to the extent practicable, restore the environment including land, air, water, fish and wildlife.
3. Return the mine site to an acceptable state of use that reflects pre-mining land use where practicable.
4. Maximize local and Yukon socio-economic benefits.
5. Manage long-term site risk in a cost effective manner.

Occurring in parallel to the closure planning objectives work, over 100 technical studies and assessments have been conducted at the FMC to help inform YG and its contractors of site characteristics. In 2005, based on these technical studies, 12 sample closure alternatives were created representing the range of options that could be considered (YG, 2011a). The sample closure options were then reviewed by an Independent Peer Review Panel, as well as discussed with First Nations, federal and territorial governments and stakeholders (YG, 2011a). Based on these reviews the 12 options were narrowed down to five final options in 2006. The five final options were evaluated by the federal, territorial, and First Nations governments, who agreed on one preferred option for the final remediation plan (YG, 2011a).

Currently the detailed engineering and design for the preferred remediation option are being developed. Once that is complete, a project proposal will be submitted to the YESAB Executive Committee for an assessment, as well as undergo regulatory licences and permits processes.

2.3 Faro Mine Interim Works

The Interim Works (IW) involves works and activities that are required to protect people and the environment from the ongoing effects associated with the legacies of mining activities at the FMC, and to manage risks associated with those legacies, until the full remediation plan is in place. The environmental and socio-economic assessment for the IW considers the consolidated effects of all undertakings and accessory activities during this interim period.

The following three areas make up the IW environmental and socio-economic assessment scope:

- Site operations (further described in the Project Proposal Section 5.3): The Site operations are the ongoing site activities required to prevent the FMC from adversely affecting persons, property or the environment. It will also counteract, mitigate and remedy adverse effects that do occur.
- Site investigations (further described in the Project Proposal Section 5.4): Developing the Faro Mine Remediation Project and design of remediation and closure elements requires extensive site investigation programs. These programs will take place across the FMC throughout the proposed IW. It will comprise a range of land use activities that may be associated with site investigation programs such as soil and rock sampling, collecting vegetation samples, and test pitting, among other activities.
- Down Valley Interim Hydraulic Upgrades (further described in the Project Proposal Section 5.5): The Down Valley Interim Hydraulic Upgrades relate to the improvement of flood routing capacity for the Down Valley Tailings Facility, where some aspects of the facility do not meet the minimum standards specified in the Canadian Dam Association Dam Safety Guidelines. Activities under this component involve raising the capacity of the spillway, relocating infrastructure, and other improvements.

A fourth element of the IW scope is the ancillary activities (e.g., worker accommodation and borrow source investigation and development). These may relate to one or more of the three main areas. While these are considered to be ancillary to the IW work itself, they may have a substantive effect on socio-economic considerations of the proposed project. The detailed list of ancillary activities is as follows (Section 5.6 of the Project Proposal describes ancillary activities in greater detail):

- Maintaining site security by providing an ongoing site presence, establishing security facilities and programs, and managing site access as needed to secure the FMC and manage health and safety risks
- Maintaining and operating an office and gatehouse building at the FMC
- Providing emergency response capabilities and responding to emergencies
- Implementing preventative maintenance programs
- Maintaining buildings, site infrastructure, and utility systems (e.g., electrical distribution system maintenance and a waste-oil heating system)
- Maintaining stationary and mobile equipment
- Expanding existing borrow sources to supply aggregate and construction materials for care and maintenance, water treatment plant construction, and Down Valley Interim Hydraulic Upgrades activities
- Providing onsite accommodations for site workers, including temporary camps (e.g., construction activities, field investigation programs)
- Maintaining and operating employee housing within the Town of Faro (Faro)
- Procuring supplies and energy sources for the FMC (e.g., lime for water treatment, materials for water treatment plant construction, and fuel)
- Transporting goods and equipment to and from the FMC (e.g., providing the materials listed herein and removing hazardous waste)

- Using existing solid waste disposal facilities at the FMC
- Managing special wastes (this includes operating a waste-oil heating system)
- Withdrawing and using fresh water for domestic purposes
- Using, maintaining, and repairing existing septic systems at the FMC
- Performing additional ancillary activities to complete the IW activities

SECTION 3

Methodology

3.1 Values-based Approach

The assessment team has employed a values-based approach for this IW project. That means the things that people care about (the "values") that could be affected by the IW were identified and considered. As a first step, a list of socio-economic values was identified. These values were determined based on an analysis of existing socio-economic information. Also included were indicators for each value that may be measured quantitatively or qualitatively. These indicators provided the basis for the research plan for the socio-economic baseline and effects assessment.

Baseline data collection focused on understanding the conditions of individuals, communities, and businesses as they are related to the following socio-economic VCs:

- Economy and employment
- Community stability and well-being
- Infrastructure and services
- Land use and access
- Culture and heritage

Table 6L-1 describes each of these VCs, their indicators, and the rationale for including them. The socio-economic effects assessment provides predictions on how the IW activities might affect these valued components (see Section 7.3.6 of the IWPP).

TABLE 6L-1
Socio-economic Valued Components and Indicators
Faro Mine Interim Works

Valued Component	Indicators	Rationale for Inclusion
Economy and Employment	Business development Economic diversification Employment opportunities and income Education and training	The IW may stimulate local economies, and has the potential to increase employment, and develop skills, training and education in local communities. This value evaluates the community's ability to adapt to economic growth, effects of increased disposable income, distribution of costs/benefits among affected people (adverse effect/income equity), and effects on local and regional cost of living.
Community Stability and Well-being	Demographics Cultural well-being Social cohesion	The influx of temporary workforce during each project component may influence community makeup, including demographics and mobility such as effects of migration (in and out), changes in social and cultural makeup of communities, influence on individual, family and community health.
Infrastructure and Services	Roads and traffic Housing Health services Emergency services Community infrastructure	Potential influx of temporary workforce may cause strain on community infrastructure, housing, and emergency and health services. Increased traffic due to the IW construction and maintenance may affect local road safety and cause wear to road infrastructure.

TABLE 6L-1
Socio-economic Valued Components and Indicators
Faro Mine Interim Works

Valued Component	Indicators	Rationale for Inclusion
Land Use and Access	Traditional Land Use Hunting and Fishing Recreation Tourism Forestry	Potential effects on existing land use due to the IW, to First Nations traditional land use (for hunting, trapping and gathering), as well as effects to access for commercial and recreation land users due to Project construction/maintenance.
Culture and Heritage	Traditional Culture and Use Heritage Resources Culture	Potential effects to First Nations traditional culture, use, heritage, archaeological and spiritual resources; and effects on traditional language, education, laws and traditions due to the Interim Works construction and maintenance.

3.2 Baseline Data Limitations

The socio-economic effects assessment predicts the potential changes in the condition of the socio-economic VCs as they could change due to the IW activities. The potential changes are predicted from a set of baseline conditions. The conditions of the values can change over time. So, for the purposes of the assessment, a time is chosen for when the baseline conditions are measured. For the purposes of the IWPP, the year of the baseline conditions has been selected at 2009. This is the year that the co-proponents took over the responsibility of the FMC from the receivers.

This socio-economic conditions report is based on available secondary data for the four communities, and the affected First Nations. It provides descriptions generated from statistics from a variety of sources such as YG, and Statistics Canada, as well as information gathered from First Nations and community websites and documents.

Socio-economic data are generally less frequently available compared to environmental data. Best efforts have been made to gather relevant data from 2009 on for purposes of describing community conditions; however, not all Census data from 2011 has been released. Where data from the 2011 Census was available it has been used, but data from the 2006 Census comprises most of the description of the VCs for each community. Where available, data describes trends over time. While Census data is the primary source for VC descriptions, it has limitations with respect to small communities. Data from the Census is subject to a confidentiality procedure known as random rounding in which the numbers are rounded up or down to a multiple of five or ten in order to prevent associating statistical data to any one individual. The data also may be subject to suppression depending on the topic and the size of the community. For the purposes of the baseline conditions report, most of the census data is from Census 2006. The graphs may represent data from 2005 or 2006 depending on the question. Publication of data sets from the Census takes a period of years so the graph sources may be from a publication date later in time, such as 2008.

Primary community research to verify VCs, verify secondary data, and fill data gaps was not conducted. Given the limited scope and duration of the activities in the IWPP and guidance provided by YESAB as it relates to a Designated Office-level evaluation, the assessment team considers secondary data are satisfactory for this socio-economic effects assessment. However, care must be taken when drawing conclusions on socio-economic effects in communities when the baseline conditions are derived from secondary data.

3.3 Socio-economic Study Areas

For the purposes of this socio-economic conditions report and subsequently the socio-economic effects assessment to be prepared for the IWPP, the communities described are Faro, RRDC (primarily in Ross River), LFN

(primarily in Watson Lake), KDC, and SFN (primarily in Pelly Crossing). These were chosen through a combination of those Affected First Nations identified in the Devolution Transfer Agreement, and the community (Faro) located closest to the FMC.

The Affected First Nations impacted by the FMC identified in the Devolution Transfer Agreement are (Government of Canada, 2001):

1. Ross River Dena Council (based in the community of Ross River; Traditional Territory to be all of Kaska Traditional Territory, encompassing FMC.)
2. Liard First Nation (based in the community of Watson Lake; Traditional Territory to be all of Kaska Traditional Territory, encompassing FMC.)
3. Kaska Dena Council (Umbrella organization representing interests of Kaska people in Yukon and BC; Traditional Territory encompassing FMC.)
4. Selkirk First Nation (based in the community of Pelly Crossing; the FMC upstream of its Traditional Territory.)

Faro was created as a result of the FMC in 1969, and it is the closest community to the FMC.

Secondary data related to all VCs were collected for each of these First Nations and communities, wherever possible. Secondary data as it relates to the KDC is represented through their members who are citizens of the RRDC or the LFN.

SECTION 4

Baseline Conditions of the Valued Components

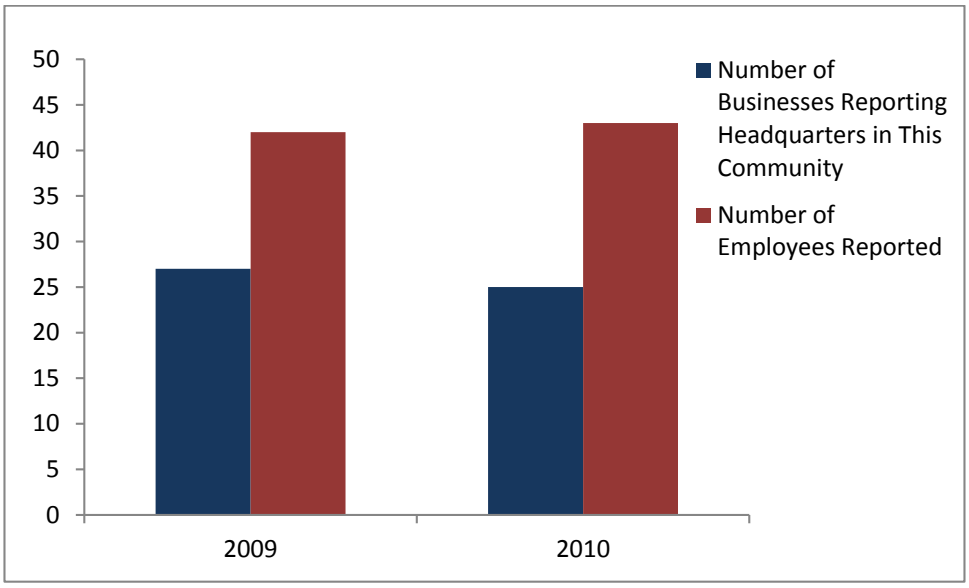
4.1 The Town of Faro

During Faro's peak, it had the second largest population in the Yukon at just under 2,000 inhabitants in 1981. However, the most recent (as of June 2013) population estimates based on the Yukon Health Care Registration state it is home to 392 people (Yukon Department of Health and Social Services, 2013). This significant decline in population was a result of the closure of the FMC. Given its once large population, Faro boasts some extensive community facilities for a town of 300, including an airport, elementary and secondary schools, a recreation centre, a health centre, a post office, and a nine-hole golf course.

4.1.1 Economy and Employment

Faro is home to 25 businesses, which altogether employed 43 people (YG, 2011c). As Figure 6L-4 shows, numbers of businesses and employees in Faro have remained relatively consistent for 2009 and 2010. It should be noted that the figure below (6L-4) represents the number of businesses headquartered in Faro and the number of people those businesses employ. The labour force accounts in later graphs represent the total labour force for Faro, including businesses without local headquarters.

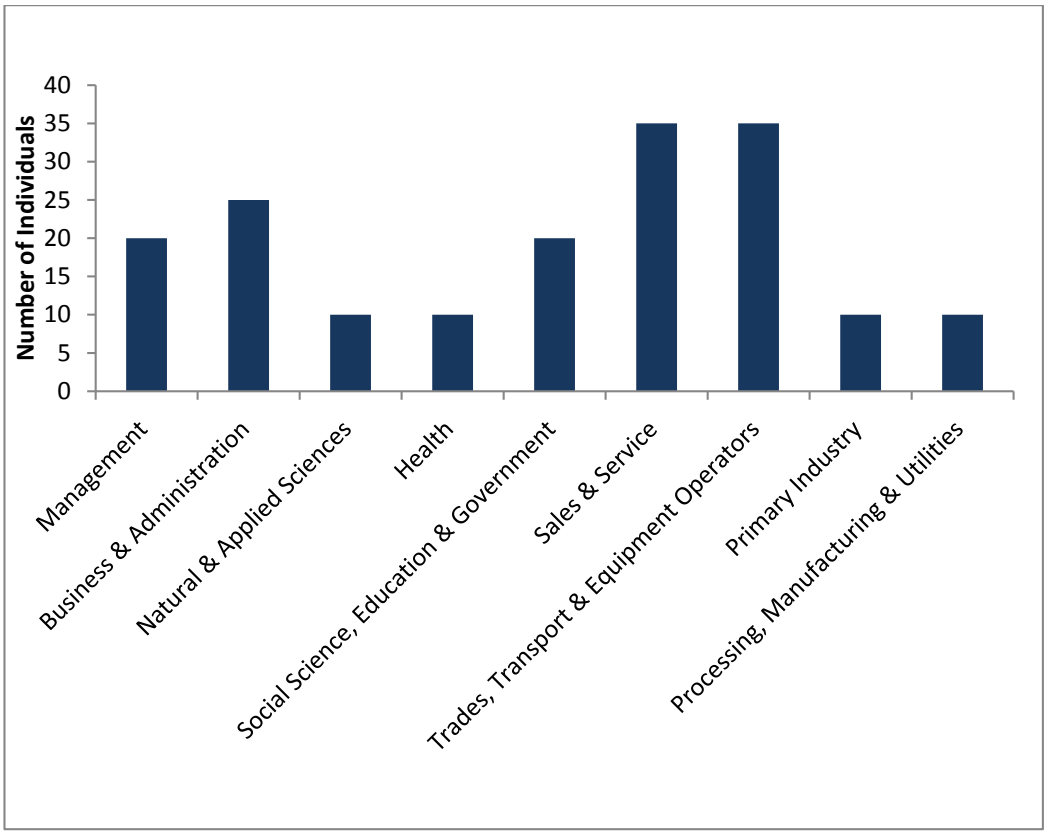
FIGURE 6L-4
Faro: Business and Employees in 2009 and 2010
Faro Mine Interim Works



Source: YG, Bureau of Statistics 2013.

Labour force by occupation shows sales and service, and trades, transport and equipment operators as the most reported occupations (Figure 6L-5). The labour force includes employed and unemployed individuals who are those without work, are available for work, and are actively seeking work.

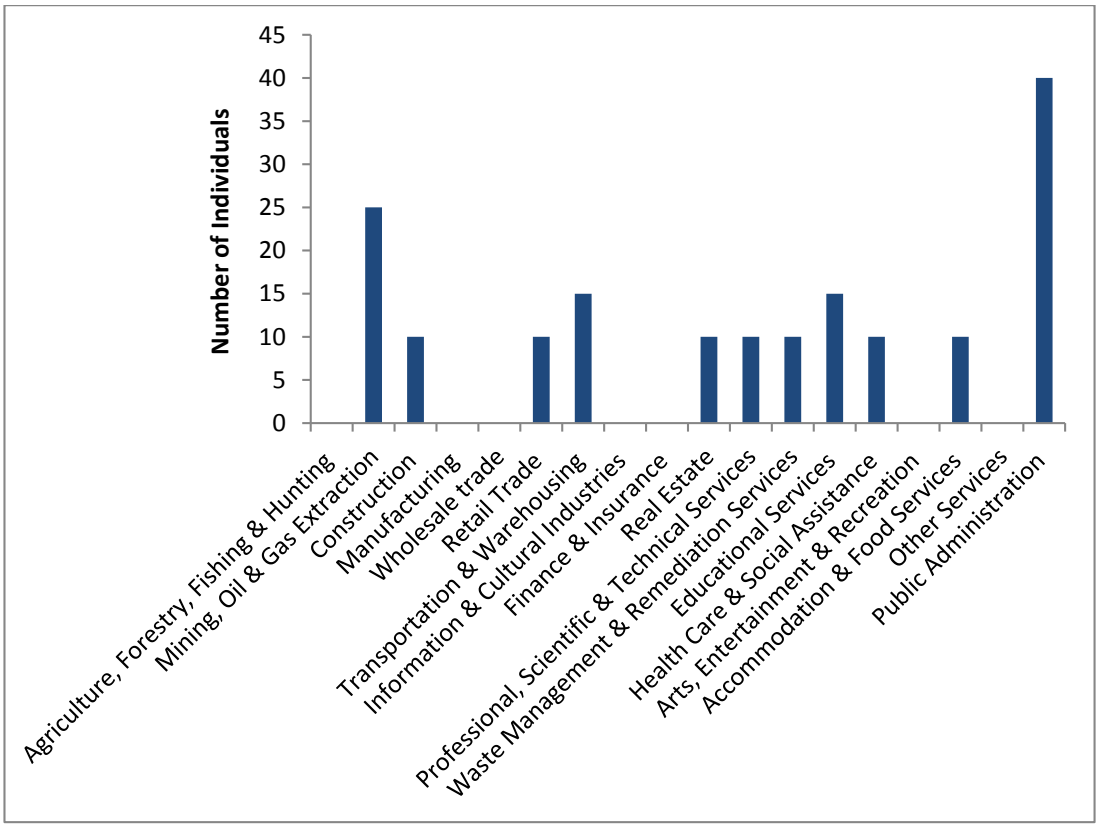
FIGURE 6L-5
Faro: Labour Force by Occupation from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

In terms of largest labour force by industry in Faro, public administration accounted for 22 percent of the overall labour force (185 individuals) in 2005 (Figure 6L-6).

FIGURE 6L-6
Faro: Labour Force by Industry from Census 2006
Faro Mine Interim Works



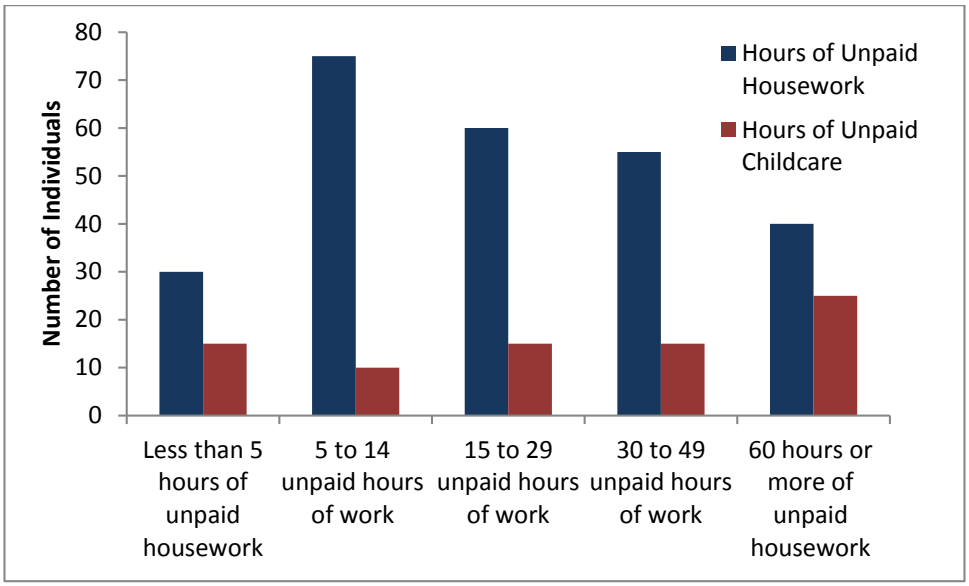
Source: Statistics Canada, 2008.

The mining sector was the second largest labour force segment, accounting for 14 percent of the overall labour force (185 individuals). The labour force participation rate for Faro was 67 percent in 2005 (Statistics Canada, 2008). The main employers in Faro are government accounting for 22 percent of labour force. The private sector provides employment in the construction, mining, service industry, and tourism fields. Faro is also home to a multitude of small home-based businesses and artisans (YG, 2013c).

The following figures show the number of individuals by hours of unpaid work per week including housework and childcare (Figure 6L-7), and senior care (Figure 6L-8). In regards to unpaid work in 2005, of the total Census population sample (280 individuals), more than one quarter reported spending 5 to 14 hours weekly doing unpaid housework. The number of individuals indicating 15 to 29 hours and 30 to 49 hours weekly of unpaid housework was relatively equal at approximately 20 percent each. Fourteen percent of respondents reported 60 or more hours of unpaid housework.

Number of weekly unpaid hours spent providing childcare was much less than unpaid housework. Approximately 4 percent of the total respondents (280 individuals) claimed performing 5 to 14 hours weekly of unpaid childcare, while 5 percent of respondents equally indicated 15 to 29 and 30 to 49 unpaid hours. Nine percent of individuals reported 60 or more hours weekly dedicated to childcare. This is corroborated by the population data in Section 4.1.2, which shows Faro has a relatively older demographic profile.

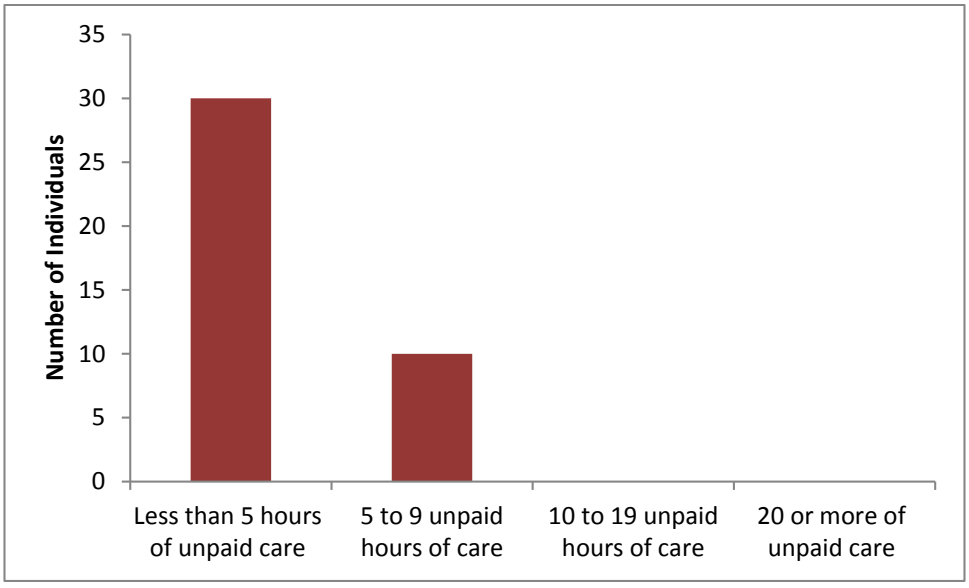
FIGURE 6L-7
Faro: Population by Weekly Hours Spent Doing Unpaid Work (Housework and Childcare) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

As shown below (Figure 6L-8), few individuals reported providing care or assistance to seniors without pay. Of the total survey respondents (280 individuals), 11 percent reported less than five unpaid hours weekly for senior care and even fewer (4 percent) reported spending 5 to 9 hours for unpaid care per week.

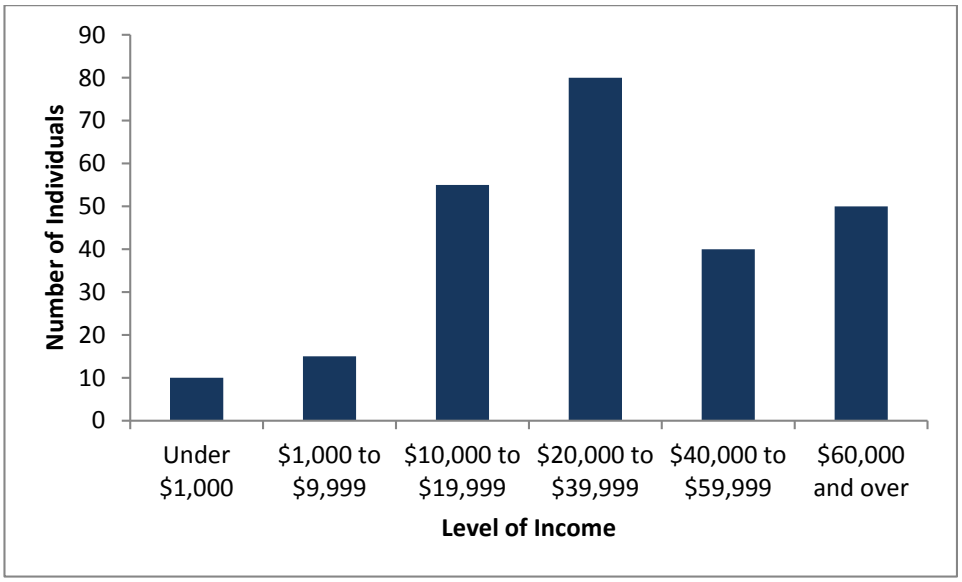
FIGURE 6L-8
Faro: Population by Weekly Hours Spent Doing Unpaid Work (Senior Care) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

In 2005, the average annual individual pre-tax income for residents of Faro was $34,232; the average annual household income was $59,628 for the same year as shown in Figure 6L-9 (Statistics Canada, 2008).

FIGURE 6L-9
Faro: Annual Individual Pre-tax Income from Census 2006
Faro Mine Interim Works

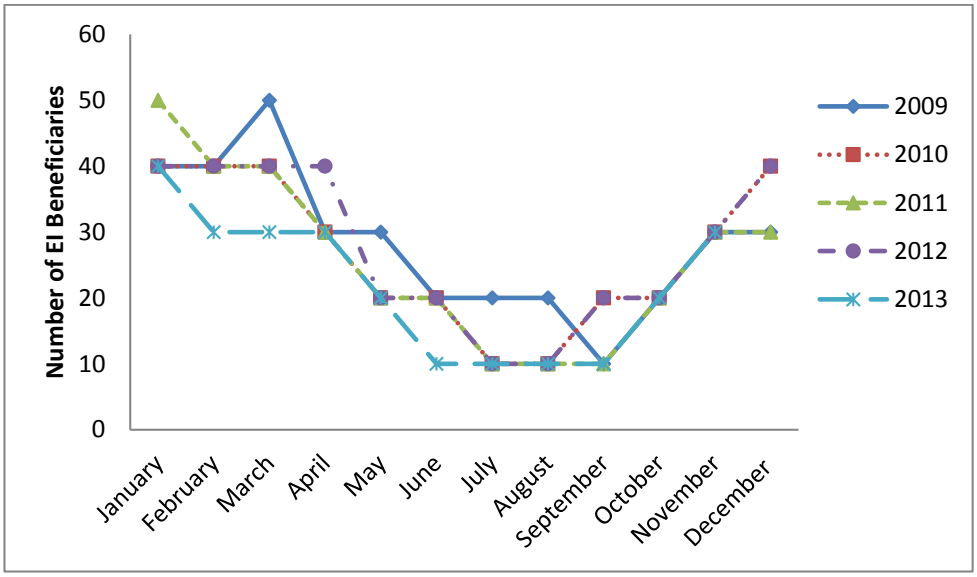


Source: Statistics Canada, 2008

According to the Canada Revenue Agency, a total of 290 tax returns were filed by Faro residents for the 2009 tax year, of which 190 included taxable income. Total income reported on all returns was $11.4 million in 2009 (Canada Revenue Agency, 2011).

Individuals receiving regular employment insurance (EI) benefits—which excludes benefits associated with sickness, maternity, fishing, work sharing, adoption, parental, regular, training, job creation, and self-employment assistance—have remained relatively stable between 2009 and 2013. As observed in Figure 6L-10, the greatest number of EI benefits occurs during the winter months between November and April. Lower EI levels during the summer months may be attributed to increased employment associated with the busier tourism industry, field research, and environmental work that typically occurs during the warmer months. Recently, there has been a slight decrease in the number of EI beneficiaries during the winter months.

FIGURE 6L-10
Faro: Employment Insurance Beneficiaries from 2009 to 2013
Faro Mine Interim Works

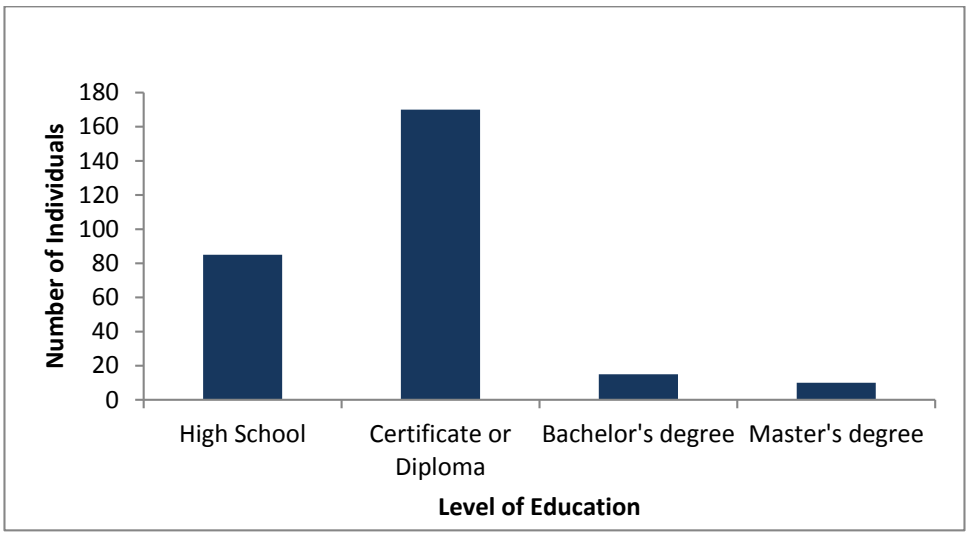


Source: Statistics Canada, no date.

The Consumer Price Index measures the cost of living experienced by communities in Canada. Relative to Whitehorse, in 2012 Faro residents spent $1.11 for every dollar that was spent in Whitehorse on household goods and supplies, and in 2013 that rose very slightly to $1.17 (YG, 2013c). In addition to shopping online and by phone, Faro residents often travel to Whitehorse for shopping. People in Faro supplement groceries by hunting, fishing and harvesting from the hinterland surrounding their community (YG, 2013c).

The highest levels of educational attainment in Faro are shown in Figure 6L-11.

FIGURE 6L-11
Faro: Education Levels from Census 2006
Faro Mine Interim Works



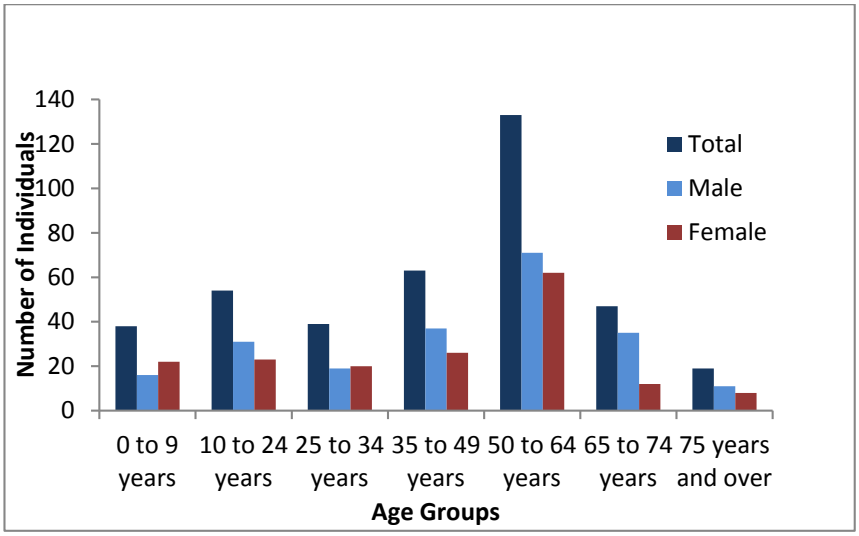
Source: Statistics Canada, 2008.

Of the 275 individuals aged 15 years and older, the 2006 Census data reported 95 had completed a certificate or diploma in the trades or other non-university programs. A total of 25 individuals reported having a Bachelor's or Master's degree as their highest level of schooling (Statistics Canada, 2008).

4.1.2 Community Stability and Well-being

Figure 6L-12 shows population estimates by age and sex from the Yukon Health Care Registration from June 2013.

FIGURE 6L-12
Faro: Population by Age and Sex in 2013
Faro Mine Interim Works

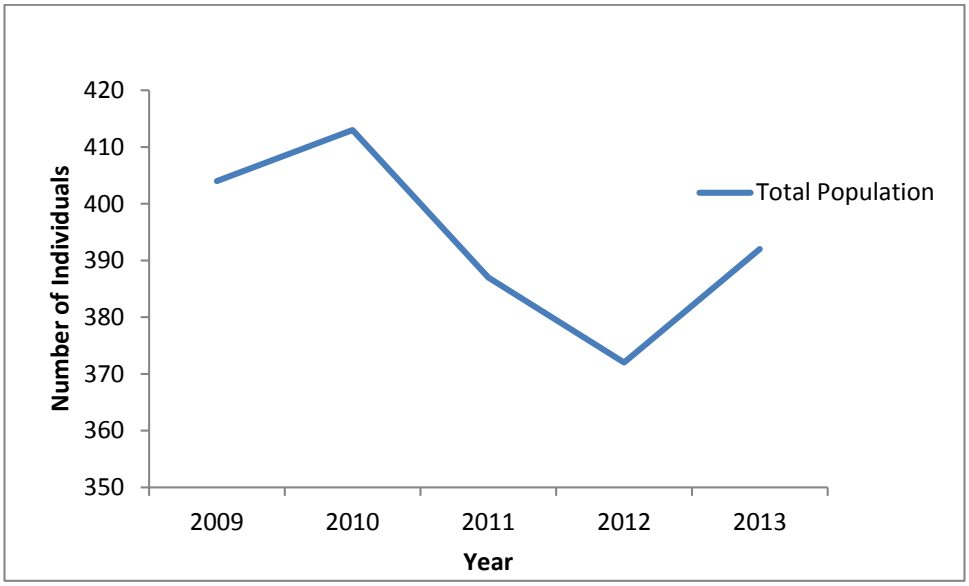


Source: YG, Department of Health & Social Services and Yukon Bureau of Statistics, 2013.

Of the 392 residents in Faro as of June 2013 there were 219 males and 173 females (YG, 2013a). In general, Faro has an aging population, especially as compared to other communities in the study area (YG, 2013a).

Figure 6L-13 shows a slight decline in population from 2010 to 2012. However, between 2012 and 2013, the population rose.

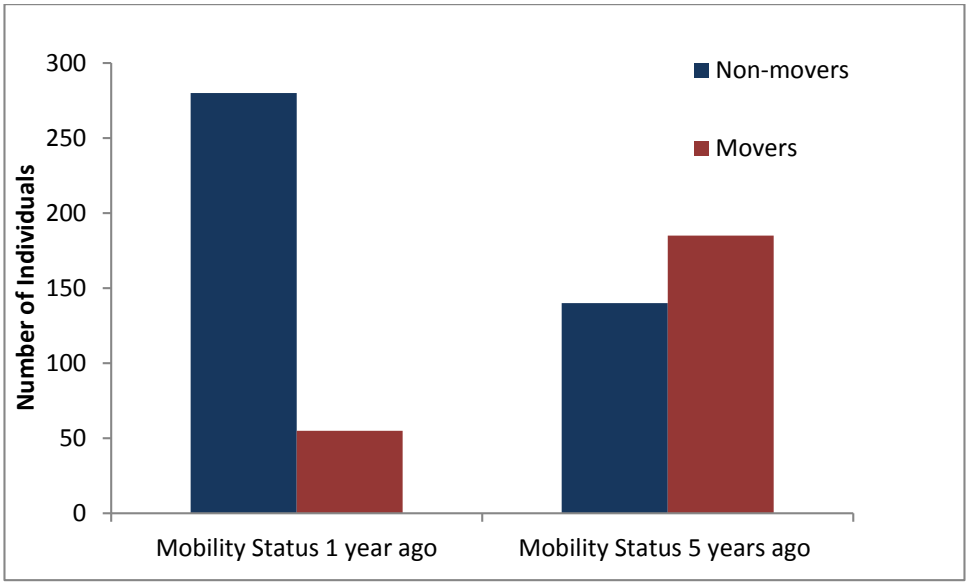
FIGURE 6L-13
Faro: Total Population from 2009 to 2013
Faro Mine Interim Works



Source: YG, Department of Health & Social Services and Yukon Bureau of Statistics, 2013.

As Figure 6L-14 shows, most people in Faro are non-movers, reporting no moves within the previous year, which signifies a very stable population base. Mobility status from 5 years ago indicates if a respondent moved within the last 5 years.

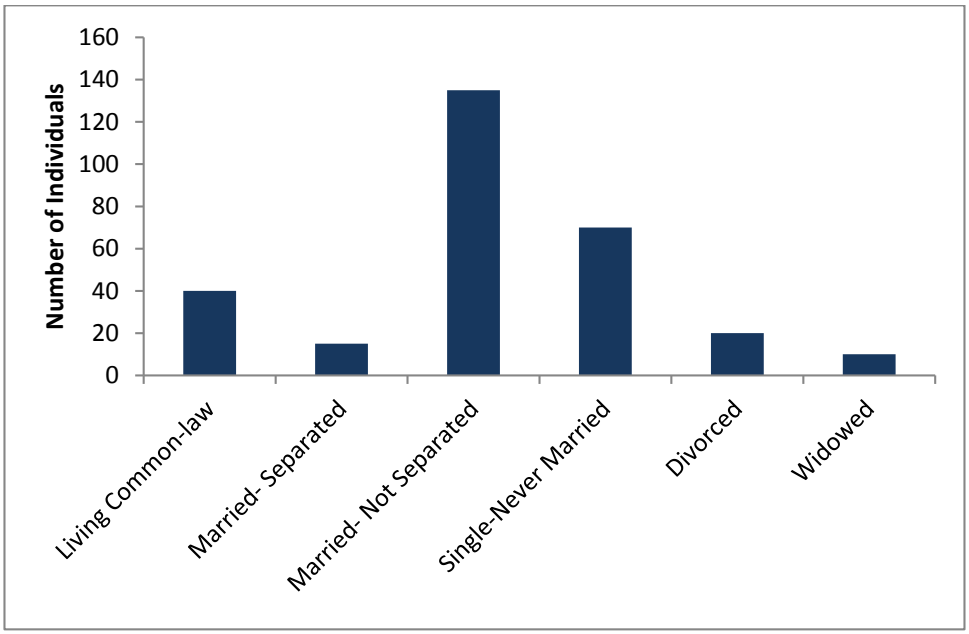
FIGURE 6L-14
Faro: Mobility Status from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

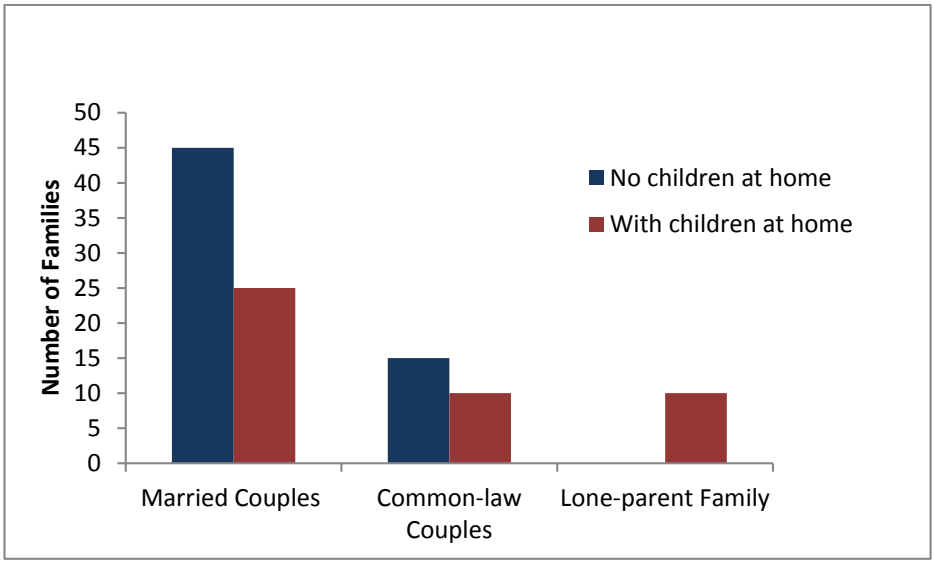
Faro has a large number of homes with married or common-law couples, with no children living at home (Figures 6L-15 and 6L-16) (Statistics Canada, 2012a).

FIGURE 6L-15
Faro: Marital Status from Census 2011 [1]
Faro Mine Interim Works



Source: Statistics Canada, 2012a.

FIGURE 6L-16
Faro: Family Structure from Census 2011
Faro Mine Interim Works

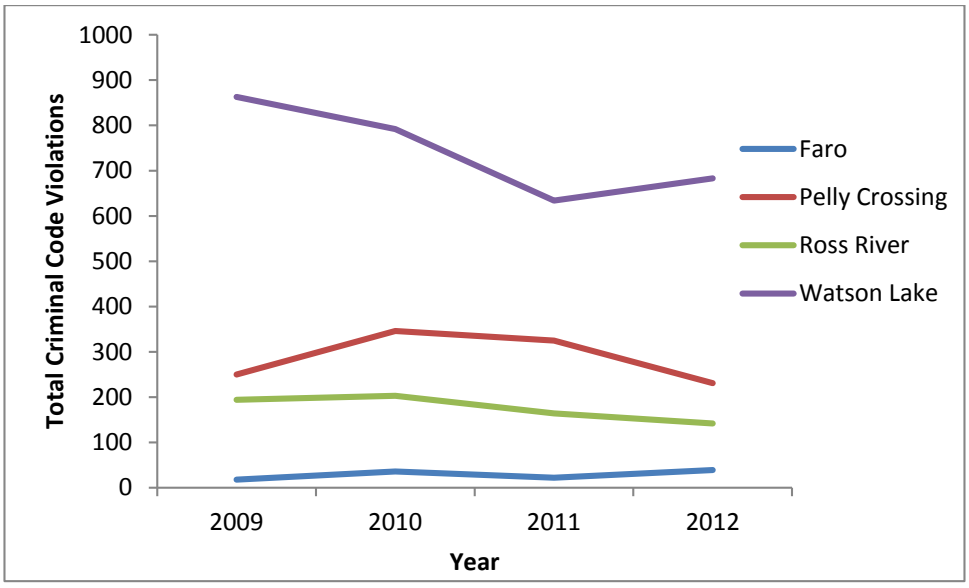


Source: Statistics Canada, 2012a.

[1] Statistics Canada provides the following classifications of marital status: "Living common-law includes persons who are living with person of the opposite sex or of the same sex as a couple but who are not legally married to that person. Married-separated includes persons currently legally married, but who are no longer living with their spouse and have not obtained a divorce. Married includes persons whose opposite- or same-sex spouse is living, unless the couple is separated or a divorce has been obtained. Also included are persons in civil unions. Single includes persons who have never married (including all persons less than 15 years of age). It also includes persons whose marriage has been legally annulled who were single before the annulled marriage and who have not remarried. Widowed includes persons who have lost their legally-married spouse through death and who have not remarried" (Statistics Canada, 2012b).

As Figure 6L-17 shows, in comparison with other communities in the Yukon, Faro has very low rates of crime (YG, 2012).

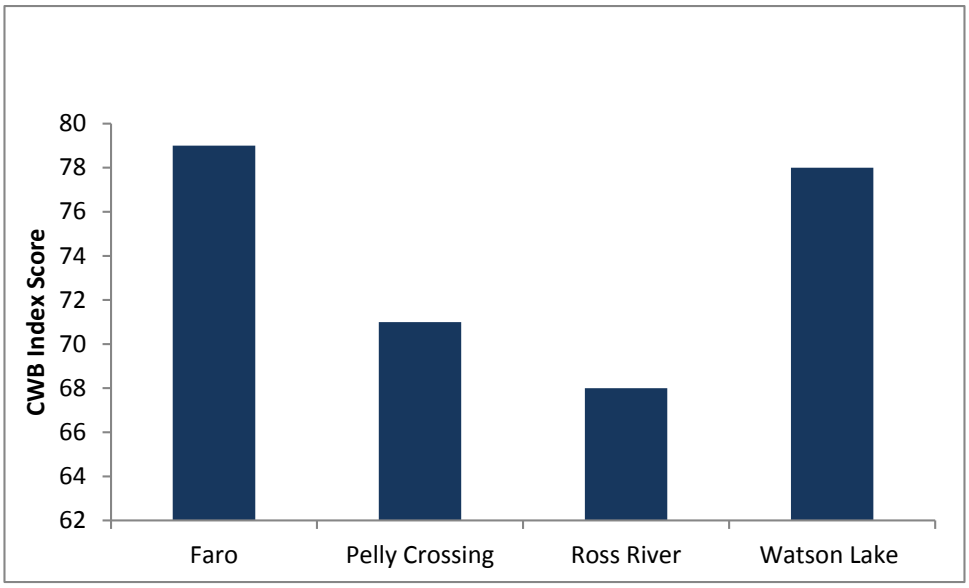
FIGURE 6L-17
Community Crime Rates: 2009-2012
Faro Mine Interim Works



Source: Yukon Bureau of Statistics, 2012.

The Community Well-Being score is a number generated by Aboriginal Affairs and Northern Development Canada (AANDC) which reflects data on income, education, housing conditions and labour force activity. It can range from a low of 0 to a high of 100. Figure 6L-19 presents the Community Well-Being score for all communities in the study area in 2006, indicating that Faro and Watson Lake had higher scores.

FIGURE 6L-19
Community Well-Being Index Score in 2006
Faro Mine Interim Works



Source: AANDC Community Well-Being Database. 2006

4.1.3 Infrastructure and Services

Faro has high-speed internet over telephone lines, as well as landlines and cell phone service provided by Northwestel. Yukon Energy Corporation provides customer electricity directly in Faro.

Faro has a kindergarten to grade 12 school with a 2012 enrollment of 39 students and 52 students enrolled as of September 2013 (YG, 2013c). Yukon College has a local community campus and coordinator, and courses are offered on-line or via teleconference facilities. The community library is co-located with the Del Van Gorder School, with free internet and computer access.

Faro is located approximately 358 km northeast of Whitehorse and 179 km east of Carmacks on the Robert Campbell Highway. The Faro Airport, located adjacent to Johnson Lake 3.5 km from Faro, has a 4,000-foot gravel runway and there is also a nearby float-plane base at Johnson Lake (YG, 2013c).

Faro has a nursing station staffed by two nurses on call 24 hours a day, as well as 24-hour access to Yukon HealthLine 811. The Yukon Children's Dental Program comes to Del Van Gorder School on a regularly scheduled basis. More complex medical and dental treatment is handled in Whitehorse, or, depending on the specialty required, outside of Yukon. In emergency situations patients are medevac'd out of Faro to the nearest appropriate facility.

Faro has a 24-hour ambulance service staffed by volunteers, which also services the community of Ross River. It also has a Royal Canadian Mounted Police detachment and volunteer fire services.

There are approximately 425 dwellings (2011) in Faro, which are a mixture of single family, multi-units, and mobile homes, as well as a country residential subdivision within the municipal boundary (YG, 2013c).

Faro is surrounded by natural beauty in the form of lakes, rivers and mountain ranges, and is home to abundant and rare wildlife, such as the Fannin Sheep, as well as migratory species like the Sandhill Cranes. The remaining community members have made great efforts in recent years to further tourism development for the community as a means to decrease dependence on the cyclical resource development sector as their main economic driver (YG, 2013).They have also been successful in attracting new community members interested in the natural environment and the arts (Miyagawa, 2004).

Faro has an active recreational community in both summer and winter. Local recreational facilities include softball, squash, a seasonal pool, ice rink, and carpet bowling. Faro also has a nine-hole golf course, a gym and weight room in the recreational centre, several playgrounds, and an arboretum. Hiking trails are well established, as are wildlife-viewing stations for cranes and sheep. The Dena Cho Trail and Van Gorder Falls trail provide outdoor hiking and skiing opportunities. Johnson Lake and Fish Eye Lake provide space for outdoor recreation, including swimming, water-skiing, fishing, and boating. Johnson Lake also supports a float-plane base and canoe-rental facility (YG, 2013c).

Faro is an incorporated municipality, so is responsible for delivering services to properties and residents within its boundary, such as fire protection, water, and road maintenance. Area residents living outside the municipal boundary are serviced by YG. Faro typically has an elected Mayor and four Councillors; the current government is identified in Table 6L-3.

TABLE 6L-3
Faro Mayor and Council (2014)
Faro Mine Interim Works

Name	Role
Mel Smith	Councillor
Heather Grantham	Councillor
Deborah Carreau	Deputy Mayor
Mike McMahon	Councillor

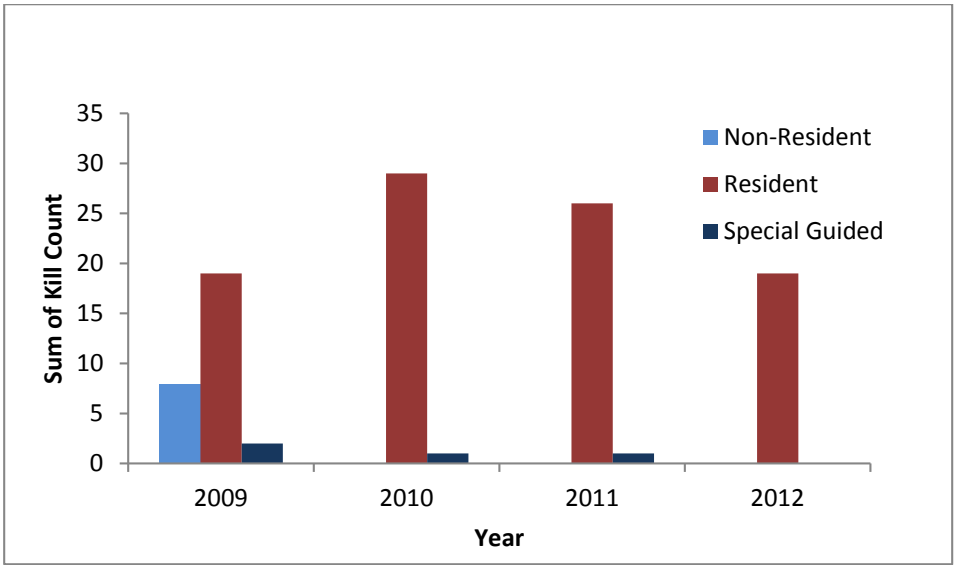
Source: Town of Faro, 2014

4.1.4 Land Use and Access

Timber harvest occurs in the area around Faro, primarily for personal and commercial home heating fuel (YG, 2011b). The Mount Mye Timber Harvest Plan identifies a timber harvest area to the east of the FMC (YG, 2011b). The area is part of the historic Faro burn of 1969. It is anticipated that 5,000 cubic metres of timber can be harvested from the area. To access the timber harvest area, permit holders must travel on the Blind Creek mining road and some parts of the identified timber harvest areas overlap with the FMC reserve.

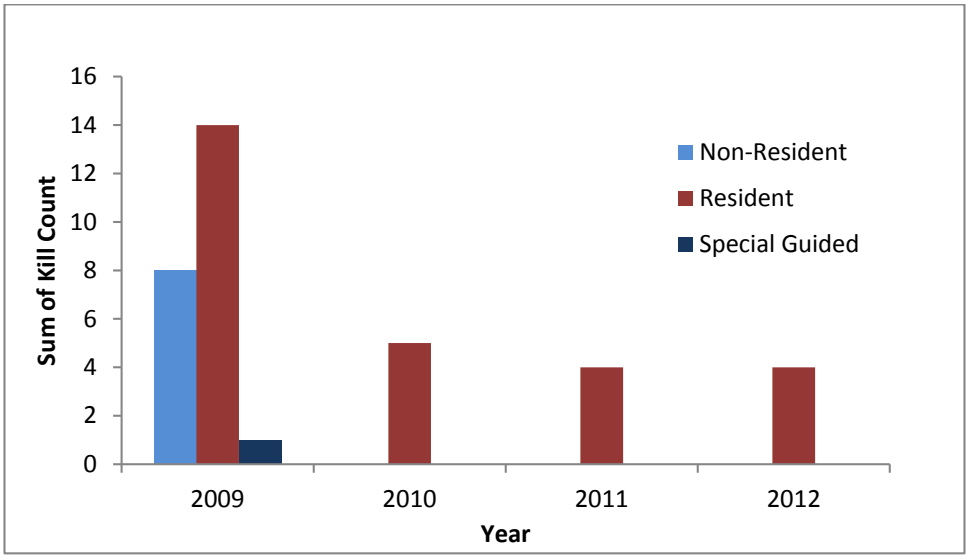
There is wildlife harvest (particularly moose and caribou by resident hunters) (Figures 6L-20 and 6L-21) in Game Management Subzones (GMS) 445 and 446 (Figure 6L-22), which are accessed through the FMC.

FIGURE 6L-20
Moose Harvest in GMS 445 and 446, 2009 to 2012
Resident, Non-Resident, and Special Guided (does not include First Nations harvest)
Faro Mine Interim Works



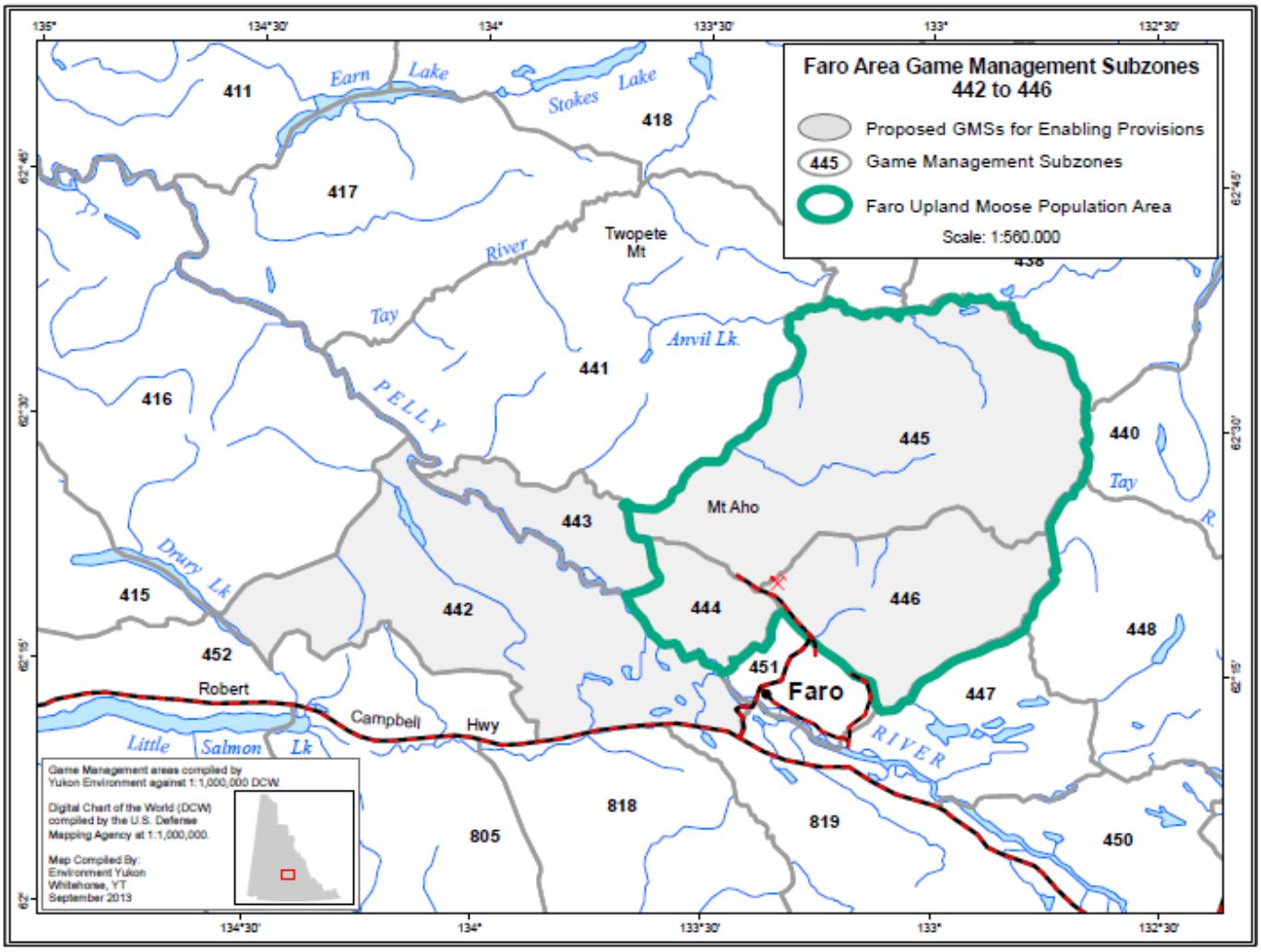
Source: Yukon Government Department of Environment, no date

FIGURE 6L-21
Caribou Harvest in GMS 445 and 446, 2009 to 2012
Resident, Non-Resident, and Special Guided (does not include First Nations harvest)
Faro Mine Interim Works



Source: Yukon Government Department of Environment, no date

FIGURE 6L-22
Faro Area Game Management Subzones 442 to 446
Faro Mine Interim Works



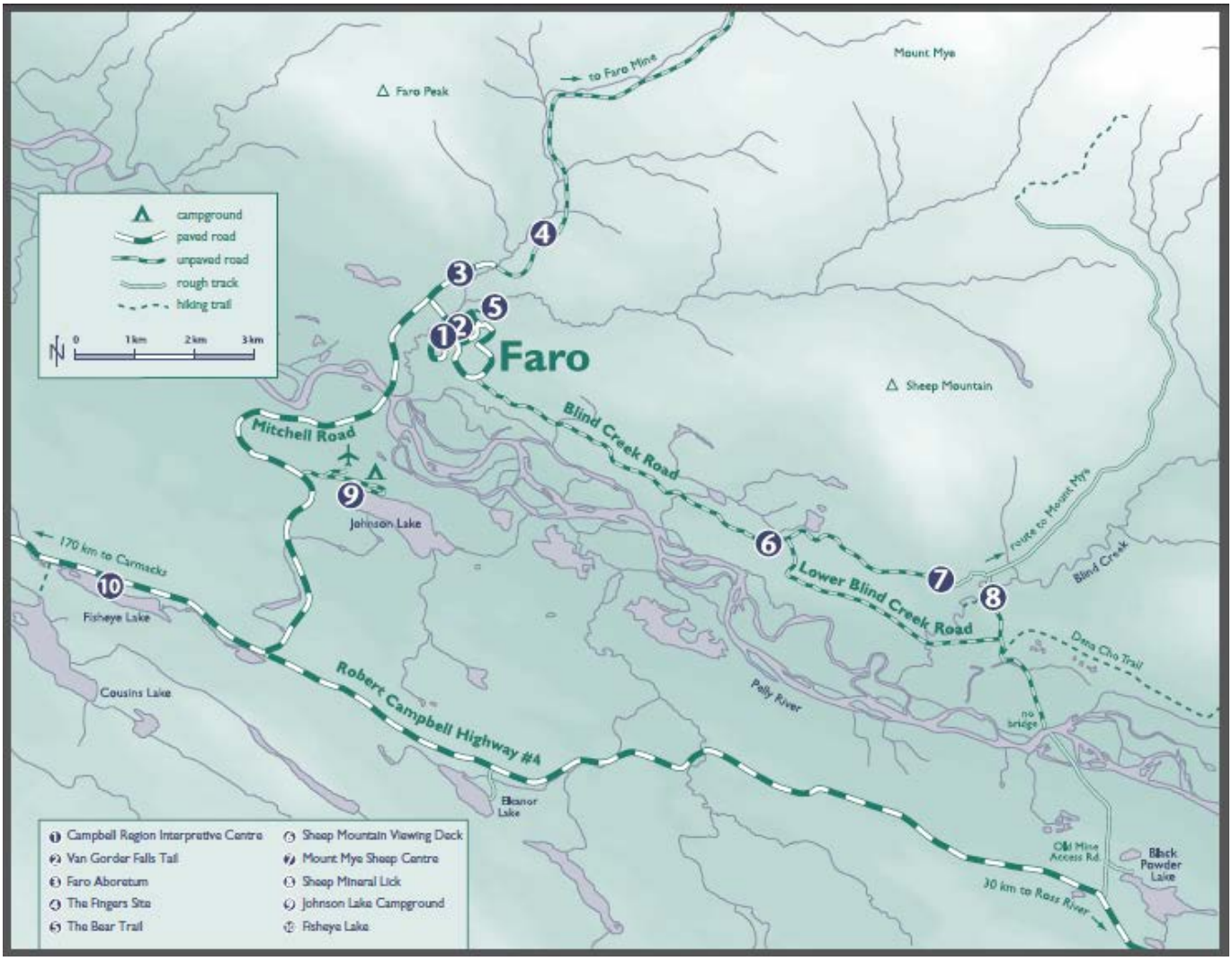
Source: Yukon Fish and Wildlife Management Board Website, 2013

Moose hunters have been asked to voluntarily limit their harvest in the area since 1999, for reasons unrelated to the FMC. However, harvest rates for licensed hunters remain high and consistently are over standard harvest management thresholds (Yukon Fish and Wildlife Management Board, 2013). YG is currently considering further moose harvest management regulations in all game management subzones in the Faro area, which may have an effect on the number of harvesters that access the FMC in the future.

There are several hiking and mountain biking trails designated around Faro. The Dena Cho Trail is a 65-km multi-use trail that has been established using traditional travel routes between Faro and Ross River. Trail-based activities are widely promoted as a recreation and tourism opportunity in the region (Town of Faro, 2007).

Yukon has a wildlife-viewing plan that identifies viewing areas close to the FMC (Figure 6L-23) (YG 2013c).

FIGURE 6L-23
Tourism Sites in the Faro Area
Faro Mine Interim Works



Source: YG, 2011

The Mount Mye Sheep Centre has a heated cabin and viewing platform for viewing sheep on Mt. Mye. Each May, Faro hosts a Crane and Sheep viewing festival during the annual migration of the Sandhill cranes. This has become a major event for the community and draws visitors from around the territory to view the cranes as they migrate up the Tintina Trench (Town of Faro, 2013).

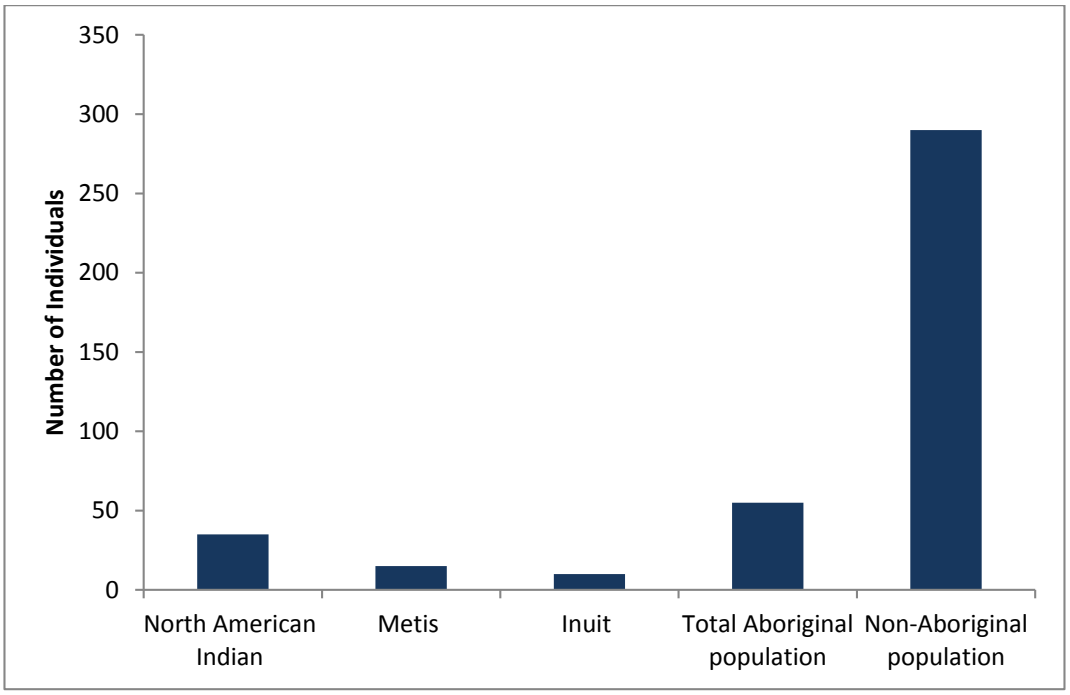
Tourism has become a major focus of the community and is identified as a priority in Faro's Integrated Community Sustainability Plan (Town of Faro, 2007). At present, there are at least six bed and breakfasts and one hotel in Faro (Town of Faro, 2013). All advertise wilderness experiences as a major reason to visit the Faro region. Faro is also home to the Yukon's Campbell Region Visitor's Centre, providing services to local visitors and housing a small museum covering the region's natural and human history (Town of Faro, 2013).

4.1.5 Culture and Heritage

Faro was created to service the FMC in 1969. As such, its history and heritage is very much tied to the mining industry. The community has strongly felt the boom and bust with each opening and closing of the FMC. While on-going operations at FMC and further mineral exploration in the area is important to providing economic stimulus to Faro, there has been a concerted effort in recent years to develop small home-based businesses, and tourism opportunities, such as the Crane and Sheep viewing festival.

The figure below identifies the Aboriginal population of Faro (Figure 6L-24).

FIGURE 6L-24
Faro: Aboriginal and Non-Aboriginal Population from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

Most Faro residents speak English. Although hosting a small Aboriginal population within the Town itself, Faro is located in the traditional territory of the RRDC of the KDC (see section 4.2).

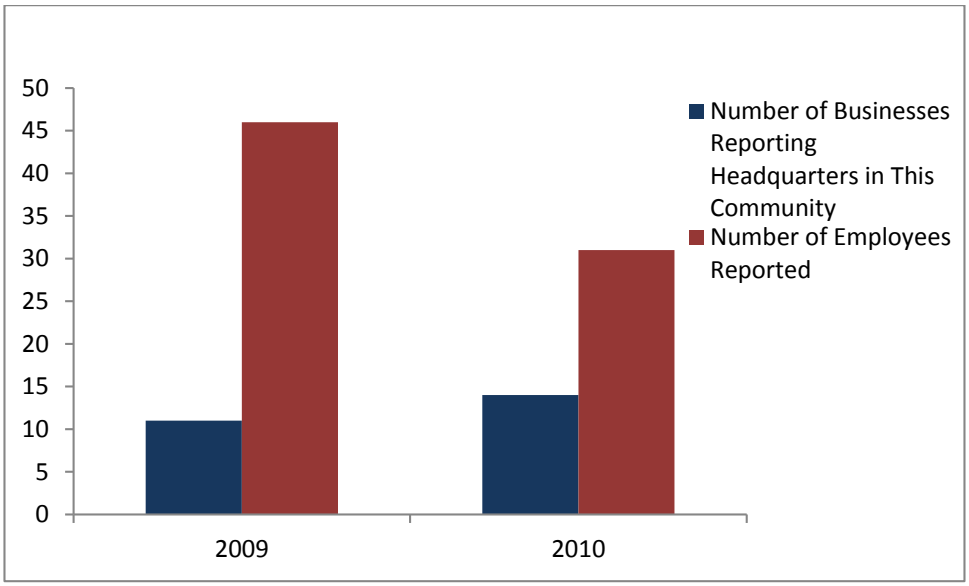
4.2 Ross River Dena Council

The confluence of the Ross and Pelly Rivers was traditionally used as a summer gathering spot for the people of the RRDC. In 1901, a fur trading post was established and created the community of Ross River. The community of Ross River is primarily home to members of the RRDC.

4.2.1 Economy and Employment

In 2010, Ross River was home to 14 businesses, which altogether employed 31 people (Figure 6L-25) (YG, 2011c). It should be noted that the Figure 6L-26 represents the number of businesses headquartered in Ross River and the number of people those businesses employ. The labour force accounts in later graphs represent the total labour force for Ross River, including businesses without local headquarters.

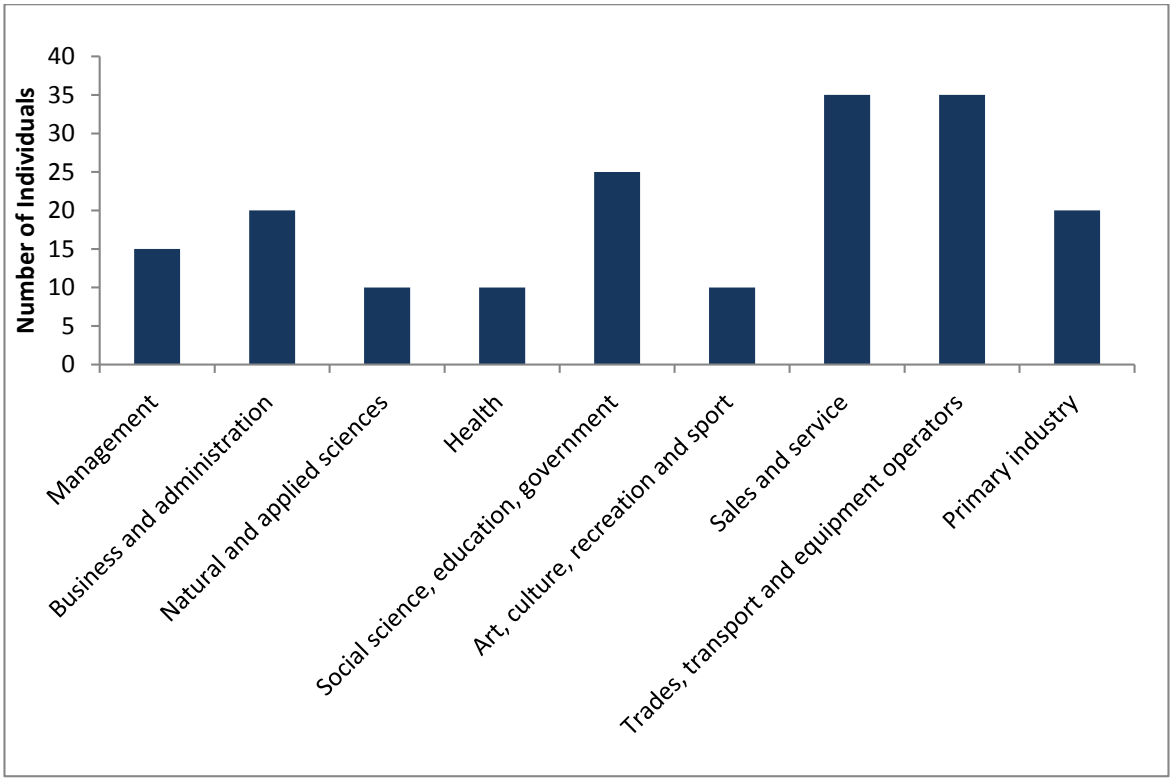
FIGURE 6L-25
Ross River: Business and Employees in 2009 and 2010
Faro Mine Interim Works



Source: YG, Bureau of Statistics, 2011c and 2010d.

Similar to Faro, sales and service, and trades, transport and equipment operators make up the majority of occupations in the labour force in Ross River (Figure 6L-26). The labour force includes employed and unemployed individuals who are those without work, are available for work, and are actively seeking work.

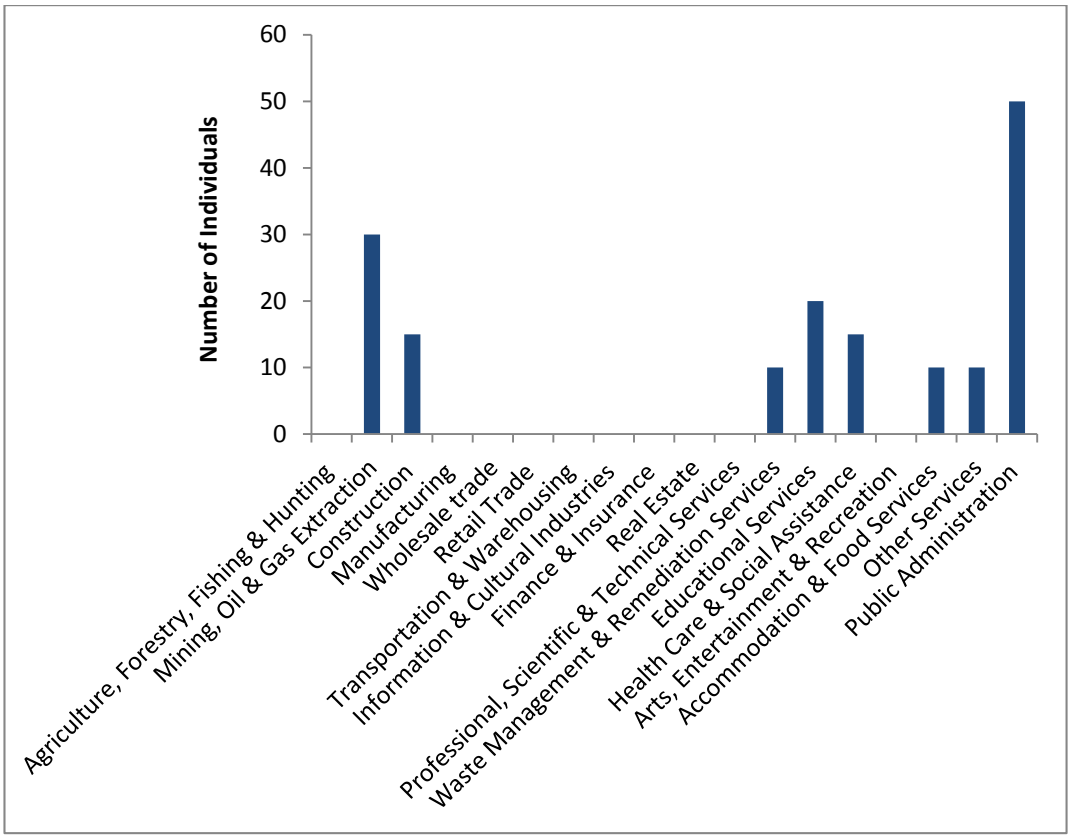
FIGURE 6L-26
Ross River: Labour Force by Occupation from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

In terms of labour force by industry in 2005, public administration accounted for 31 percent of the overall labour force (165 individuals) (Figure 6L-27).

FIGURE 6L-27
Ross River: Labour Force by Industry from Census 2006
Faro Mine Interim Works



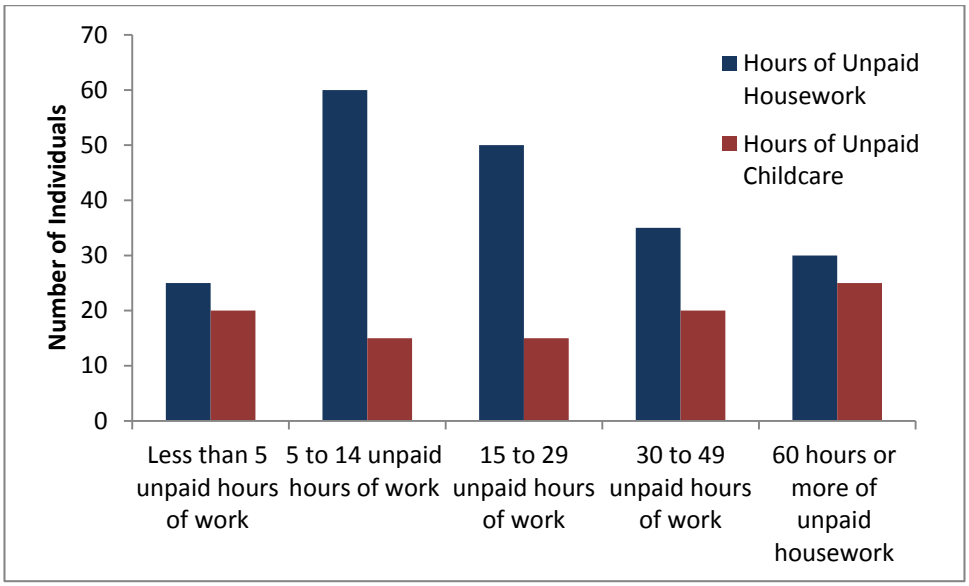
Source: Statistics Canada, 2008.

Following public administration, the mining sector was the second largest labour force segment, accounting for 19 percent of the overall labour force (165 individuals). The labour force participation rate for Ross River was 72 percent in 2005 (Statistics Canada, 2006).

The following figures show the population by hours spent doing unpaid work per week including housework and childcare (Figure 6L-28) and senior care (Figure 6L-29). In regards to unpaid housework, in 2005, more than one quarter of the Census population sample (230 individuals) reported spending 5 to 14 hours weekly doing unpaid housework. Twenty-two percent of individuals indicated 15 to 29 unpaid hours weekly. The number of respondents reporting 30 to 49 hours weekly of unpaid housework was similar to those indicating 60 or more hours of unpaid housework at 15 and 13 percent, respectively.

Number of weekly unpaid hours spent providing childcare was less than hours of unpaid housework. Of the total number of survey respondents (225 individuals), 9 percent indicated 30 to 59 hours of unpaid care and 11 percent reported doing 60 or more hours weekly. The total number of respondents who indicated performing 5 to 14 hours and 15 to 29 hours of unpaid childcare was equal at seven percent each.

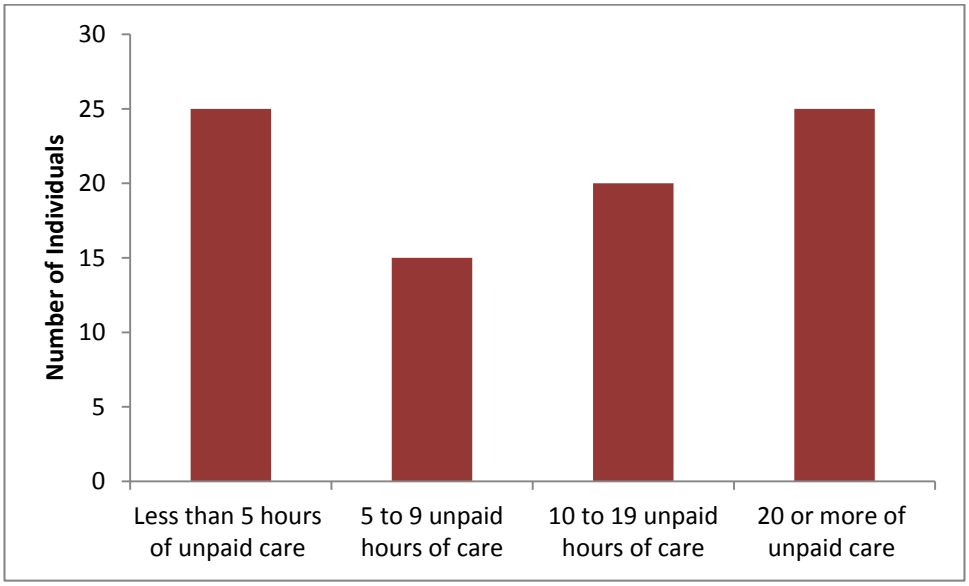
FIGURE 6L-28
Ross River: Population by Weekly Hours Spent Doing Unpaid Work (Housework and Childcare) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

In terms of providing unpaid assistance or care to seniors, 11 percent of the total survey respondents (230 individuals) reported less than five hours weekly, which was equal to the number of individuals who reported 20 or more unpaid hours weekly. Seven percent stated 5 to 9 hours and nine percent indicated 10 to 19 hours for such care without pay.

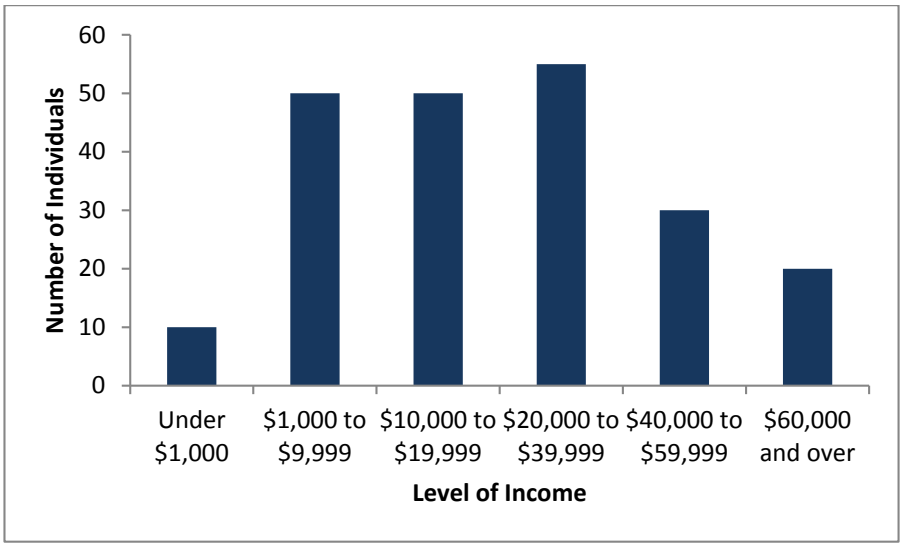
FIGURE 6L-29
Ross River: Population by Weekly Hours Spent Doing Unpaid Work (Senior Care) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

Figure 6L-30 shows in 2005, the average annual individual pre-tax income for residents of Ross River was $26,061; average annual household income was $44,069 for the same year (Statistics Canada, 2008).

FIGURE 6L-30
Ross River: Annual Individual Pre-tax Income from Census 2006
Faro Mine Interim Works

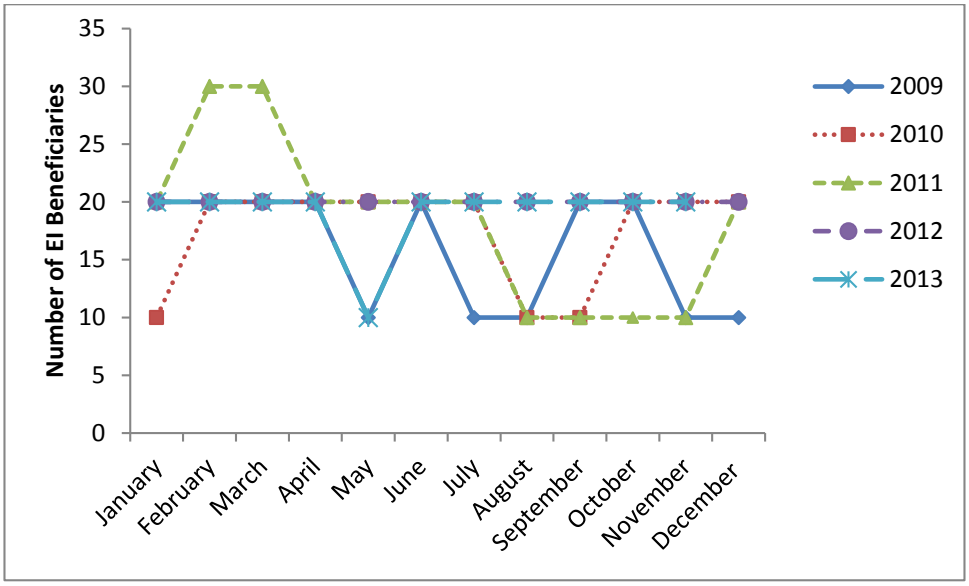


Source: Statistics Canada, 2008.

According to the Canada Revenue Agency, a total of 250 tax returns were filed by Ross River residents for the 2009 tax year, of which 130 included taxable income. Total income reported on all returns was $7.7 million in 2009 (Canada Revenue Agency, 2011).

The number of individuals receiving regular EI benefits, which excludes benefits associated with sickness, maternity, fishing, work sharing, adoption, parental, regular, training, job creation, and self-employment assistance, have remained stable during recent years (2012 and 2013). As shown in Figure 6L-31, with the exception of 2011, the number of EI beneficiaries over the years has observed slight fluctuations ranging between ten and 20 individuals in any given month.

FIGURE 6L-31
Ross River: Employment Insurance Beneficiaries from 2009 to 2013
Faro Mine Interim Works



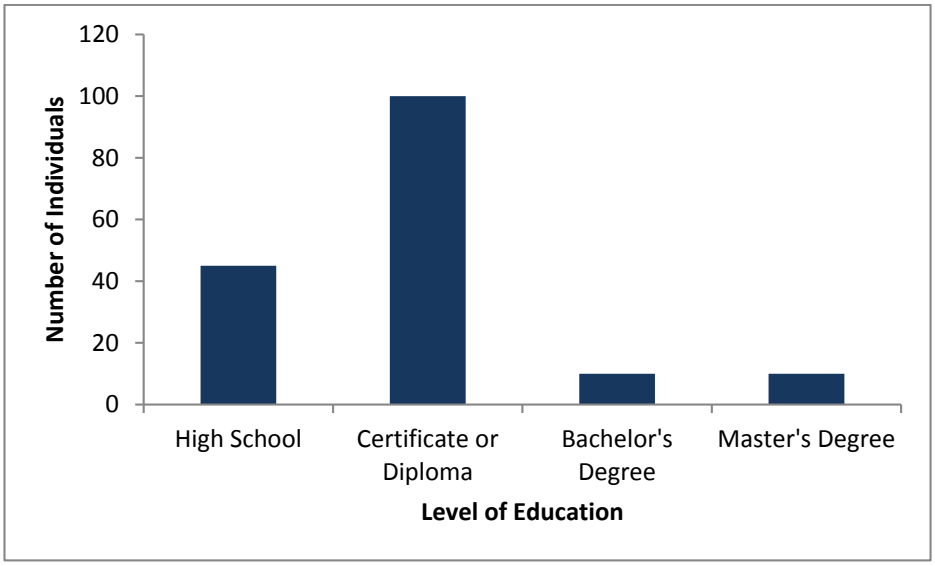
Source: Statistics Canada, no date.

The Consumer Price Index measures the cost of living experienced by communities in Canada. In 2013, Ross River residents spent $1.21 for every dollar that an individual would spend on similar goods and supplies in Whitehorse (YG, 2013e).

In Ross River, as in many rural Yukon communities, many people travel to Whitehorse (a distance of 410km) for the bulk of their household goods and provisions or order goods online or by phone. Supplementing groceries by country-harvested foods, such as game, berries and fish, is also an important aspect of household economics (YG, 2013e).

In terms of educational attainment in Ross River, of the 230 individuals who were aged 15 years and older in 2006, 100 had completed a certificate or diploma (Figure 6L-32).

FIGURE 6L-32
Ross River: Education Levels from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

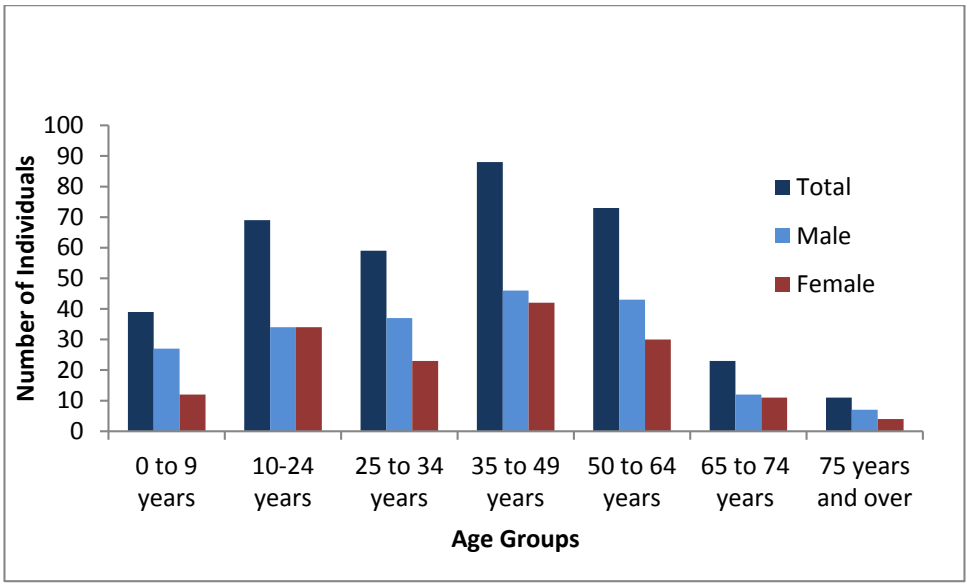
A total of 20 individuals reported having a university Bachelor's or Master's degree as their highest level of schooling (Statistics Canada, 2008).

4.2.2 Community Stability and Well-being

Estimated number of residents based on the 2011 Census is 352, but recent estimates (as of June 2013) based on the Yukon Health Care data puts it at 363 (Figure 6L-33) (YG, 2013a).

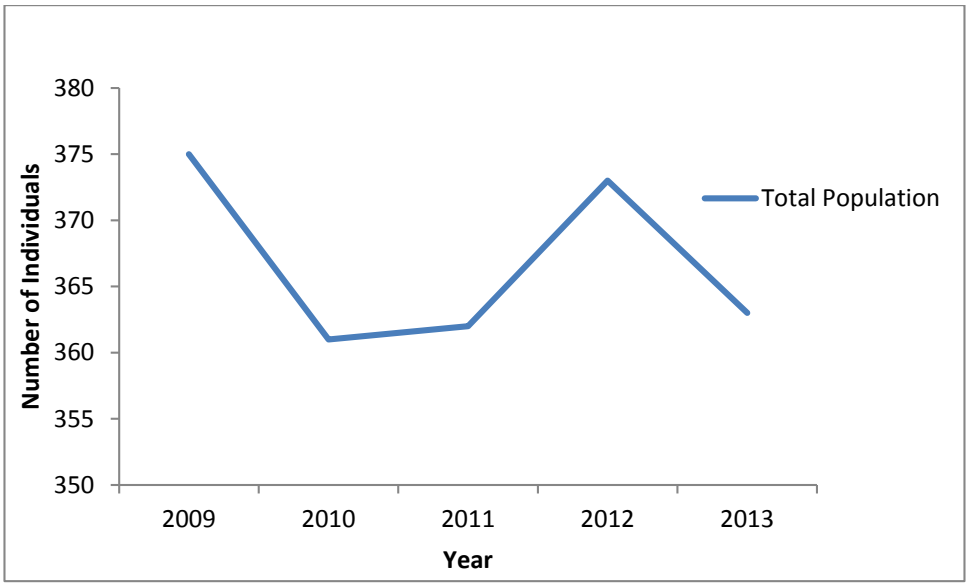
Age and sex data from the 2011 Census has been suppressed because of small sample size, but records from the Yukon Health Care Registration show in June 2013, there were 363 residents in Ross River, 206 male and 156 female (Figure 6L-34).

FIGURE 6L-33
Ross River: Population by Age and Sex in 2013
Faro Mine Interim Works



Source: YG, 2013a.

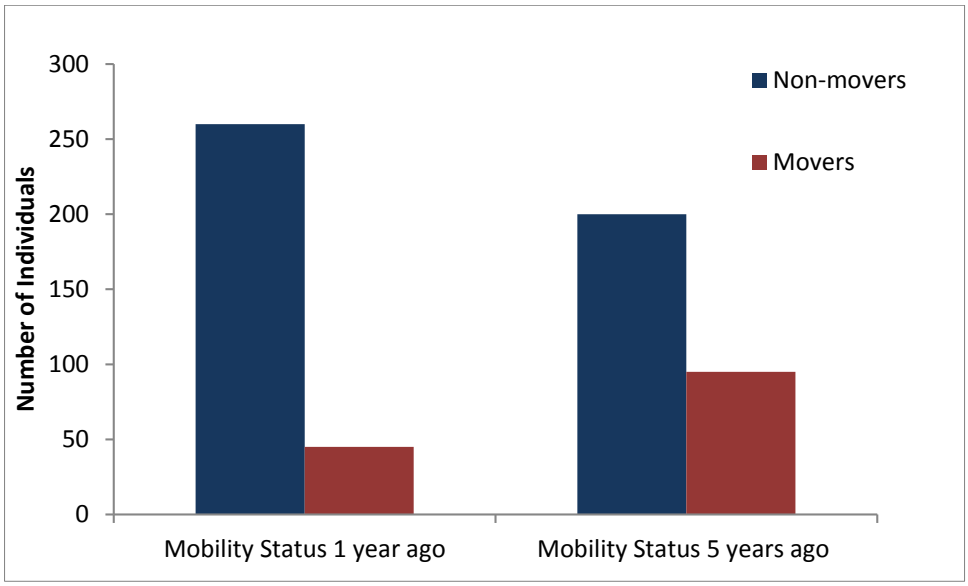
FIGURE 6L-34
Ross River: Total Population from 2009 to 2013
Faro Mine Interim Works



Source: YG, 2013a.

As found in the 2006 Census, Ross River has a very stable population base with approximately 84 percent of the total survey respondents (310 individuals) reporting no moves within the previous year (Figure 6L-35). Mobility status from 5 years ago indicates if a respondent moved within the last 5 years.

FIGURE 6L-35
Ross River: Mobility Status from Census 2006
Faro Mine Interim Works



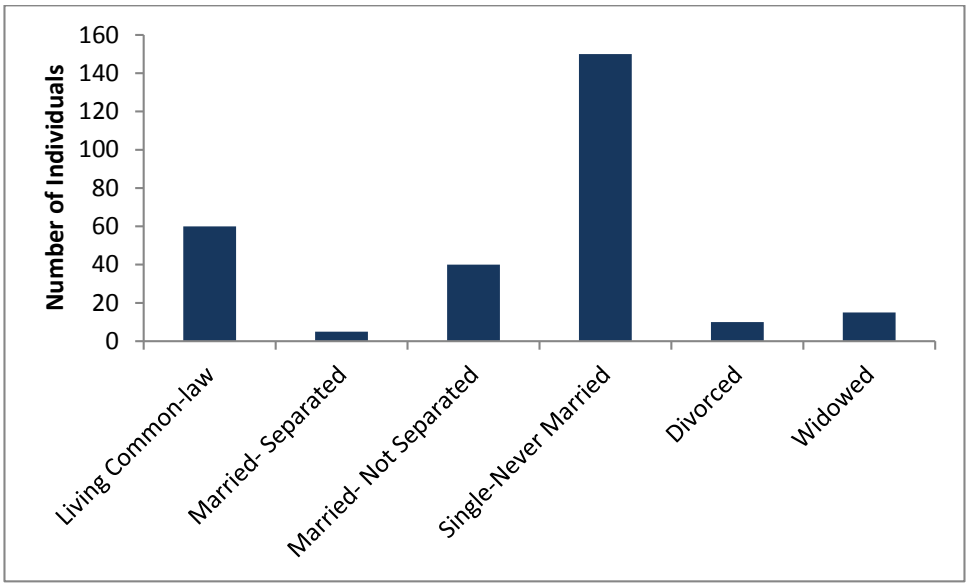
Source: Statistics Canada, 2008.

As shown below in Figure 6L-36, the majority of residents are single. Most Census data reflecting household make-up has been suppressed because of limited sample size.

FIGURE 6L-36

Ross River: Marital Status from Census 2006 [2]

Faro Mine Interim Works

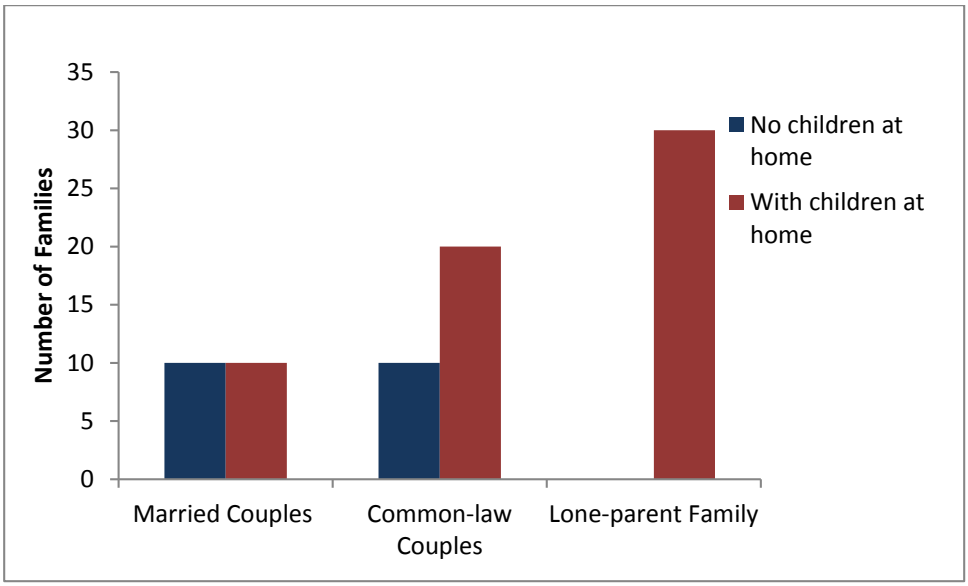


Source: Statistics Canada, 2008.

Figure 6L-37 shows family structure for the community from the 2006 Census. Of the 80 respondents, 37 percent were single parents (lone-parent family), while one quarter of common-law couples reported having children at home. Married couples equally reported having children and not having children at home.

[2] Statistics Canada provides the following classifications of marital status: "Living common-law includes persons who are living with person of the opposite sex or of the same sex as a couple but who are not legally married to that person. Married-separated includes persons currently legally married, but who are no longer living with their spouse and have not obtained a divorce. Married includes persons whose opposite- or same-sex spouse is living, unless the couple is separated or a divorce has been obtained. Also included are persons in civil unions. Single includes persons who have never married (including all persons less than 15 years of age). It also includes persons whose marriage has been legally annulled who were single before the annulled marriage and who have not remarried. Widowed includes persons who have lost their legally-married spouse through death and who have not remarried" (Statistics Canada, 2012b).

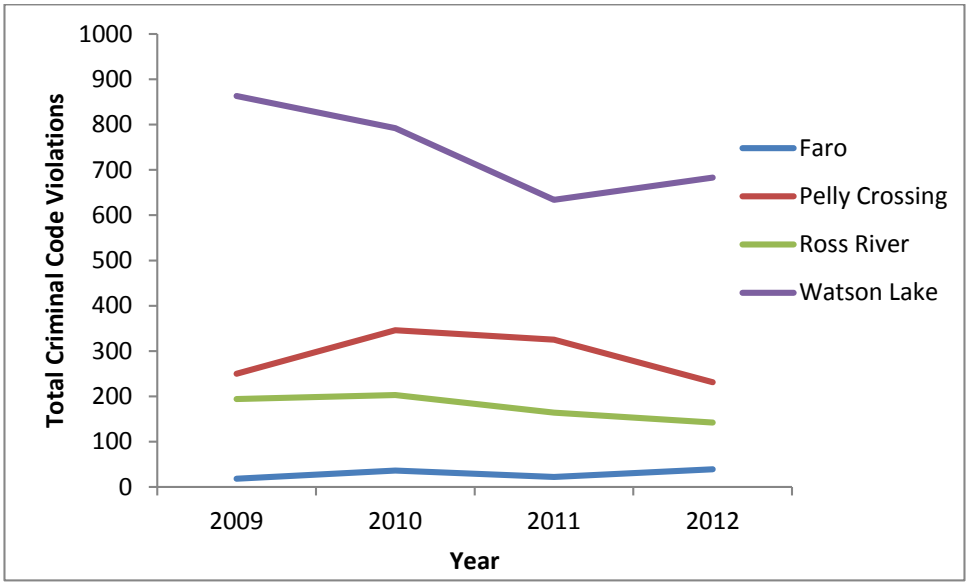
FIGURE 6L-37
Ross River: Family Structure from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

Figure 6L-38 indicates 142 Criminal Code violations were reported in Ross River in 2012. This is comparable with other communities of its size in the Yukon.

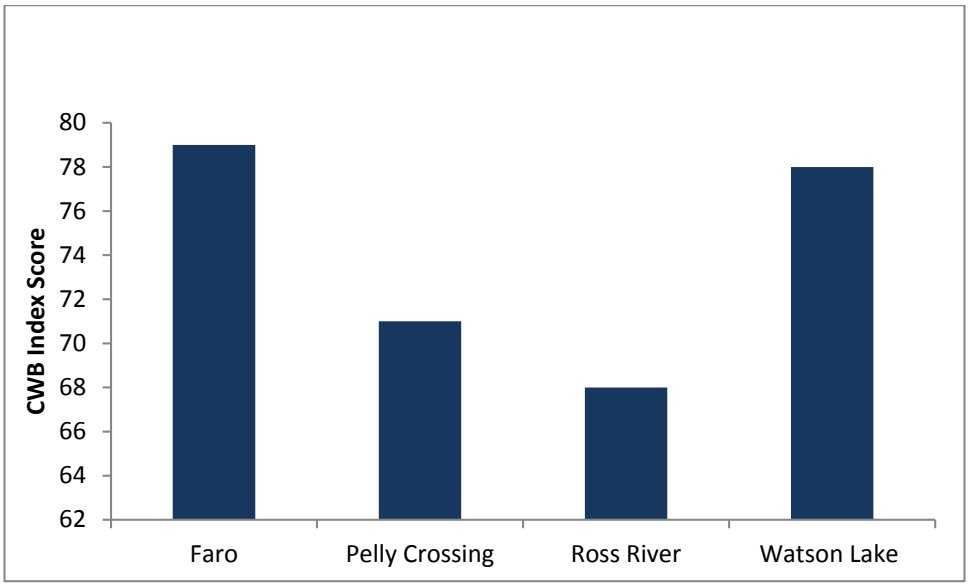
FIGURE 6L-38
Community Crime Rates: 2009-2012
Faro Mine Interim Works



Source: YG, 2012

The Community Well-Being score is a number generated by AANDC which reflects data on income, education, housing conditions and labour force activity. It can range from a low of 0 to a high of 100. Figure 6L-39 identifies the Community Well-Being score for all communities in the study area in 2006. Ross River has the lowest Community Well-Being score of all the communities.

FIGURE 6L-39
Community Well-Being Index Score in 2006
Faro Mine Interim Works



Source: AANDC Community Well-Being Database, 2006.

4.2.3 Infrastructure and Services

Ross River is linked to communities outside via high-speed internet, cellular service, and landline telephone service (YG, 2013e). Yukon Electrical purchases grid power from Yukon Energy Corporation, a Crown corporation of the Yukon Government, for distribution to its customers in Ross River (Yukon Electrical, 2013).

The Ross River School is a Kindergarten to Grade 10 school, with the 2012 enrollment at 48 and 2013 enrollment at 43 (YG, 2013e). Most students are members of the RRDC, and as such, the curriculum incorporates many aspects of traditional values. Yukon College has a community campus, which assists with courses online or through teleconferencing. The public library is shared with the public school and also offers internet and computer access (YG, 2013e).

After a devastating fire burned down the community arena in 2011, resource development companies operating in the region quickly began fundraising for the replacement of the recreation centre. With further funding assistance from the YG, construction began in 2012, and was completed in 2013. The new facility includes a hockey arena and multi-purpose areas designed for recreation and sport programming. The recreation centre was officially opened to the public on January 14, 2014 (YG, 2014).

Ross River is the gateway to the North Canol Road, a popular destination for adventure tourists looking for a scenic drive in one of the most remote regions in the country. A summer cable ferry transports vehicles from Ross River to the North Canol (YG, 2013e).

Ross River has a nursing facility for all residents, staffed by two nurses on call 24 hours a day. The Yukon Children's Dental Program provides dental services, community visits are scheduled through the Ross River School. Additional services and support are provided to members of the RRDC through the RRDC Health and Social Services Department (YG, 2013e).

In Ross River, ambulance services are volunteer run and provided out of Faro, which is 74 km away. There is a Royal Canadian Mounted Police detachment located in Ross River, as well as volunteer fire services (YG, 2013e).

According to the 2011 National Household Survey, there are 130 private dwellings, mostly single detached homes. Yukon Housing Corporation provides 14 social housing units and 12 staff units in Ross River, as well as programs and services which assist with home renovations, construction of rental units, mortgages, and financing (YG, 2013e).

Ross River is located 409 km northeast of Whitehorse via Carmacks on the North Klondike and Robert Campbell Highway. It is 74 km east of Faro, on the Robert Campbell Highway. Both highways are all weather and paved. There is a gravel airstrip maintained year-round, located adjacent to town. As an unincorporated municipality, Ross River's services to its residents and business are delivered by the YG. This includes water and wastewater services, landfill operations, and municipal road maintenance (YG, 2013e).

4.2.4 Land Use and Access

The FMC is located within the traditional territory of the Ross River Dena, who are part of the KDC. The RRDC does not have a settled land claim agreement. However, they identify a large portion of the central and eastern Yukon as being part of their traditional lands. RRDC and LFN claim overlapping traditional territories.

The area around the FMC was traditionally used by local First Nations primarily as a hunting and gathering location (Weinstein, 1992). However, for families who traditionally used the Mt. Mye/Blind Creek area, their harvesting and other land-use activities moved to other locations when the mine was developed (Weinstein, 1992). At this time, there is one RRDC Site-specific claim (RRDC S-11B) within the FMC Reserve.

The Dena Cho Trail, a 65-km multi-use trail between Faro and Ross River traces old travel routes used by local First Nations. This trail is promoted as a tourism and recreation activity in the area.

There is active trapping in the area around the FMC. Trap line number 405 is a group trap line managed by the RRDC and used by First Nation members.

4.2.5 Culture and Heritage

The RRDC is one of the five members of the KDC and is based in the community of Ross River. The Ross River Dena are currently one of the three Yukon First Nations without a settled land claim or self-government agreement. As such, they are administered as an Indian Band under the Indian Act. The governance structure includes a Chief, Deputy Chief, and three Councillors (Table 6L-4).

TABLE 6L-4
Chief and Council of the Ross River Dena, 2014
Faro Mine Interim Works

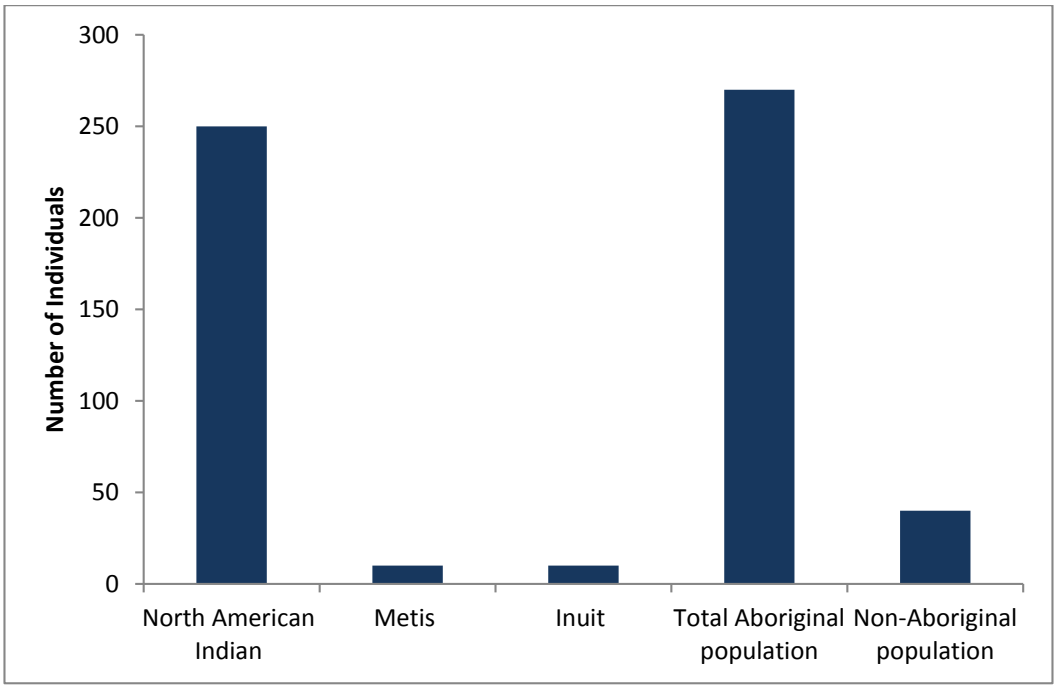
Chief	Councillors
Brian Ladue	Verna Nukon (Deputy Chief)
	Jenny Caesar
	James Dick
	Yvonne Moon

Source: KDC, 2014

The area surrounding the community of Ross River was used traditionally for seasonal harvesting and camping by the people of the Ross River Dena, and it is still used as a source of wildlife for hunting, trapping and fishing. The Ross River Dena are also known for their exceptional drumming and singing, and host stick gambling events at Coffee Lake, a historical gathering place.

As noted previously, Ross River has a large Aboriginal population. Figure 6L-40 shows the breakdown of the Aboriginal population by identity.

FIGURE 6L-40
Ross River: Aboriginal and Non-Aboriginal Population from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

The traditional language of the Ross River Dena is primarily Kaska, although a number of citizens are also Slavey speakers. English is currently the predominant language.

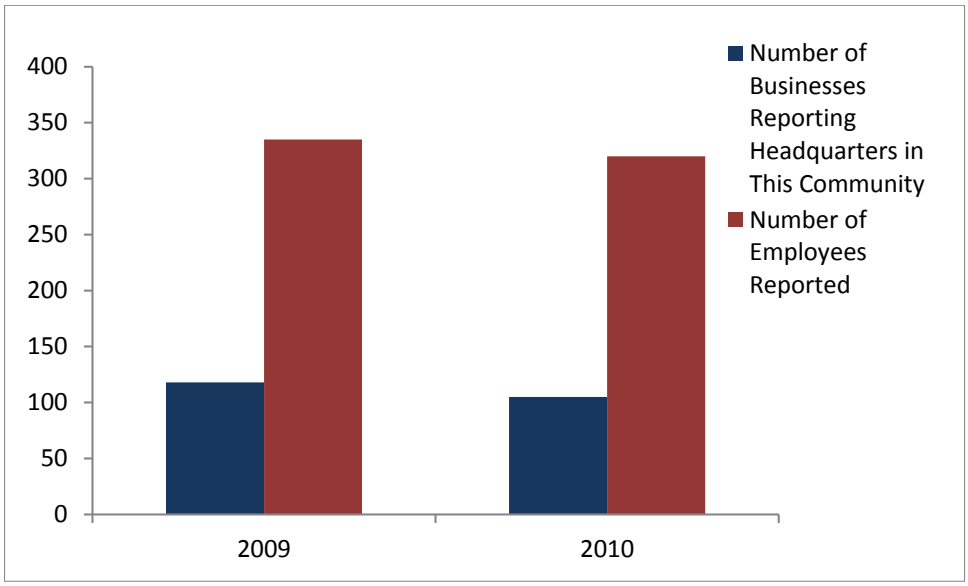
4.3 Liard First Nation

Watson Lake is home to the LFN, a member of the KDC. References to the community of Watson Lake often include the Town of Watson Lake and the adjoining settlements of the LFN, including Upper Liard, Two-Mile Village, and Two and a Half Mile Village. The Town of Watson Lake was established in 1939 during the development of a chain of airports across the North by the Canadian government, and its presence was further enhanced by the construction of the Alaska Highway in 1942. Watson Lake is known as the "Gateway to the Yukon" since it is the first community encountered when driving north into the Yukon via the popular Alaska Highway. Watson Lake is the third-largest community in the Yukon, behind Whitehorse and Dawson City.

4.3.1 Economy and Employment

Figure 6L-41 represents the number of businesses and employees reported in the community. As indicated, in 2010 Watson Lake was home to 105 businesses, which altogether employ 320 people (YG, 2011c). It should be noted that the figure below (6L-43) represents the number of businesses headquartered in Watson Lake and the number of people those businesses employ. The labour force accounts in later graphs represent the total labour force for Watson Lake, including businesses without local headquarters.

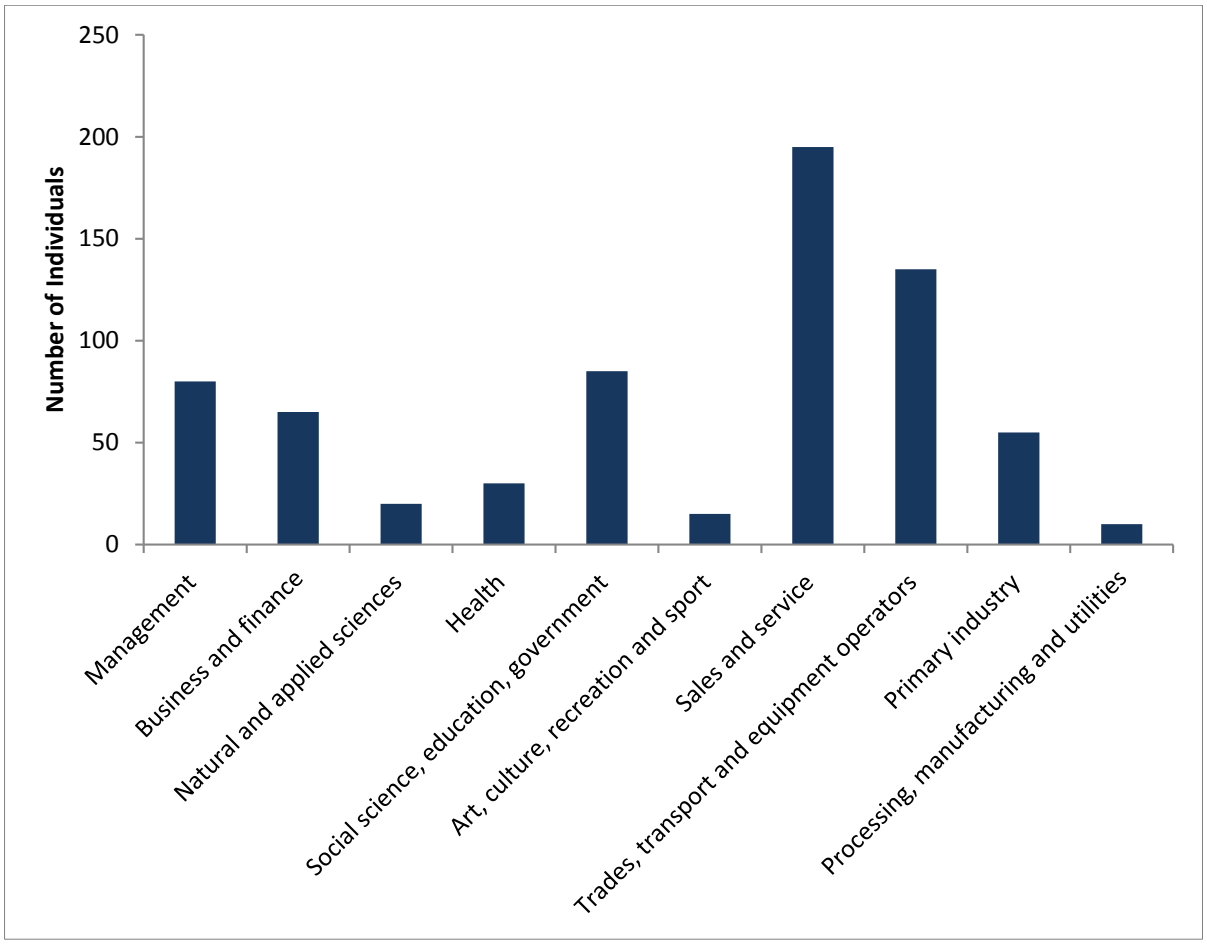
FIGURE 6L-41
Watson Lake: Business and Employees in 2009 and 2010
Faro Mine Interim Works



Source: YG2011c and 2010d.

Sales and service makes up the greatest number of occupations in the local labour force (Figure 6L-42). The labour force includes employed and unemployed individuals who are those without work, are available for work, and are actively seeking work.

FIGURE 6L-42
Watson Lake: Labour Force by Occupation from Census 2006
Faro Mine Interim Works

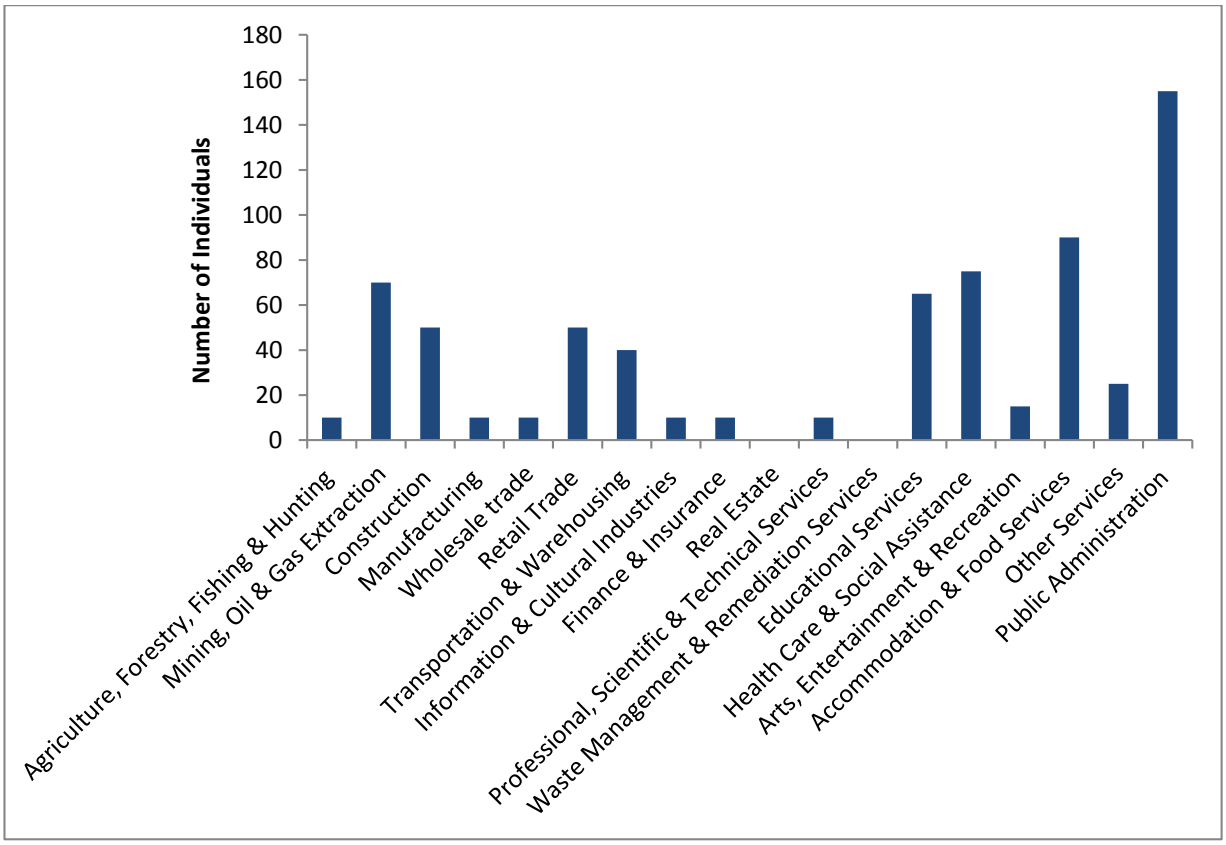


Source: Statistics Canada, 2008.

In 2005, the largest labour force industry was public administration, accounting for 22 percent of the overall labour force (725 individuals) (Figure 6L-43). Accommodation and food services were the second largest labour force segment, accounting for 13 percent of the overall labour force. The labour force participation rate for Watson Lake was 76 percent in 2005 (Statistics Canada, 2008).[3]

[3] Census information presented for Watson Lake is a combination of multiple census subdivisions to provide a more representative estimate of the regional statistics.

FIGURE 6L-43
Watson Lake: Labour Force by Industry from Census 2006
Faro Mine Interim Works

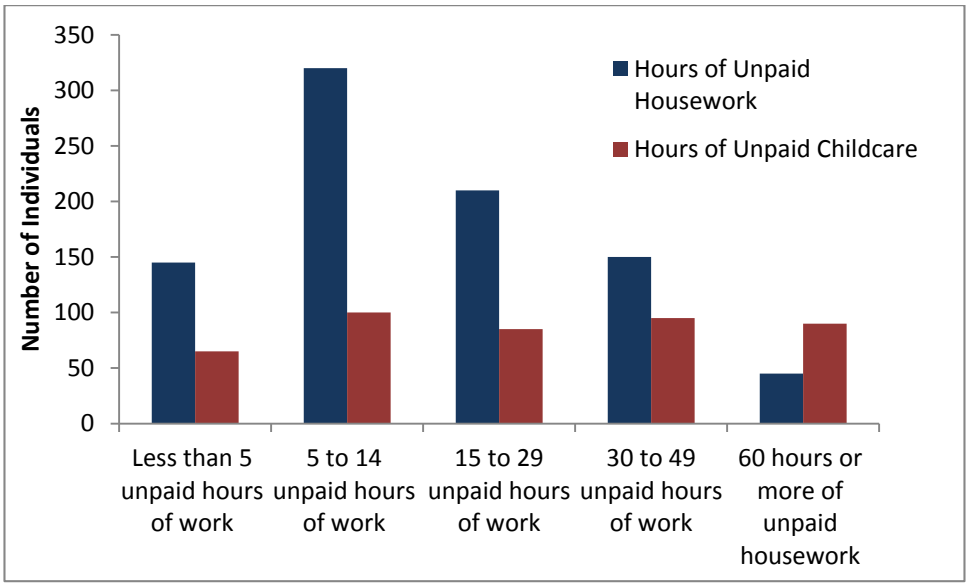


Source: Statistics Canada, 2008.

The following figures show the number of individuals by hours spent doing unpaid work per week, including housework and childcare (Figure 6L-44), and senior care (Figure 6L-45). In regards to unpaid housework, in 2005, 34 percent of the Census population sample (955 individuals) reported spending 5 to 14 hours weekly doing unpaid housework. Twenty-two percent of individuals indicated 15 to 29 hours and 16 percent stated 30 to 49 hours of unpaid housework. Five percent of respondents reported 60 or more hours of unpaid housework.

Number of weekly unpaid hours spent providing childcare was less than unpaid housework. Of the total survey respondents (960 individuals), approximately 10 percent reported 5 to 14 hours of unpaid childcare, while 9 percent of respondents indicated 15 to 29 hours and ten percent stating 30 to 49 hours. Nine percent of individuals reported 60 or more unpaid hours weekly dedicated to childcare.

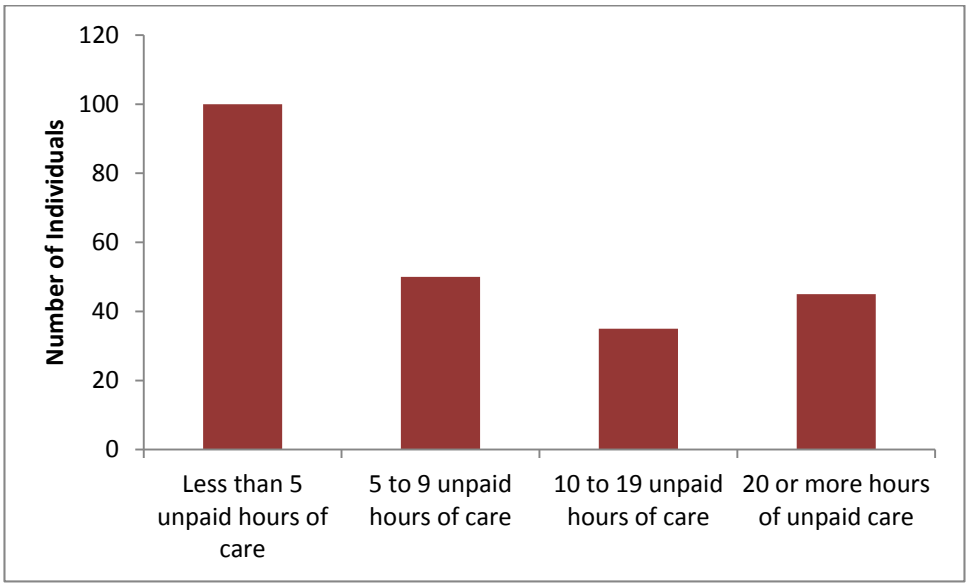
FIGURE 6L-44
Watson Lake: Population by Weekly Hours Spent Doing Unpaid Work (Housework and Childcare) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

Figure 6L-45 shows number of unpaid hours dedicated to providing assistance or care to seniors. Of the total survey respondents (960 individuals), 10 percent reported less than five hours of unpaid care and even less (5 percent) reported 60 or more hours per week.

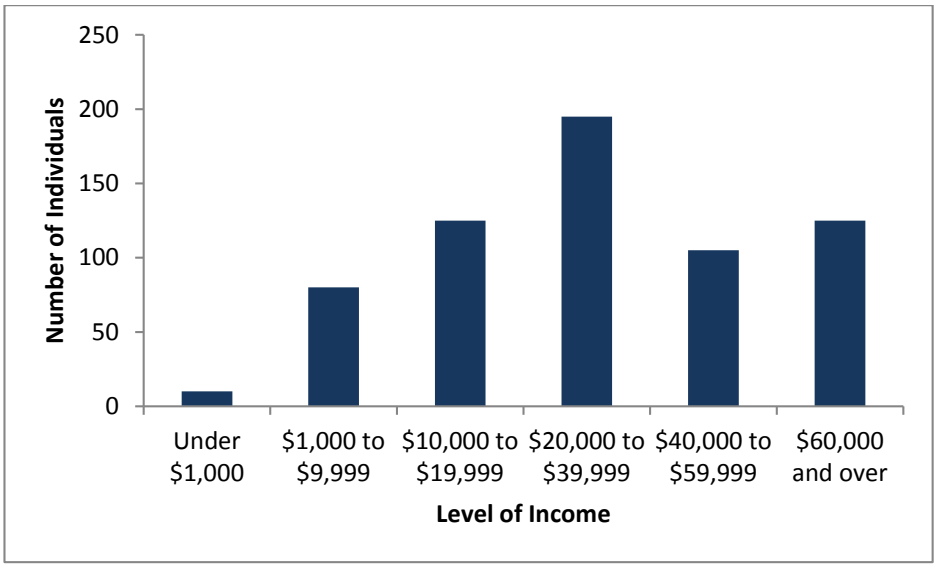
FIGURE 6L-45
Watson Lake: Population by Weekly Hours Spent Doing Unpaid Work (Senior Care) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

As Figure 6L-46 shows, in 2005, the annual average individual pre-tax income for residents of Watson Lake was $30,284; the annual average household income was $56,340 for the same year (Statistics Canada, 2008).

FIGURE 6L-46
Watson Lake: Annual Individual Pre-tax Income from Census 2006
Faro Mine Interim Works

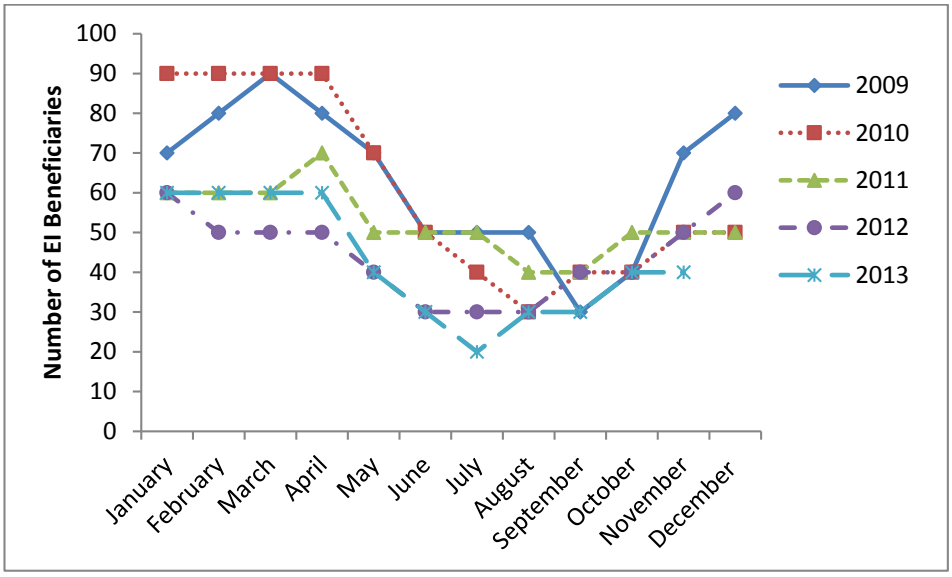


Source: Statistics Canada, 2008.

According to the Canada Revenue Agency, 1,010 tax returns were filed by Watson Lake residents for the 2009 tax year, 610 of which included taxable income. Total income reported on all returns was $34.6 million in 2009 (Canada Revenue Agency, 2011).

Figure 6L-47 shows the number of individuals receiving regular EI benefits, which excludes benefits associated with sickness, maternity, fishing, work sharing, adoption, parental, regular, training, job creation, and self-employment assistance. Number of EI beneficiaries have decreased since 2009 with July of 2013 having the lowest EI insurance levels recorded during the 5-year period. The greatest number of EI benefits occurs during the winter months between November and April. Similar to the other communities, the lower EI levels during the summer months may be attributed to increased employment associated with the summer tourism industry, field research, and environmental work that typically occurs during the warmer months. In comparison to 2009, the number of EI beneficiaries in 2013 decreased by approximately 30 percent.

FIGURE 6L-47
Watson Lake: Employment Insurance Beneficiaries from 2009 to 2013
Faro Mine Interim Works



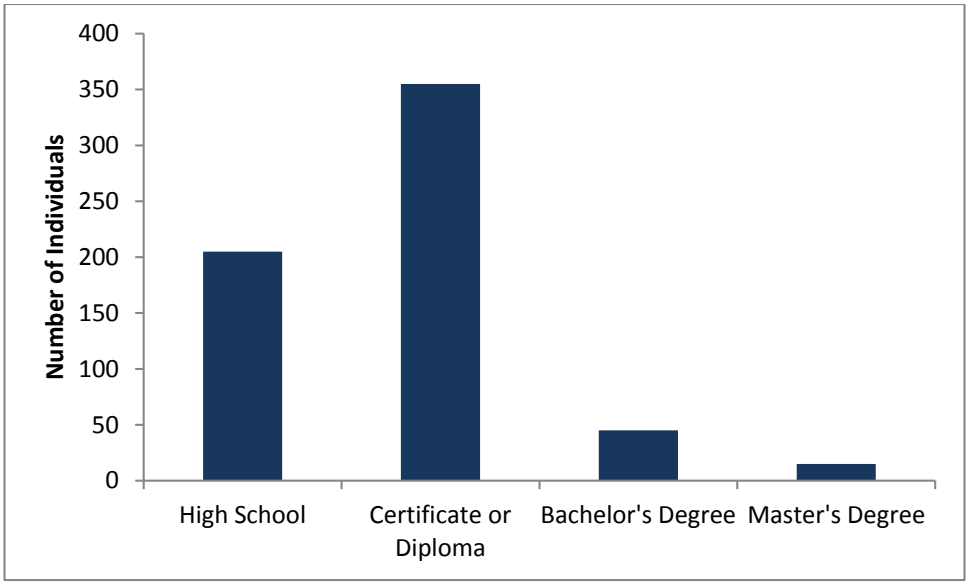
Source: Statistics Canada, no date.

The Consumer Price Index reported that on average for every dollar spent on purchases of goods and groceries in Whitehorse, the same products in Watson Lake would be purchased at a rate of a $1.15 (April 2013) (YG, 2013f).

The Town of Watson Lake has recently completed a *Strategic Plan for Revitalization of the Watson Lake Economy* (Town of Watson Lake, no date), to ensure the community is well positioned in future years to take advantage of opportunities across all business sectors.

In terms of educational attainment in Watson Lake, of the total survey respondents (965 individuals) aged 15 years and older in 2006, 355 had completed a certificate or diploma (Figure 6L-48). A total of 60 individuals reported having a Bachelor's or Master's degree as their highest level of schooling (Statistics Canada, 2008).

FIGURE 6L-48
Watson Lake: Education Levels from Census 2006
Faro Mine Interim Works

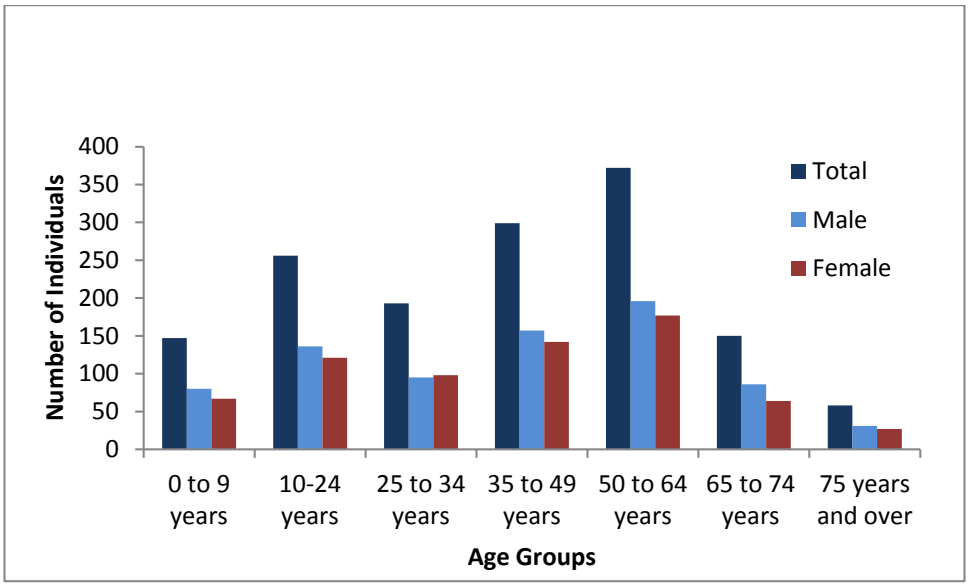


Source: Statistics Canada, 2008.

4.3.2 Community Stability and Well-being

According to recent 2013 estimates, Watson Lake has a population of 1,474, representing 780 males and 694 females (Figure 6L-49) (YG, 2013a).

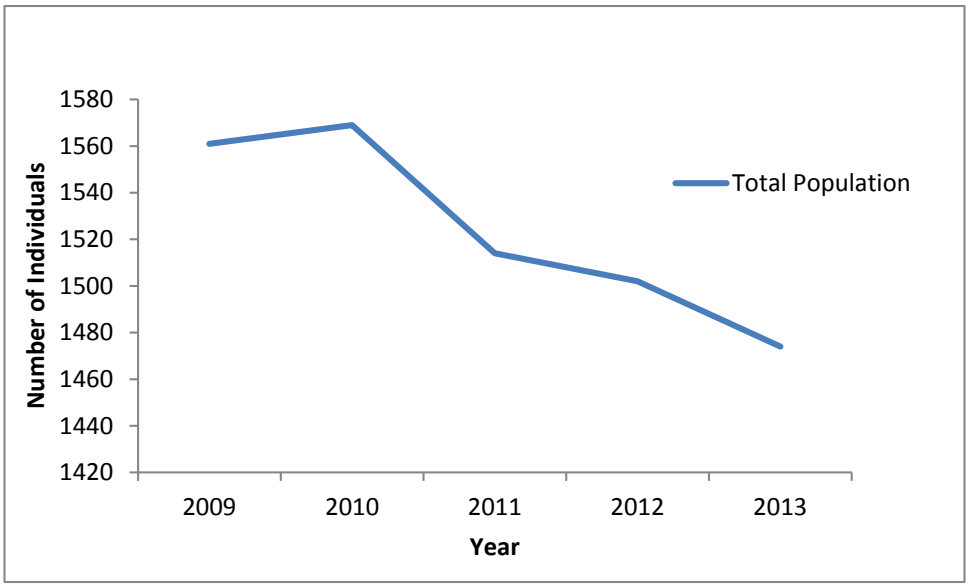
FIGURE 6L-49
Watson Lake: Population by Age and Sex in 2013
Faro Mine Interim Works



Source: YG2013a.

Since 2010, there has been a gradual decline in population (Figure 6L-50).

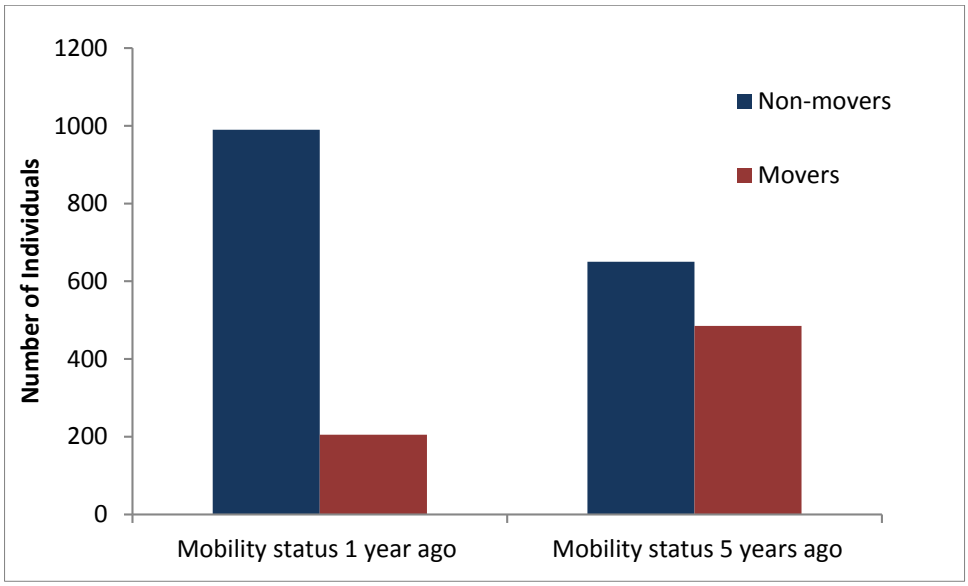
FIGURE 6L-50
Watson Lake: Total Population from 2009 to 2013
Faro Mine Interim Works



Source: YG, 2013a.

The majority of Watson Lake residents are non-movers, over 82 percent of survey respondents (1195 individuals) having lived in Watson Lake for over a year and 54 percent for over 5 years in the 2006 Census (Figure 6L-51). This reflects a relatively stable population base, but more transient than other small communities such as Ross River and Faro.

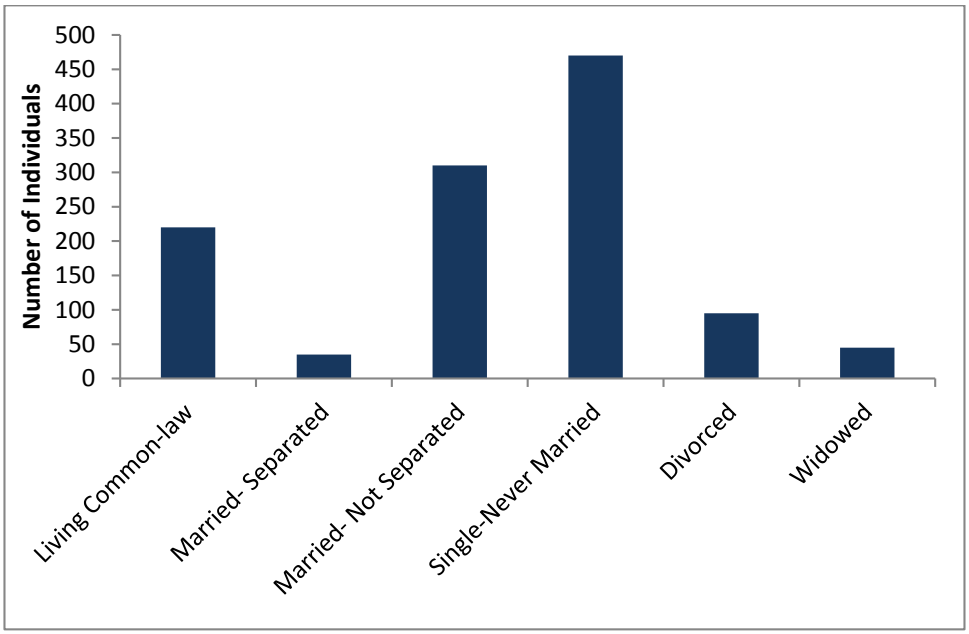
FIGURE 6L-51
Watson Lake: Mobility Status from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

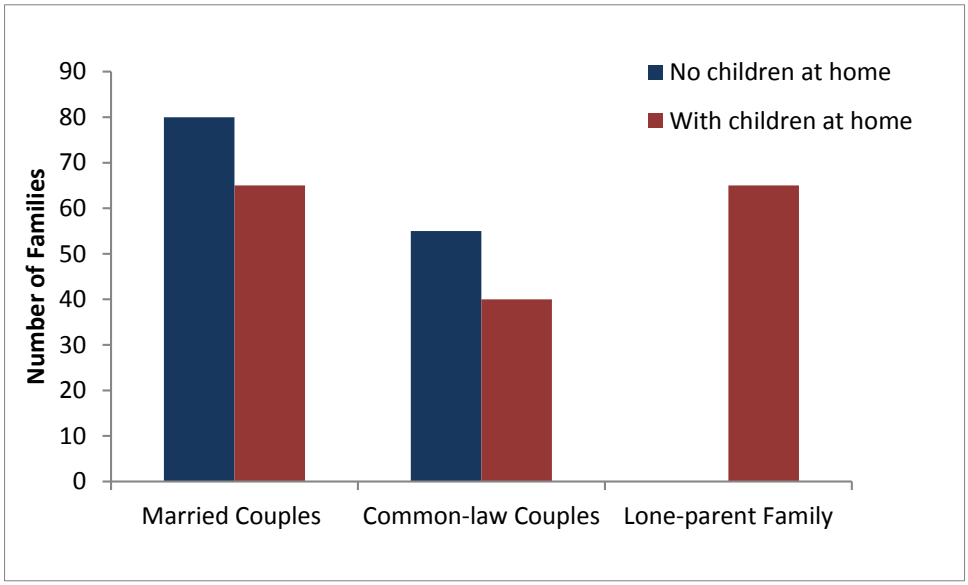
Nearly half of survey respondents (910 individuals) were single. Watson Lake has a high number of married and common-law couples with the majority of households without children (Figures 6L-52 and 6L-53).

FIGURE 6L-52
Watson Lake: Marital Status from Census 2011 [4]
Faro Mine Interim Works



Source: Statistics Canada, 2012a.

FIGURE 6L-53
Watson Lake: Family Structure from Census 2011
Faro Mine Interim Works

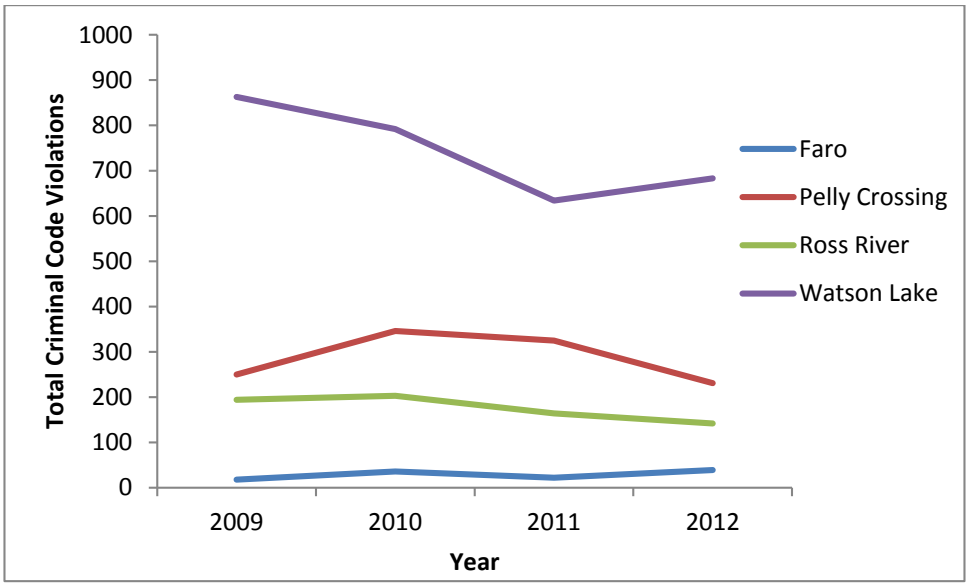


Source: Statistics Canada, 2012a.

[4] Statistics Canada provides the following classifications of marital status: "Living common-law includes persons who are living with person of the opposite sex or of the same sex as a couple but who are not legally married to that person. Married-separated includes persons currently legally married, but who are no longer living with their spouse and have not obtained a divorce. Married includes persons whose opposite- or same-sex spouse is living, unless the couple is separated or a divorce has been obtained. Also included are persons in civil unions. Single includes persons who have never married (including all persons less than 15 years of age). It also includes persons whose marriage has been legally annulled who were single before the annulled marriage and who have not remarried. Widowed includes persons who have lost their legally-married spouse through death and who have not remarried" (Statistics Canada, 2012b).

As Figure 6L-54 shows, Watson Lake has the second highest number of criminal code violations in the Yukon, at 683 reported in 2012 (YG, 2012).

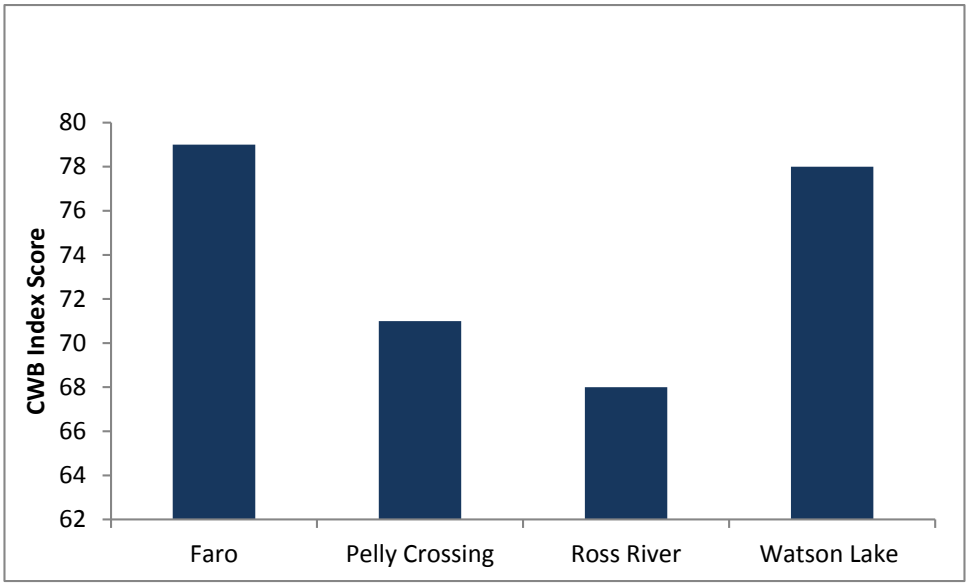
FIGURE 6L-54
Community Crime Rates: 2009-2012
Faro Mine Interim Works



Source: YG, 2012.

The Community Well-Being score is a number generated by AANDC which reflects data on income, education, housing conditions and labour force activity. It can range from a low of 0 to a high of 100. Figure 6L-55 identifies the Community Well-Being score for all communities in the study area in 2006. Watson Lake's score is 78 (AANDC, 2006).

FIGURE 6L-55
Community Well-Being Index Score in 2006
Faro Mine Interim Works



Source: AANDC Community Well-Being Database, 2006.

4.3.3 Infrastructure and Services

Watson Lake is an incorporated municipality with an elected Mayor and four councillors (Table 6L-5). The municipality is responsible for providing programs and services to its citizens, and the YG provides services to residents living outside of the municipal boundary.

TABLE 6L-5
Watson Lake Mayor and Council, 2013
Faro Mine Interim Works

Name	Role
Richard Durocher	Mayor
Brenda Leach	Councillor
Cynthia Kearns	Councillor
Thomas Slager	Councillor
Tim O'Brien	Councillor

Source: Town of Watson Lake, 2013

Watson Lake has an airport with a 5,500-foot asphalt runway capable of handling a 737 aircraft. Planes, buses, and taxis all operate in Watson Lake (YG, 2013f).

Watson Lake has two schools. Johnson Elementary School serves Kindergarten to Grade 7. Watson Lake Secondary School has grades 8 to 12. Most students at both of these schools are members of the LFN. Yukon College is located in a wing of the secondary school and provides some courses, as well as equipment for distance learning (YG, 2013f).

The Watson Lake Library is within the Town of Watson Lake Administration Building (YG, 2013f).

Watson Lake has a 24-hour Ambulance service, after regular business hours it is staffed by volunteers. The Royal Canadian Mounted Police have a detachment with one sergeant, one corporal, and seven constables. The fire department has one staffed fire chief and many volunteers. Watson Lake has a new medical facility, which was opened by YG in August 2013. It provides the community with emergency services, six in-patient beds, as well as diagnostic services. The Watson Lake Seniors Complex has a 12-unit seniors housing complex (YG, 2013f).

The Town of Watson Lake has a recreation centre, including a heated pool for summer use, an arena, a fitness centre, and a curling rink. There is also a skateboard park, a golf course, and a small ski hill near the community (YG, 2013f).

High-speed internet, cellular, and landline service is provided by Northwestel. Yukon Electrical generates and distributes its own electricity in Watson Lake (Yukon Electrical, 2014).

Four hundred and sixty homes were reported in the 2011 Census. Yukon Housing offers 46 social units and 34 staff units (YG, 2013f).

4.3.4 Land Use and Access

The FMC lies within the traditional territory of the Kaska Dena, of which the LFN is a member. As such, the traditional use of lands in the region could also be associated with LFN. At this time, LFN has not settled its land claim agreement and has not identified any specific lands near the mine site. Similar to the RRDC, the LFN does not have a land claim settlement or self-government agreement.

4.3.5 Culture and Heritage

The LFN is another Yukon member of the KDC. They are based out of Watson Lake, Yukon, with many of their members also living in Upper Liard, Yukon or Lower Post, British Columbia. An election was held in

December 2013, and the new Chief is Daniel Morris and the Councillors are Roy Dick, Don Magun, Cynthia Porter, and Timothy Stewart (Table 6L-6) (KDC, 2013).

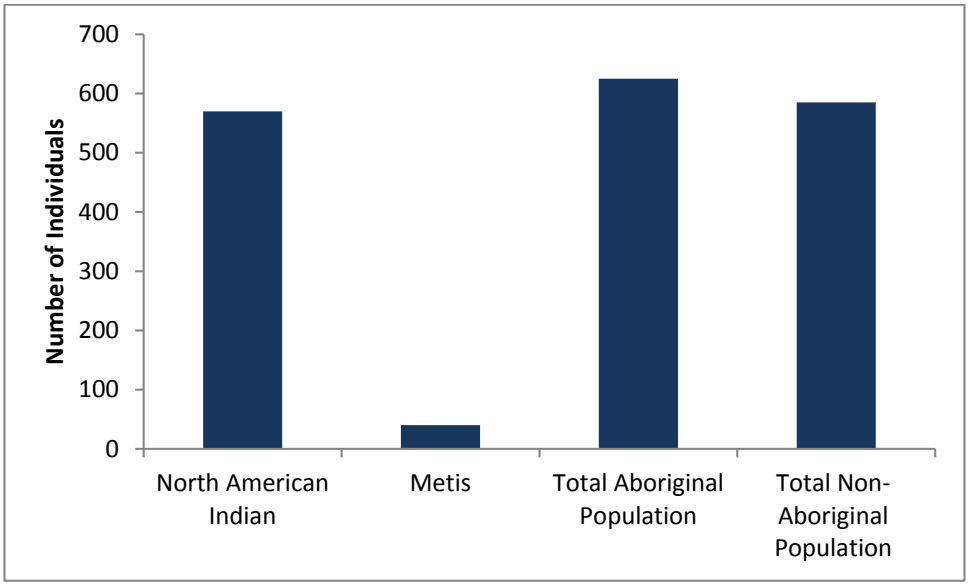
TABLE 6L-6
Liard First Nation Chief and Council, 2013
Faro Mine Interim Works

Name	Role
Daniel Morris	Chief
Roy Dick	Councillor
Don Magun	Councillor
Cynthia Porter	Councillor
Timothy Stewart	Councillor

Source: KDC, 2013

Of the total survey respondents (1205 individuals), 52 percent is comprised of Aboriginal peoples (Figure 6L-56).

FIGURE 6L-56
Watson Lake: Total Aboriginal and Non-Aboriginal Population from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

4.4 Kaska Dena Council

The KDC was formed in 1981 to provide a voice for the five-member First Nations who share a historical relationship and a traditional territory spanning the British Columbia-Yukon border (KDC, 2013). The KDC has a Board of Directors which includes six Directors and three elected officers (Table 6L-7).

TABLE 6L-7
Kaska Dena Council
Faro Mine Interim Works

Name	Role
Chief Cat Lee	Dease River First Nation (Good Hope Lake)
Chief Donny Van Somer	Kwadacha First Nation (Fort Ware)
Deputy Chief Peter Stone	Daylu Dena Council (Lower Post)
Dennis Porter	Fireside
Steven Jakesta	Hereditary System
Victor Kisoun	Muncho
George Miller	Chair
Ruby Johnny	Vice-Chair, Finance and Administration
Danny Case	Vice-Chair, Lands and Resources

Source: KDC, 2014b

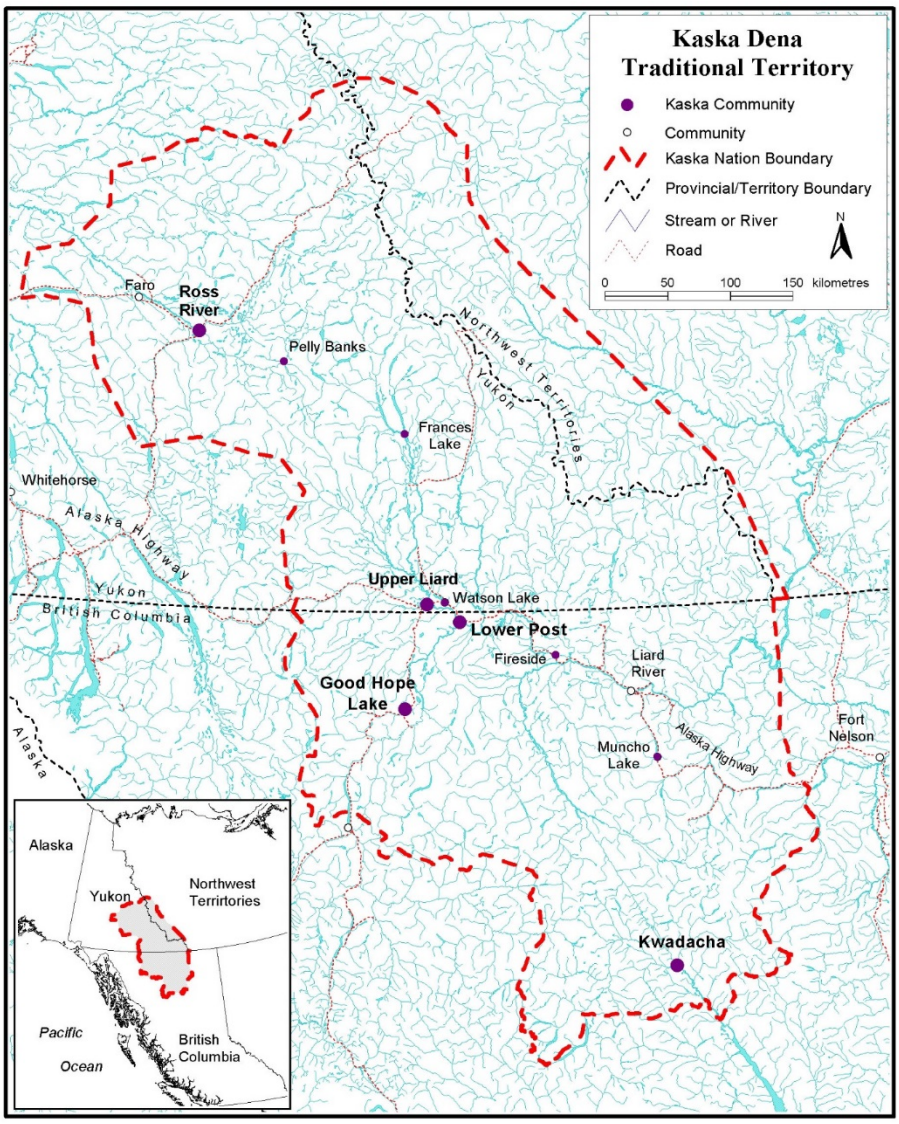
The following are objectives of the KDC are (KDC, 2013):

1. Promote and protect respect for the land and cultural heritage of the Kaska Dena people;
2. Promote unity and sharing amongst all Kaska;
3. Assist in the delivery of services including social, economic, cultural and educational programs to Kaska Dena communities;
4. Promote a community environment wherein all Kaska people can enjoy physical and spiritual health and live with dignity and pride;
5. Work toward the recognition and protection of the aboriginal rights of all Canadian Native people, and;
6. Do all things necessary to achieve the foregoing objectives

The traditional territory of the KDC encompasses over 240,000 square kilometres of land, from the MacMillan Pass on the Yukon/Northwest Territories border to the community of Kwadacha in British Columbia, and from Little Salmon Lake, Yukon in the west to Fort Nelson in the east (Figure 6L-57). Member nations in British Columbia are the Daylu Dena Council, Dease River First Nation, and the Kwadacha Nation. The RRDC and the LFN are the two Yukon members of the KDC. The FMC lies just within the northern boundary of the KDC traditional territory (KDC, 2013).

In October of 2011, the KDC signed an historic agreement amongst all its member nations. The “Kaska Collaboration Agreement” outlines the responsibilities and processes to facilitate the negotiation and implementation of agreements between project proponents looking to pursue projects within Kaska traditional territory. Of note, this agreement specifically addresses the on-going work of the FMC remediation, and acknowledges that the RRDC is the primarily impacted community of the Faro project and will be the lead community (KDC, 2011).

FIGURE 6L-57
Kaska Dena Traditional Territory
Faro Mine Interim Works



Source: KDC, 2013.

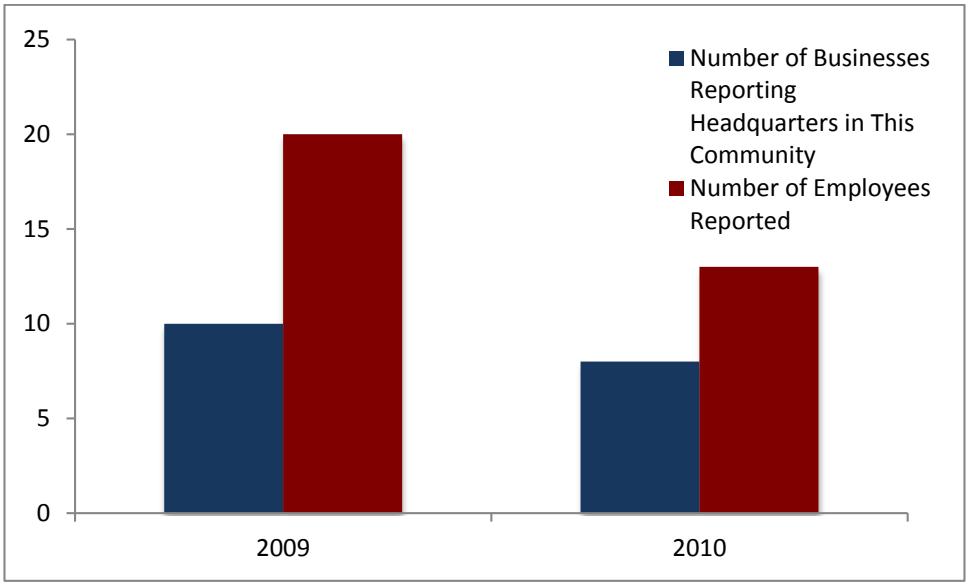
4.5 Selkirk First Nation

The SFN is based in Pelly Crossing, in a valley on the banks of the Pelly River. The SFN is part of the Northern Tutchone, who traditionally used the nearby sites of Fort Selkirk and Minto for camping while hunting, trapping and gathering in the area. In 1997, the SFN became the seventh Yukon First Nation to sign their land claim and self-government agreements. Unrelated to the FMC and the IW, but important to the SFN, is the Minto Mine. The Minto Mine, owned by Capstone Mining, is a copper-gold-silver mine located on SFN settlement land southwest of Pelly Crossing on the west side of the Yukon River. The mine commenced operations in 2007 (Capstone, 2014). The Minto Mine contributes to the local economy of Pelly Crossing by accessing its labour force and some local services as well as contributing to the Selkirk First Nation revenues due to its location on Type A settlement land (YG, 2010e). Economy and Employment

4.5.1 Economy and Employment

As Figure 6L-58 shows, in 2010 Pelly Crossing was home to eight businesses, which altogether employ 13 people (YG, 2011c). It should be noted that the figure below (6L-58) represents the number of businesses headquartered in Pelly Crossing and the number of people those businesses employ. The labour force accounts in later graphs represent the total labour force for Pelly Crossing, including businesses without local headquarters.

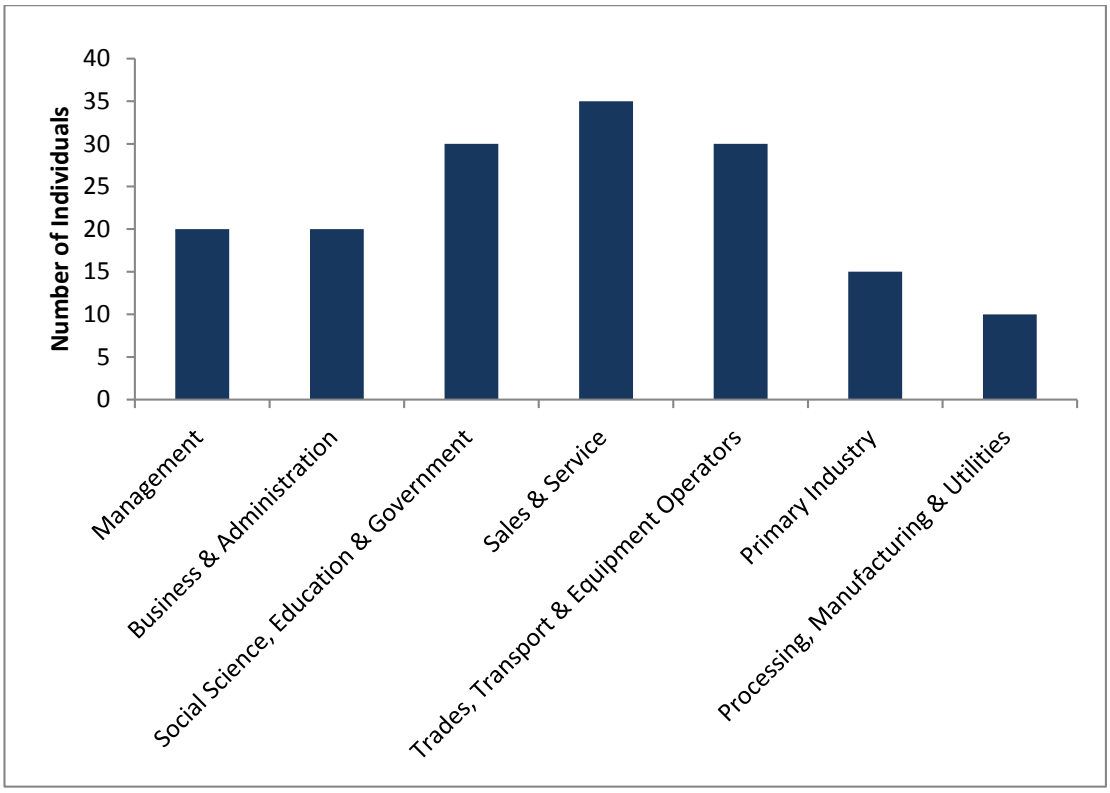
FIGURE 6L-58
Pelly Crossing: Businesses and Employees in 2009 and 2010
Faro Mine Interim Works



Source: YG, 2011c and 2010d.

Sales and service represents the greatest labour force in regards to occupation type (Figure 6L-59). The labour force includes employed and unemployed individuals who are those without work, are available for work, and are actively seeking work.

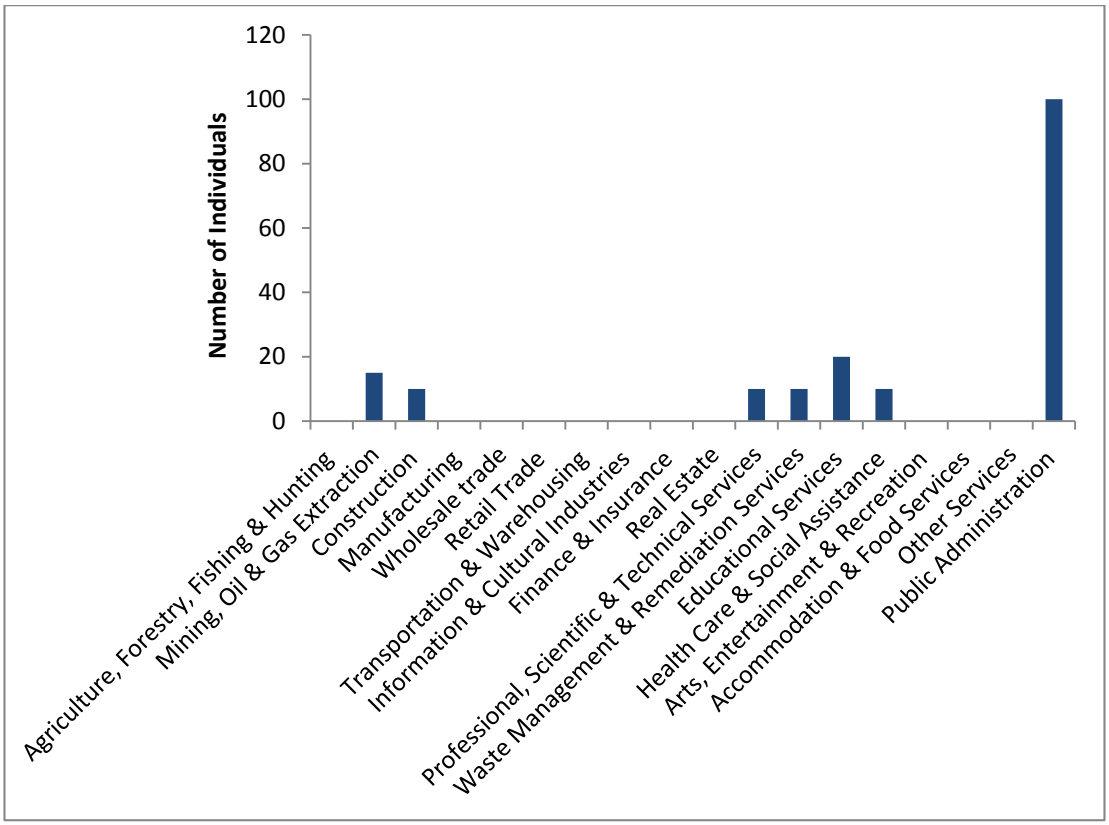
FIGURE 6L-59
Pelly Crossing: Labour Force by Occupation from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

In 2005, the largest labour force industry in Pelly Crossing was public administration, accounting for 57 percent of the overall labour force (180 individuals) (Figure 6L-60). Educational services was the second largest labour force segment, accounting for 11 percent of the overall labour force. The labour force participation rate for Pelly Crossing was 77 percent in 2005 (Statistics Canada, 2008).

FIGURE 6L-60
Pelly Crossing: Labour Force by Industry from Census 2006
Faro Mine Interim Works

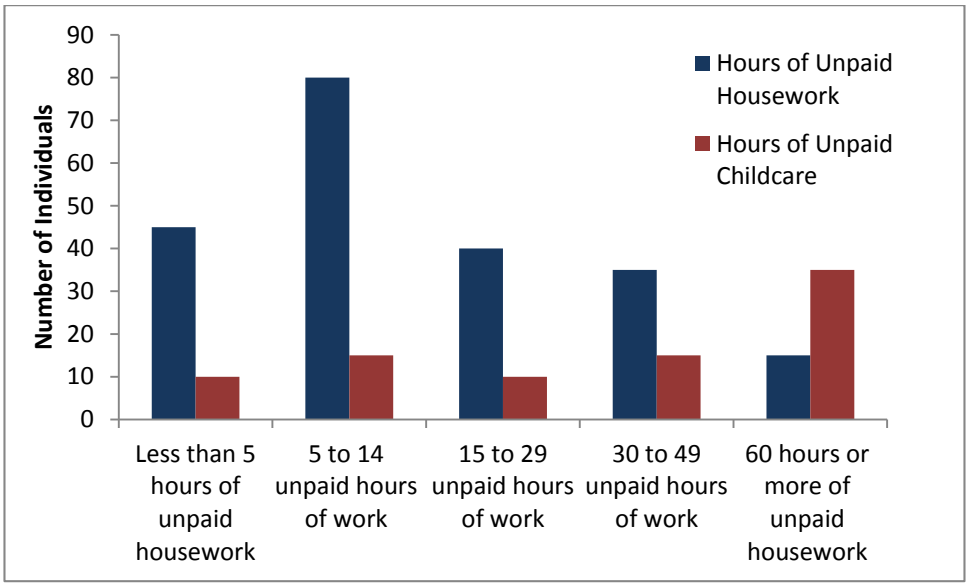


Source: Statistics Canada, 2008

The following figures show individuals by hours spent doing unpaid per week work including housework and childcare (Figure 6L-61) and senior care (Figure 6L-62). In regards to unpaid work, in 2005 34 percent of the Census population sample (235 individuals) reported spending 5 to 14 hours doing unpaid housework. The number of individuals indicating 15 to 29 hours and 30 to 49 hours of unpaid housework was relatively equal at approximately 17 and 15 percent, respectively. Six percent of respondents reported 60 or more hours of unpaid housework.

Number of weekly unpaid hours spent providing childcare was less than unpaid housework. Approximately 6 percent of respondents claimed performing 5 to 14 hours of unpaid childcare, while 4 percent of respondents indicated 15 to 29 unpaid hours. Six percent reported 30 to 49 hours and 15 percent stated doing 60 or more hours of unpaid childcare.

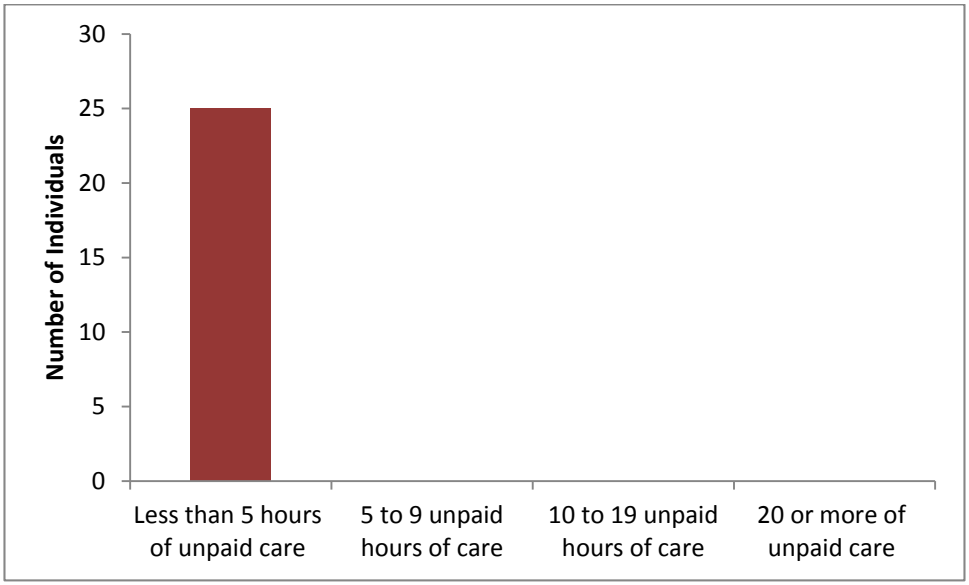
FIGURE 6L-61
Pelly Crossing: Population by Weekly Hours Spent Doing Unpaid Work (Housework and Childcare) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

As shown below (Figure 6L-62), of the total survey respondents (240 individuals), 10 percent reported less than 5 unpaid hours per week to providing assistance or care to seniors.

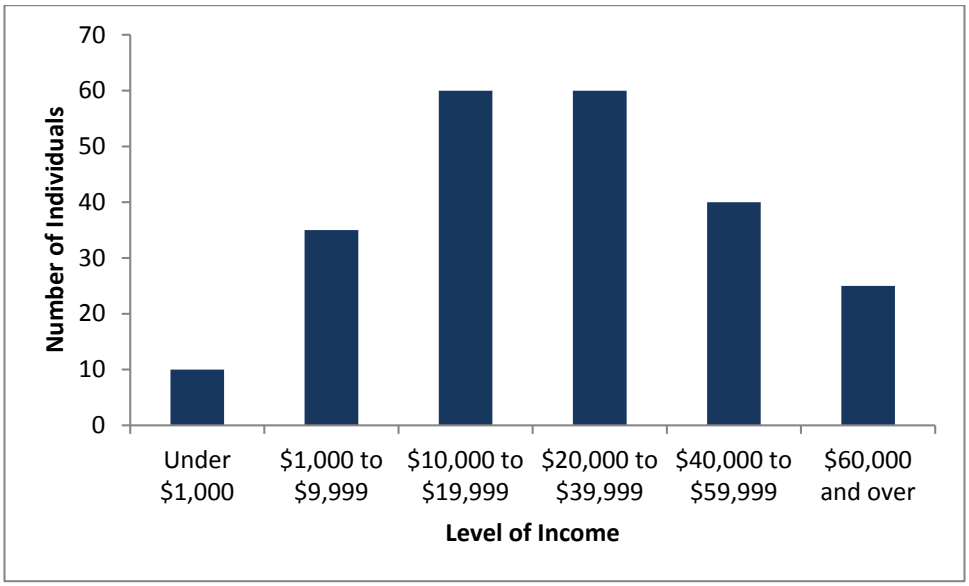
FIGURE 6L-62
Pelly Crossing: Population by Weekly Hours Spent Doing Unpaid Work (Senior Care) from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

In 2005, the average annual individual pre-tax income for residents of Pelly Crossing was $29,092; average annual household income was $56,331 for the same year (Figure 6L-63) (Statistics Canada 2008). According to the Canada Revenue Agency, a total of 250 tax returns were filed by Pelly Crossing residents for the 2009 tax year, 140 of which included taxable income. Total income reported on all returns was $7.9 million in 2009 (Canada Revenue Agency, 2011).

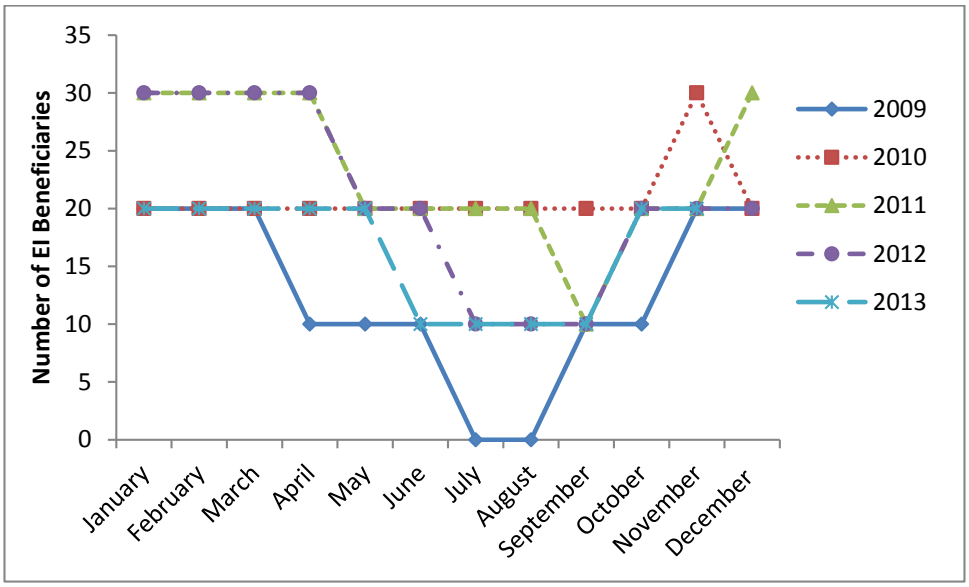
FIGURE 6L-63
Pelly Crossing: Annual Individual Pre-tax Income from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

Figure 6L-64 shows the number of individuals receiving regular EI benefits, which excludes benefits associated with sickness, maternity, fishing, work sharing, adoption, parental, regular, training, job creation, and self-employment assistance. Between 2009 and 2013, EI insurance levels have maintained the trend of increased EI beneficiaries during the winter months with a decline in the summer. Once again, similar to the other communities, the lower EI levels during the summer months may be related to increased employment associated with the summer tourism industry, field research, and environmental work that typically occurs during the warmer months. The highest number of EI beneficiaries was observed in the winter of 2012. However, more recently in 2013 these numbers have decreased by approximately 30 percent.

FIGURE 6L-64
Pelly Crossing: Employment Insurance Beneficiaries from 2009 to 2013
Faro Mine Interim Works

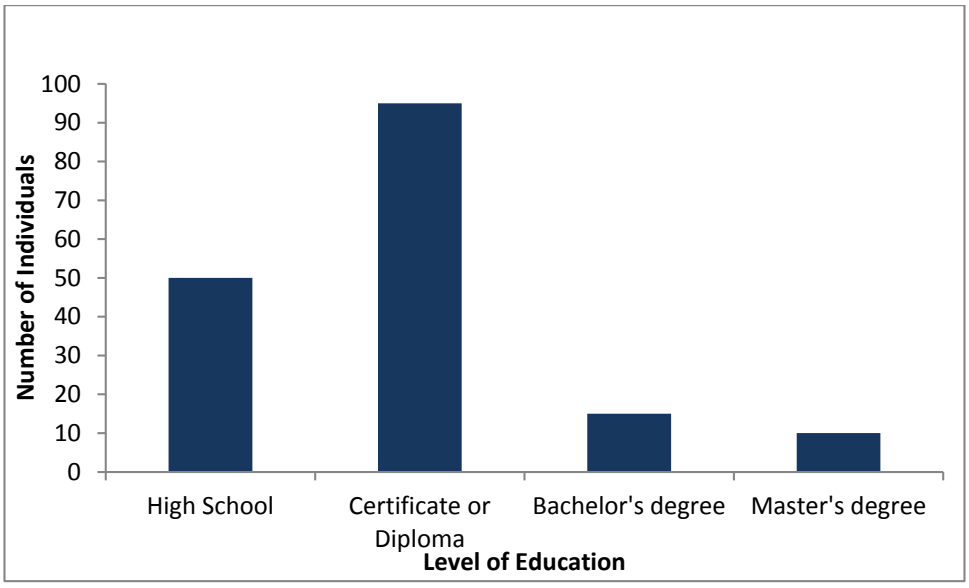


Source: Statistics Canada, no date.

In terms of educational attainment, of the 240 individuals who were aged 15 years and older in 2006, 65 had completed a certificate or diploma in the trades or other non-university programs (Figure 6L-65). A total of

25 individuals reported having a Bachelor's or Master's degree as their highest level of schooling (Statistics Canada, 2008).

FIGURE 6L-65
Pelly Crossing: Education Levels from Census 2006
Faro Mine Interim Works

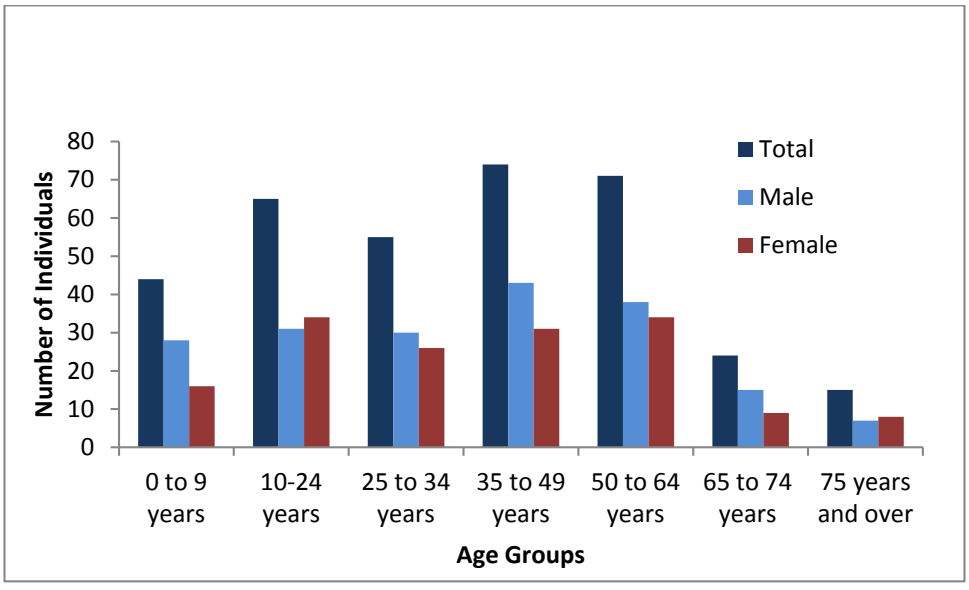


Source: Statistics Canada, 2008.

4.5.2 Community Stability and Well-being

The population of Pelly Crossing in June 2013 was 348 people representing a 189 males and 159 females (Figure 6L-66) (YG, 2013a).

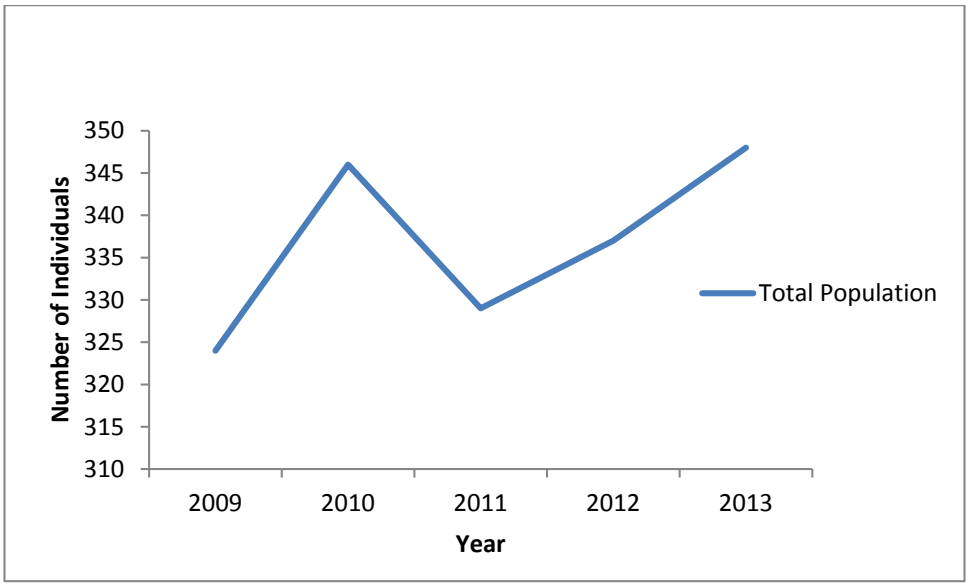
FIGURE 6L-66
Pelly Crossing: Population by Age and Sex in 2013
Faro Mine Interim Works



Source: Statistics Canada, 2012.

Figure 6L-67 indicates a trend of population growth since 2011.

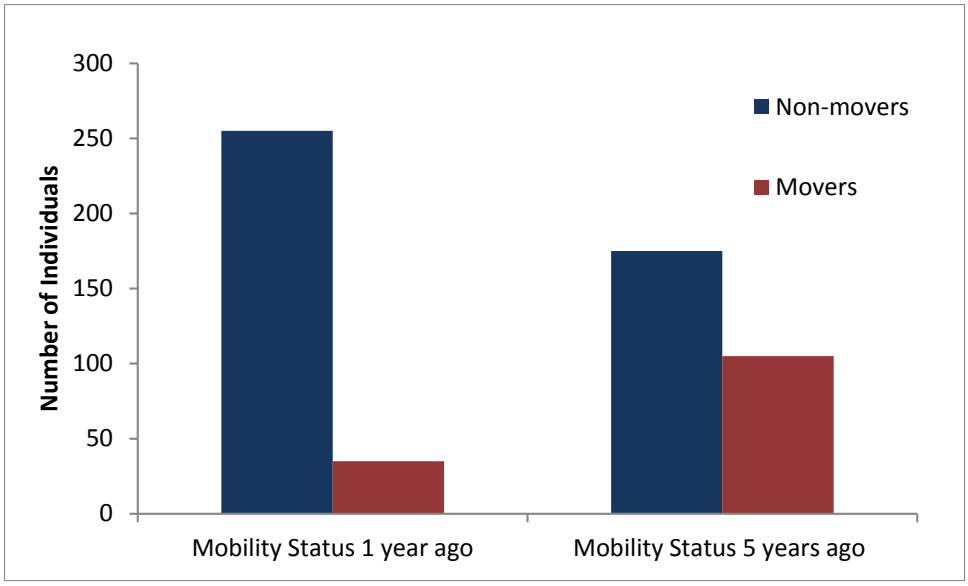
FIGURE 6L-67
Pelly Crossing: Total Population 2009 to 2013
Faro Mine Interim Works



Source: YG2013a.

Figure 6L-68 shows the community is very stable. Of those Census respondents (290 individuals), only 12 percent of the community having indicated they moved during 2005 (Statistics Canada, 2008). The Mobility Status 5 years ago represents the number of people that moved within the last 5 years.

FIGURE 6L-68
Pelly Crossing: Mobility Status from Census 2006
Faro Mine Interim Works



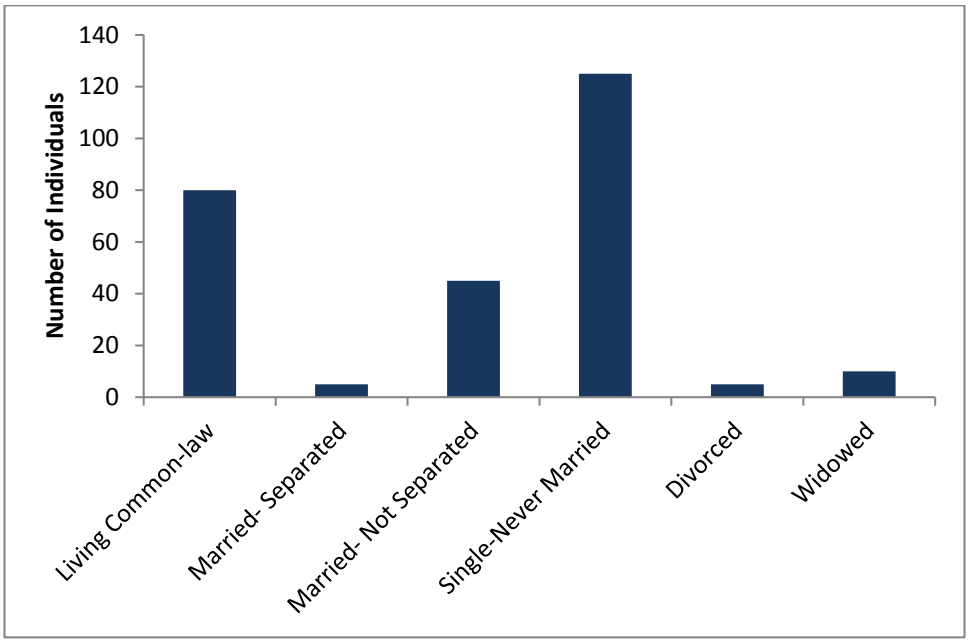
Source: Statistics Canada, 2008.

Pelly Crossing has a high number of both individuals reporting single marital status (Figure 6L-69) and lone-parent households (Figure 6L-70).

FIGURE 6L-69

Pelly Crossing: Marital Status from Census 2011[5]

Faro Mine Interim Works

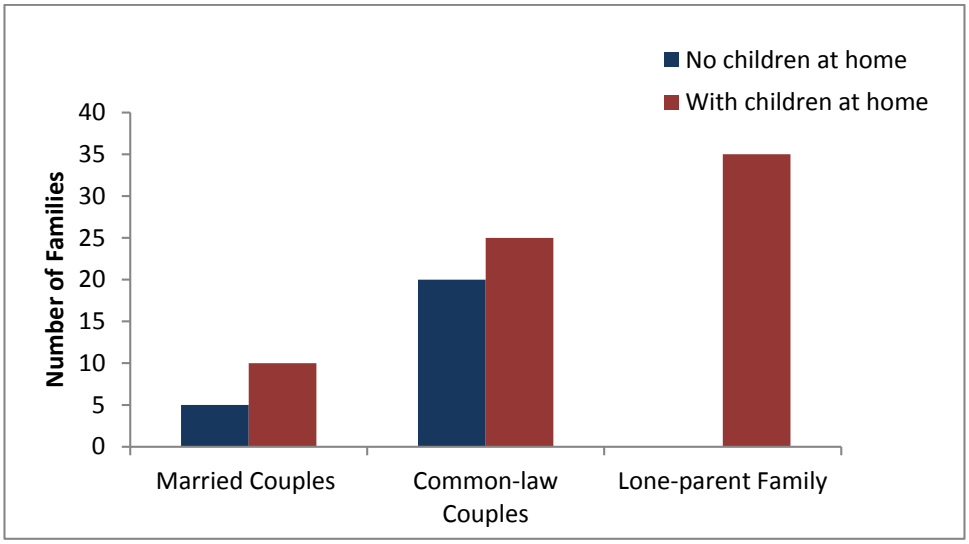


Source: Statistics Canada, 2012a.

FIGURE 6L-70

Pelly Crossing: Family Structure from Census 2011

Faro Mine Interim Works

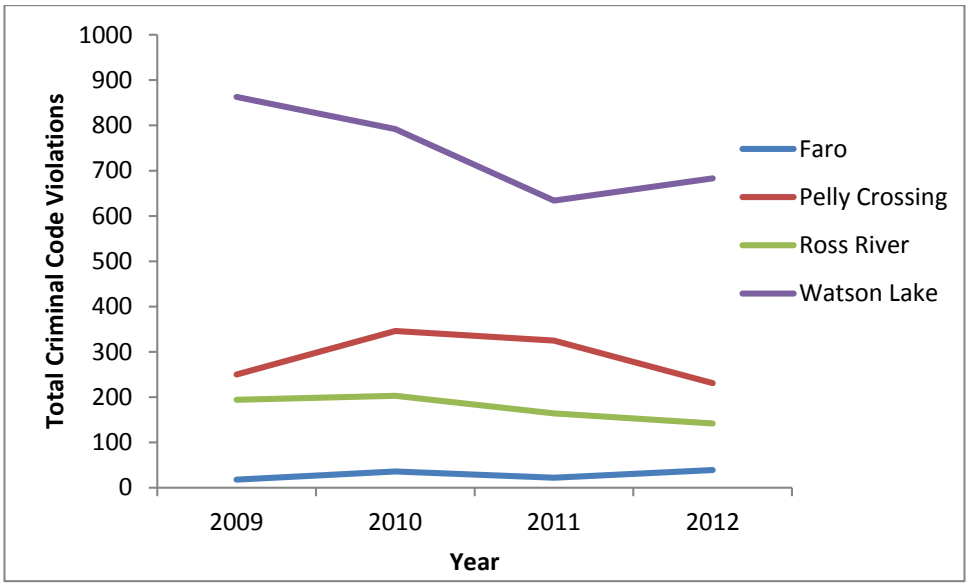


Source: Statistics Canada, 2012a.

[5] Statistics Canada provides the following classifications of marital status: "Living common-law includes persons who are living with person of the opposite sex or of the same sex as a couple but who are not legally married to that person. Married-separated includes persons currently legally married, but who are no longer living with their spouse and have not obtained a divorce. Married includes persons whose opposite- or same-sex spouse is living, unless the couple is separated or a divorce has been obtained. Also included are persons in civil unions. Single includes persons who have never married (including all persons less than 15 years of age). It also includes persons whose marriage has been legally annulled who were single before the annulled marriage and who have not remarried. Widowed includes persons who have lost their legally-married spouse through death and who have not remarried" (Statistics Canada, 2012b).

Pelly Crossing suffers from high crime rates relative to other rural Yukon communities (Figure 6L-71). In 2012, there were 231 criminal code violations reported—a per capita rate of 0.69 (YG, 2012).

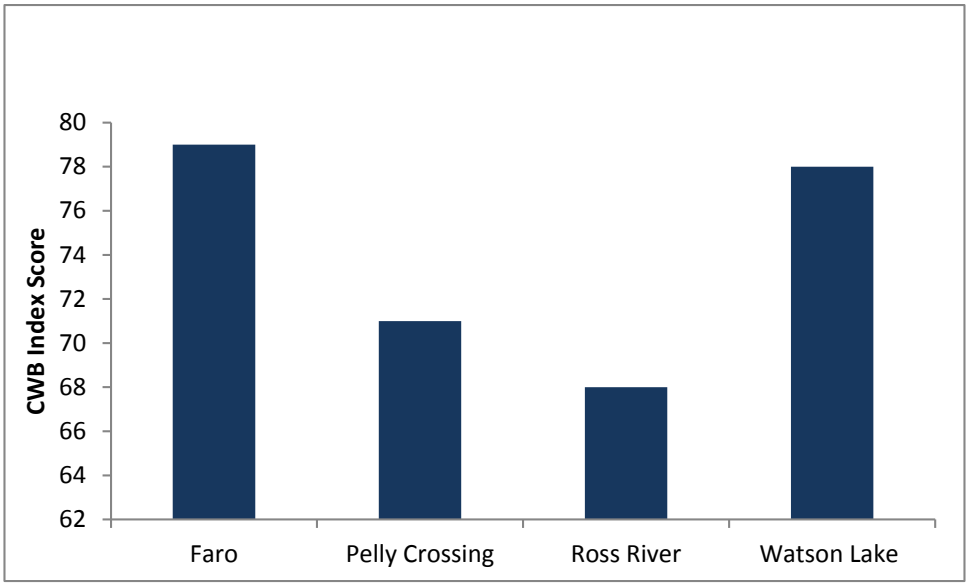
FIGURE 6L-71
Community Crime Rates: 2009-2012
Faro Mine Interim Works



Source: YG, 2012.

The Community Well-being score is a number generated by AANDC, which reflects data on income, education, housing conditions and labour force activity. It can range from a low of 0 to a high of 100. Figure 6L-72 identifies the Community Well-being score for all communities in the study area in 2006. Pelly Crossing's score is 71 (AANDC, 2006).

FIGURE 6L-72
Community Well-being Index Score in 2006
Faro Mine Interim Works



Source: AANDC Community Well-being Database, 2006.

4.5.3 Infrastructure and Services

Pelly Crossing is located along the Klondike Highway, 282 km northwest of Whitehorse and 254 km southeast of Dawson City.

Like Ross River, Pelly Crossing is an unincorporated community where the YG is responsible for delivering services to property and residents. The SFN provides water, wastewater services, and municipal road maintenance services; landfill operation is managed by YG. Yukon Electric provides electrical power from the Yukon grid, with a backup diesel generator. Northwestel offers high-speed internet, cellular, and land line service. Yukon Highways and Public Works maintains the highways around Pelly Crossing. Pelly Crossing has a 3,305-foot gravel airstrip. YG's Department of Highways and Public Works provides limited maintenance of the airstrip (YG, 2013d).

The Eliza Van Bibber School had 48 students in 2012, which increased to 67 students enrolled in the 2013 school year. The school serves Kindergarten to Grade 12. Most students are members of SFN. Yukon College provides a local campus in Pelly Crossing with courses offered online or through teleconferencing facilities. The community library is co-located in the Eliza Van Bibber School (YG, 2013d).

The ambulance service for Pelly Crossing and area is provided by Yukon Emergency Medical Services based out of the fire hall in Pelly Crossing. The Emergency Medical First responders are all volunteers and are dispatched to calls by the Pelly Crossing nursing station. Pelly Crossing houses a Royal Canadian Mounted Police detachment. A nursing facility is staffed by one nurse on-call 24 hours per day (YG, 2013d). The SFN provides additional services and support to its citizens through their department of Health and Social Services. The Yukon Children's Dental Program provides diagnostic, preventative, and restorative dental services, scheduled through the school (YG, 2013d).

There are approximately 135 private dwellings in Pelly Crossing, predominately single-detached dwellings. Most housing is owned by the First Nation (Statistics Canada, 2012). Yukon Housing Corporation offers 11 staff units in Pelly Crossing and offers programs and services that enable home renovations, construction of additional rental suites, mortgages and financing (YG, 2013d).

Pelly Crossing has a recreation centre, youth centre, swimming pool and seasonal heritage centre. The natural environment around Pelly Crossing provides seasonal recreation, such as hiking, cross-country skiing, and snowmobiling.

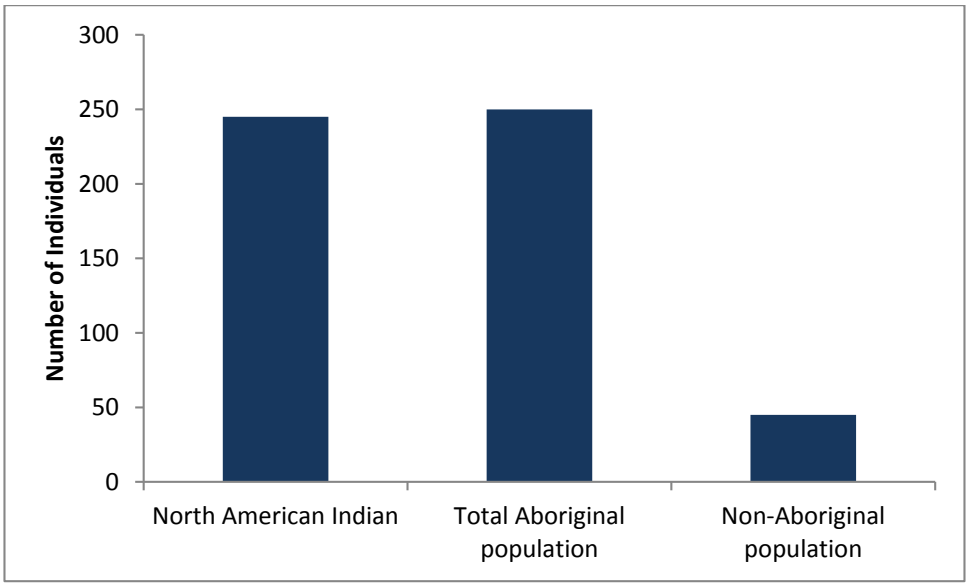
4.5.4 Land Use and Access

The FMC is not within the traditional territory of the SFN, nor do they typically use the land near the FMC. However, the creeks and rivers that flow through the FMC feed into the Pelly River watershed, and the SFN traditional territory extends upriver on the Pelly River to a location a few kilometres downstream of the FMC. Traditional activities such as stick gambling, hunting, fishing, and trapping are all popular. Ta'Tla Mun, Ddhaw Ghro, Minto, and Fort Selkirk are important sites used for recreation and leisure activities by residents of Pelly Crossing (SFN, 2013).

4.5.5 Culture and Heritage

As Figure 6L-73 shows, Pelly Crossing is predominantly Aboriginal, with the non-Aboriginal population accounting for 15 percent of the total population.

FIGURE 6L-73
Pelly Crossing: Aboriginal and Non-Aboriginal Population from Census 2006
Faro Mine Interim Works



Source: Statistics Canada, 2008.

The current Chief and Council of SFN is identified in Table 6L-8. On February 14, 2014, a Call for General Election was announced, and the election will be held in April (SFN, 2014a).

TABLE 6L-8
Selkirk First Nation Chief and Council
Faro Mine Interim Works

Name	Role
Kevin McGinty	Chief
Milly Johnson	Crow Councillor
Roger Alfred	Crow Councillor
Lori Sims	Deputy Chief, Wolf Councillor
Jeremy Harper	Wolf Councillor

Source: Selkirk First Nation, 2014b

The SFN people are part of the Northern Tutchone Tribal Council and part of the Northern Tutchone language and cultural grouping.

The Northern Tutchone inhabit the centre of the Yukon, often referred to as the 'heart.' There are three modern-day political organizations that make up the Northern Tutchone Tribal Council: The First Nation of Na-cho N'yak Dun, Selkirk First Nation, and the Little Salmon/Carmacks First Nation. All have signed their First Nation Final and Self-Government Agreements and are now self-governing.

SECTION 5

Conclusion

This report presents the baseline conditions for each of the identified VCs in the potentially affected communities for the FMIW, for the purpose of an environmental and socio-economic assessment under the *Yukon Environmental and Socio-economic Assessment Act*. Every effort has been made by the assessment team to reflect as much relevant and appropriate secondary data for the communities in the study area. A baseline conditions report simply provides a snapshot of community conditions at a certain point in time based on available secondary data for purposes of conducting a socio-economic effects assessment.

SECTION 6

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Appendix 7A
Air Quality Effects Report

Draft

Air Quality Effects Report
Faro Mine Interim Works

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

February 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon

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Acronyms and Abbreviations

µm/m^3	micrometres per cubic metre
AAQC	ambient air quality criteria
AAQO	ambient air quality objective
AQO	Air Quality Objective
AUT	automated
BC	British Columbia
BMP	Best Management Practice
CO	carbon monoxide
DVIHU	Down Valley Interim Hydraulic Upgrades
EC	Engineering Calculation
EF	Emission Factors
FMC	Faro Mine Complex
GLC	Ground Level Concentration
IW	[Faro Mine] Interim Works
km	kilometre
km^2	square kilometres
MDL	method detection limit
NO_x	nitrogen oxides
NPRI	National Pollution Release Inventory
O_3	ozone
PM_{10}	particulate matter with aerodynamic diameter less than 10 microns
$PM_{2.5}$	particulate matter with aerodynamic diameter less than 2.5 microns
POI	Point of Impingement
RCTA	Rose Creek Tailings Area
SENES	SENES Consultants Ltd.
SO_2	sulphur dioxide
TEOM	Tapered Element Oscillating Microbalance
TSP	total suspended particulates
YG	Government of Yukon
USEPA	U.S. Environmental Protection Agency
UTM	Universal Transverse Mercator
WMO	World Meteorological Organization

SECTION 1

1 Introduction

This appendix presents an assessment of the potential effects of Interim Works (IW) activities on ambient air of the area around the Faro Mine Complex (FMC), more specifically of particulate matter, and of metals within airborne particulate matter. Air quality is important to the health of humans, wildlife, and vegetation. IW construction and maintenance activities may cause dust and particulate matter to become airborne and thereby affect the air quality in the region.

The baseline air quality in the area surrounding the FMC was described in the *Air Quality Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a). The baseline climate and meteorological conditions were described in the *Climate Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013b). The Baseline Climate Report summarized the meteorological data and stations from which the meteorological surface data used in air dispersion modelling in this Air Quality Effects Report were pulled.

An initial assessment was performed to identify which IW activities may have the potential for specific pathways between the activity and the air quality valued component. Based on the results of the initial assessment, this report considered emissions from haul roads and access roads, construction activities associated with the Down Valley Interim Hydraulic Upgrades (DVIHU), and wind erosion from the tailings area. The haul roads and construction activities were considered as an aggregate pathway and were explicitly considered in the effects assessment. In addition, dust resuspension from the tailing area was quantified, because it was deemed a possible source of emissions and pathway.

Air dispersion modelling was performed using the U.S. Environmental Protection Agency (USEPA) CALPUFF model. This model was used to quantify the dispersion of the estimated emissions from the identified emission sources and to estimate contaminant air concentrations resulting from those emissions. The dispersion modelling was conducted in accordance with the BC Ministry of the Environment's March 2008 Guidelines for Air Quality Dispersion Modelling Guidance, except where otherwise noted. The air quality effects of the interim work activities described above were assessed by comparing to Yukon ambient air quality standards. In the absence of Government of Yukon (YG) standards, British Columbia (BC) or Ontario ambient air quality standards and guidelines were used.

The overall significance of the IW construction and maintenance activities were assessed by quantifying changes in ambient air concentrations relative to those of the baseline concentrations for particulate matter and metals. This was accomplished by developing an inventory of emission sources, estimating the emissions for each source of emissions, and performing comprehensive air quality dispersion modelling for receptors located both on- and off-property of the FMC. Based on the modelled results, consideration was given to a number of indicators such as magnitude and likelihood of the expected change, geographic extent of the change, and reversibility of the change in order to assess the overall significance of effect on air quality. Following this introduction, the Air Quality Effect Report is organized as follows:

- Section 2 describes the method of assessment used.
- Section 3 discusses the ambient air quality criteria (AAQC) (that is, the government regulations and standards) for relevant pollutants evaluated in the assessment.
- Section 4 describes the modelling results.
- Section 5 presents an assessment of the air quality impacts.

SECTION 2

2 Methods and Data

This section summarizes the methodology used for estimating air quality effects that could occur as a result of IW activities.

The FMC has a footprint of over 25 square kilometres (km^2) and consists of three primary areas, as follows:

- The Faro Mine Area, incorporating the Faro Pit, an out-of-service mill, and associated buildings.
- The Rose Creek Tailings Area (RCTA) and its impoundment, which is located in Rose Creek Valley.
- The Vangorda/Grum Area, which is located on the Vangorda Plateau and includes the Grum and Vangorda Pits.

The study area was based on the anticipated extent of potential air quality effects that could be attributable to project-related emissions, and comprised a 100-kilometre (km) -by-100-km square area approximately centred on the project site. The effects assessment used dispersion modelling to evaluate the air quality effects of the project over the study area. The emissions associated with each of the activities considered were estimated based on published emission factors and estimated activity parameters for similar activities.

Because of the complexity of the terrain in the vicinity of the FMC, it was decided that USEPA's CALPUFF air dispersion model would be most suitable to analyze the effects of IW activities on ambient air in the study area. The input parameters and rationale are presented in Attachment 7A-2 for both the CALMET meteorology pre-processing and CALPUFF dispersion modelling. A discussion of the assumptions used in emissions estimates and modelling methodology is presented in the following subsections.

2.1 Emissions and Scenarios

Only emissions directly associated with ongoing IW-related activities were quantified for the effects determination. Further, only activities that were deemed to have a pathway that could potentially affect air quality were considered in this study. Emission mitigation activities that will be implemented during construction and maintenance activities were included in the emission estimating process; the specific sources of emissions are discussed in the following subsections.

2.1.1 Sources and Contaminants

Based on a review of potential sources of emissions at the FMC facility, three primary sources of emissions were identified, namely the tailings area, haul and access roads, and construction activities. The dispersion modelling analysis was conducted to assess the effects on ambient air quality of total suspended particulate matter (TSP), particulate matter with aerodynamic diameter less than 10 microns (PM_{10}), and particulate matter with aerodynamic diameter less than 2.5 microns ($PM_{2.5}$).

It is noted that "dust" is a more general term associated with particulate matter but it typically refers to any form of particulate matter that is considered to be visible and therefore includes larger particles that tend to settle to the ground relatively quickly. There is no ambient air quality standard for "dust." Ambient air quality standards exist for TSP, PM_{10}, and $PM_{2.5}$. Also, the *Air Quality Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a) characterized the content of metals within TSP and PM_{10} and concentration estimates of metals within ambient air are presented in this assessment as well.

The sources of emissions considered in this study are summarized in Table 7A-1.

TABLE 7A-1
Source Identification Table
Faro Mine Interim Works

Source Identifier	Source Type	Source Description	Contaminants
TA	Tailings Area	• Waste and Water Management – Storage of tailings material in the RCTA	TSP, PM_{10}, $PM_{2.5}$, metals
RD	Roads	• Supporting Activities: – Transport of fuel and materials – Transport of personnel and supplies – Sourcing and transport of borrow material – General Project-related traffic	TSP, PM_{10}, $PM_{2.5}$, metals
CN	Construction	• Intermediate Dam Spillway Upgrade – Excavation of Intermediate Dam Spillway – Sourcing and transport of borrow material – Construction of erosion protection in spillway • Intermediate Dam Raise • Geomembrane and concrete barrier installation	TSP, PM_{10}, $PM_{2.5}$, metals

There are expected to be only minor amounts of combustion-related emissions occurring on the site during the IW activities. These emissions will be associated with comfort heating, diesel generators, and tailpipe emissions from onsite traffic. Combustion related contaminant emissions from the IW have been assumed to be small and of a nature that will not result in a significant change in ambient air quality at any location; therefore, these emissions have not been estimated or modelled.

2.1.2 Emission Estimates

Emission estimates have been developed for IW activities in each of the three identified areas using generally accepted methods, such as emission factors, source activity levels, meteorological parameters, and material properties. A discussion of the emission calculations for each source type is listed in Table 7A-1. Detailed emission estimate calculations are provided in Attachment 7A-1 for each of the source types.

2.1.2.1 Tailings Area Emissions

When the FMC was operational, the milling of ores resulted in solid waste which left the mill as a slurry. The slurry was channelled to the Original, Secondary, and Intermediate Impoundments, where the solids were allowed to settle out of suspension and now form a large, exposed tailings surface. The tailings area can be subject to wind erosion during periods of dryness. Fugitive particulate matter emissions from wind erosion of these tailings were included in this assessment. The emission factors of the RCTA were calculated using an equation published by Evans and Cooper (1980) using onsite meteorological data obtained in 2010 from the Faro Dump meteorological station. The meteorological data used in the estimation of emissions from the RCTA included monthly precipitation totals and mean monthly temperatures.

This method was designed to estimate annual emissions; therefore, it was necessary to scale the estimated annual emission factors to 24-hour average emission factors. This scaling helps account for the variability that occurs in a source's emissions on a day-to-day basis and that modelling of 24-hour concentrations should be done using a maximum 24-hour emission instead of an annual average. This scaling was performed consistent with a the Ontario Ministry of the Environment guidance document "Procedure for Preparing An Emissions Summary and Dispersion Modelling Report", Version 3, Table 7-1 (Ontario Ministry of the Environment, 2009). A summary of particulate matter emissions for the Tailings Area is provided in Table 7A-2.

2.1.2.2 Construction Emissions

The construction activities associated with the DVIHU have the potential to result in particulate matter emissions in the immediate vicinity of the Intermediate Dam area. Fugitive particulate matter resulting from construction

activities will have a significant fraction of particles with large aerodynamic diameters that have a tendency to settle out of the atmosphere rapidly.

The contaminants that arise from diesel engine combustion will be small and localized and are not expected to result in a significant impact on ambient air quality beyond the FMC site. The air emissions associated with construction activities will be highly variable in that the exact number of machines and timing are very difficult to quantify. Consequently, predicting emission impacts from these sources and activities has a high degree of uncertainty. Construction emissions associated with material handling and movement were included in the estimates of emissions for particulate matter.

Emissions from construction have been estimated using the methodology from the current USEPA AP-42, Fifth Edition, Chapter 13.2.3 (1995). This emission methodology is an all-inclusive estimate of particulate matter emissions from construction areas where the emissions are proportional to the amount of land being worked and to the level of construction activities. Sources of emissions from construction-related activities will include land clearing and forming, drilling, ground excavation, cut and fill operations (earth moving), and construction-related activities of roads and facilities. In this report, construction areas were assumed to cover the DVIHU construction area, the Cross Valley Pond area and the Intermediate Pond area; thus the impacts of construction activities are considered conservative.

Construction was assumed to be year-round for the purposes of modelling, but much of the activity is done during the summer months only. Also, the construction activity was restricted to daytime only, from 7 a.m. to 7 p.m.

A summary of particulate matter emissions for the construction area is provided in Table 7A-2 and further details about the emission calculations are provided in Attachment 7A-1 of this report.

Fugitive Particulate Matter Emissions from Roads and Access Routes

Particulate matter emissions from onsite unpaved roads, trails and access routes were estimated using methods provided in Environment Canada's *National Pollution Release Inventory Tool Box – General NPRI Reporting Tools* (1986). It was assumed that snow cover would mitigate road dust during the winter months (October to April inclusive). Further, roads were only assumed travelled during the day (7 a.m. to 7 p.m.). The emission rates of identified contaminants for each identified sources used in the modelling are presented in Table 7A-2. The emissions from the roadways are dependent on the length of the roads, silt content, vehicle weight, and vehicle traffic counts on each road segment.

Since there are numerous smaller roads in both the Faro side and the Vangorda/Grum sides of the FMC, the total road distances were estimated and aggregated into a single area source for each side of the FMC. These sources were designated as RD_FS and RD_GS for Faro side and Vangorda/Grum side respectively in Table 7A-2. The haul road connecting the two sides of the FMC and the access road to the south were modelled as a series of elongated area sources of 15 metres (m) by 150 m.

Emission Controls

An average control efficiency of 60 percent was applied to the uncontrolled tailings area emissions, construction emissions, and road dust emissions. This is because of the expected addition of water and dust suppression substances on the roadways and the tailings area, and use of best management practices (BMPs) for fugitive reduction control during construction activities. This control efficiency is consistent with that provided in Cowherd et al. (1988), for similar activities and was applied to all emissions of TSP, PM_{10}, and $PM_{2.5}$ in this study.

All of the particulate matter emission sources were modelled as area sources. A summary of the total emissions, normalized to a square metre area from each of the modelled emission sources is shown in Table 7A-2, along with the percent contribution from each source with respect to total FMC-wide emissions. A summary of the total emissions by type (i.e. tailings, construction, and roads), as well as the percent contribution to total emissions are shown in Table 7A-3. A summary of the diurnal variation in emissions from the various sources are provided in Table 7A-4.

TABLE 7A-2
Source and Emission Summary
Faro Mine Interim Works

Source Identifier	Source Description	Contaminants	24-hour Emission Rate ($g/s/m^2$)	Method Reference	Percent of overall emissions (%)
TA-1	Tailings Area	TSP	1.14E-6	EF/EC	3.1
		PM10	5.70E-7	EF/EC	3.5
		PM2.5	5.70E-8	EF/EC	3.5
RD-HAUL	Haul Road	TSP	2.41E-5	EF	5.8
		PM10	6.38E-6	EF	3.5
		PM2.5	6.38E-7	EF	3.5
RD-ACCES	Access Road	TSP	1.59E-5	EF	4.3
		PM10	4.21E-6	EF	2.6
		PM2.5	4.21E-7	EF	2.6
RD-Faro	Faro Side Roads Area	TSP	9.78E-7	EF	9.1
		PM10	2.59E-7	EF	5.5
		PM2.5	2.59E-8	EF	5.5
RD-Grum	Vangorda/Grum Roads Area	TSP	6.33E-7	EF	6.6
		PM10	1.68E-7	EF	4.0
		PM2.5	1.68E-8	EF	4.0
CN-1	Intermediate Dam Construction Area	TSP	2.08E-5	EF	71.1
		PM10	1.04E-5	EF	80.9
		PM2.5	1.04E-5	EF	80.9

Notes:
The sum of all individual TSP sources is 100 percent, as are the sums of the individual PM_{10} and $PM_{2.5}$ sources
EF = Emission Factors
EC = Engineering Calculation
$g/s/m^2$ = grams per second per square metre

TABLE 7A-3
Summary of Total Emissions by Type
Faro Mine Interim Works

Temporal Period	TSP (g/s) and (%)	PM_{10} (g/s) and (%)	$PM_{2.5}$ (g/s) and (%)
Tailings Area	1.95 / 3.1	0.975 / 3.5	0.0975 / 3.5
Unpaved Roads	16.4 / 25.9	4.35 / 15.6	0.435 / 15.6
Construction	45.1 / 71.1	22.6 / 80.9	2.26 / 80.9

TABLE 7A-4
Summary of Diurnal and Monthly Activity
Faro Mine Interim Works

Temporal Period	Construction Area	Tailing Area	Roads
Daily	7 a.m. - 7 p.m. only	All hours	7 a.m. – 7 p.m.
Monthly	All months	All months	May-September Emissions Only

It was assumed that construction for the DVIHU would occur only within the daytime hours of 7 a.m. to 7 p.m., and construction-related emissions would not occur in the late evening and overnight hours. The haul roads and access roads were assumed to have traffic only during hours consistent with construction activities. Also, accumulated snow from October to April inclusive would mitigate fugitive emissions from the haul roads and access roads during these months. In general, the maximum 24-hour contaminant emissions estimates were used for the modelling consistent with the averaging period of most standards for particulate matter and metals.

Metals Emissions

In order to estimate the ambient air concentrations of metals within particulate matter as a result of IW activities, data from previous monitoring studies were used, specifically the data from the SENES Consultants Ltd. (SENES) 2008 field monitoring program that measured PM_{10} and metals concentrations at various locations in the FMC. A statistical analysis of the data was performed and a ratio was developed between the ambient PM_{10} concentration and the concentrations of various metals reported in that study. The metals concentrations in this assessment were then estimated by using the modelled PM_{10} concentration times the observed ratio of metals to PM_{10}, and adding the metals concentrations that are expected to constitute background concentrations.

The SENES 2008 ambient air monitoring program and results are discussed in the *Air Quality Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a).

A summary of the ratio of metals to PM_{10} derived from the SENES study are listed in Table 7A-5. Metals designated with an “MDL” indicates that the metals were below method detection limits (MDL) during the SENES 2008 monitoring program.

TABLE 7A-5
Summary of Observed Ratios of Metals to PM_{10} Concentrations
Faro Mine Interim Works

Metals	Metal/PM_{10} Ratio
Antimony	MDL
Arsenic	0.027%
Barium	0.063%
Beryllium	MDL
Boron	MDL
Cadmium	0.0036%
Chromium	1.09%
Cobalt	MDL
Copper	0.16%
Iron	2.28%
Lead	0.081%
Manganese	0.032%
Molybdenum	0.0049%

TABLE 7A-5
Summary of Observed Ratios of Metals to PM_{10} Concentrations
Faro Mine Interim Works

Metals	Metal/PM_{10} Ratio
Nickel	0.024%
Selenium	MDL
Silver	0.0035%
Strontium	0.011%
Tellurium	MDL
Tin	0.025%
Titanium	0.086%
Vanadium	MDL
Zinc	0.17%

Source: SENES 2008 Monitoring Program
Notes:
MDL = metals were below method detection limit

2.2 Modelling Methods

2.2.1 CALPUFF Dispersion Model

CALPUFF is a multi-layer, multi-species, non-steady-state puff dispersion model. Because of the complexity of the terrain, it was decided that the most recent version of the USEPA air dispersion model CALPUFF (Version 6.42) and the meteorological preprocessor for the CALPUFF modelling system (CALMET) would be most suitable to analyze the nearby and possible far-field dispersion of particulate matter emissions originating from the IW activities at the FMC.

CALPUFF is a non-steady-state Gaussian puff dispersion model with algorithms for chemical transformations and deposition. The model uses three-dimensional wind fields that can vary on an hourly basis. The model is capable of integrating surface meteorological observations from multiple sources/stations.

2.2.2 CALPUFF Methodology

The CALPUFF input files require a number of switches that must be defined by the modeller. These switches control factors such as transitional plume rise adjustments, stack-tip downwash, puff splitting, aqueous phase transformations, and wet and dry deposition to name a few. The model inputs used for the modelling were consistent with those recommended by the BC Ministry of the Environment unless otherwise noted and are shown in Attachment 7A-2.

2.2.3 Stack and Source Parameters

A summary of the area source parameters used in the modelling analyses are presented in Table 7A-6 for the FMC. All activities were modelled as area sources, including the haul and access roads. There are a number of roads in both the Faro and Vangorda/Grum sides of the FMC. The total length of roadway within the Faro and Vangorda/Grum sides of the FMC were estimated based on recent site maps. The total particulate matter emissions were allocated within the area sources provided in Table 7A-6 for the RD-FARO and RD-GRUM sources. The access roads leading to the FMC, as well as the haul road connecting the two sides of the FMC were modelled using a connected series of area sources each 15 m wide and 150 m long for both sources. The total number of vehicles estimated to be travelling on these roads were supplied by onsite personnel and people familiar with the site operations. A total of 10.24 km and 11.50 km of roadway were modelled for the haul road and access roads, respectively.

In Table 7A-6, the total area associated with each of the modelled sources is shown. Release height is the height aboveground at which emissions are assumed released to the atmosphere within the area source, and initial sigma is the initial vertical spread of the fugitive dust associated with the emission source. These values are typical for these emission types and are based on the professional judgement of the modeller.

A representation of the source layout as modelled in this study is shown in Figure 7A-1. Details of the emission estimates are shown in Attachment 7A-1.

TABLE 7A-6
Source Parameter Summary Table
Faro Mine Interim Works

Source Identifier	Point Source Description	Area (hectares)	Release Height (m)	Initial Sigma (m)
TA-1	Tailings Area	171.05	0.5	1.0
CN-1	Intermediate Dam Construction Area	217.61	2.5	5.0
RD-Faro	Faro Side Roads	588.86	1.5	3.0
RD-Grum	Grum Side Roads	666.72	1.5	3.0
HR	Haul Road	15.36	1.5	3.0
AR	Access Road	17.25	1.5	3.0

2.2.4 Receptor Grid

Ground level contaminant concentrations for the modelling domains were calculated over a uniform receptor grid with 500-m spacing as well as at discrete receptors situated along the perimeter of the FMC. Since the emissions are from near-ground level fugitive emission sources, it is expected that the highest off-property ambient air concentrations will be at the property line where the receptor spacing is 100 m. Onsite receptors were spaced at 500 m. The additional receptors were used with the following resolution:

- 100 m at the property line (defined by the boundary of the staking withdrawal area)
- 500 m out to 12,000 m from the approximate centre of the project site (i.e., 586.257 Universal Transverse Mercator [UTM] Easting, 6909.677 km UTM North Zone 8N)
- 1000 m spacing out to 50 km from approximate centre of the FMC

A total of 3409 receptors were used to calculate concentrations within the entire modelling domain.

The boundaries of the staking withdrawal area and locations of the area sources used for the effects assessment are shown in Figure 7A-1. Figure 7A-2 shows the terrain contours in the area of the FMC. A close up view of the perimeter receptors and gridded receptors in the vicinity of the FMC is shown in Figure 7A-3.

Air quality standards are generally compared to off-property air concentrations from any particular facility or site. However, maximum concentrations for both on-property and off-property receptors are shown in the summary tables. The Faro Mine staking withdrawal area was used as the property boundary.

2.2.5 CALMET Methodology

The air pollution potential is defined as the meteorological conditions which, given the existence of emissions, would be conducive to poor air quality. Conditions that allow for the accumulation of pollutants denote high air pollution potential. The dispersion of pollutants may be evaluated from the duration of light wind speeds, atmospheric stability, and mixing layer depths.

Meteorological data was processed using the most recent release of USEPA's CALMET meteorological pre-processor (Version 6.334, Level 110421). The major purpose of CALMET is to calculate atmospheric boundary layer parameters for use by CALPUFF. The CALMET meteorological model consists of a diagnostic wind field

module and micrometeorological modules for overwater and overland boundary layers. The final output for the CALMET meteorological preprocessor is a three-dimensional wind field and associated parameters required by CALPUFF to estimate dispersion and downwind concentrations of emitting sources and contaminants.

2.2.5.1 Meteorological Data Used for Effects Assessment

The local meteorology of the region must be characterized to evaluate the short-term atmospheric dispersion and transport of emissions released by the sources considered at the FMC. The data necessary to predict dispersion and transport include: wind velocities and direction, temperature, atmospheric stability, and mixing layer depth. Wind and temperature data are available from Environment Canada meteorological stations or onsite stations where available. Atmospheric stability and mixing layer depth are calculated from additional raw meteorological data such as cloud cover and solar radiation.

The surface meteorological data used in this study were presented in detail in the *Climate Baseline Report, Faro Mine Interim Works* (CH2M HILL, January 2013b). The data used in the study were taken from the Faro Dump monitoring station, the Grum Dump monitoring station, and the Faro Automated (AUT) Environment Canada station, all from the year 2010. As indicated in the *Air Quality Baseline Report, Faro Mine Interim Works* (CH2M HILL, January 2013a), the location of the Grum side monitoring station was moved in June of 2010, to a location about 1 km northeast of the old site. However, a correction factor was applied to the wind directions at the new site by the contractor responsible for those stations to keep the two data sets consistent (Denison Environmental Services, 2011). The old station location was used in the CALMET processing.

Additionally, prognostic meteorological data from the MM5 model (abbreviation for Fifth-Generation Penn State/NCAR Mesoscale Model) was used to supplement the surface data listed on Table 7A-7. These data are typically used for air dispersion modelling purposes when the study area is large and surface meteorological data may not be available for the entire domain, and when the available data may have gaps in either the parameters measured or in temporal completeness (BC Ministry of the Environment, 2008). The MM5 data were obtained through Lakes Environmental in Waterloo, Ontario, and were used as the initial wind field in the CALMET processing. No upper air radiosonde data were used in this study. Information on upper air winds and temperature structure of the atmosphere was taken from the multi-layer MM5 data. MM5 data is particularly useful in this modelling study due to the lack of upper air data in close proximity to the FMC.

A summary of CALMET switches used in the study are listed in Attachment 7A-2.

TABLE 7A-7
Meteorological Stations Used in Dispersion Modelling
Faro Mine Interim Works

Station Name	Climate ID/ WMO ID	UTM Easting (km)	UTM Northing (km)	Elevation (m)	Parameters Used
Faro Dump Station	NA	584.127	6913.966	1169	WS, WD, Temp
Grum Dump Station	NA	592.488	6904.251	1250	WS, WD, Temp
Faro (AUT)	2100518/ 71949	584.484	6898.355	717	WS, WD, Temp, Rel Hum

Notes:
AUT - Automated
ID – identification
m - metre
km - kilometre
NA – not applicable
Rel Hum – Relative Humidity
Temp – Temperature
WD – Wind Direction
WS – Wind Speed
WMO - World Meteorological Organization

SECTION 3

3 Regulations and Standards

3.1 Background

The AAQC for relevant pollutants are discussed in this section. An AAQC is a desirable concentration of a contaminant in air, based on protection against adverse effects on health or the environment. The term "ambient" is used to reflect general air quality independent of location or source of a contaminant. AAQCs are most commonly used in environmental assessments, special studies using ambient air monitoring data, assessment of general air quality in a community and annual reporting on air quality across the territory. AAQCs are set with different averaging times (e.g., annual, 24 hours, 1 hour, and 10 minutes) that are appropriate for the effect that they are intended to protect against. Health, odour, vegetation, soiling, visibility, corrosion or other effects are considered.

Existing air quality in the vicinity of the FMC was previously discussed in terms of baseline air quality emissions and was presented in the *Air Quality Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a).

Governments have promulgated a number of air quality criteria for several pollutants considered to be harmful to either the ecosystem or humans. Since there are numerous air contaminants that could exist in the air, it is not possible to promulgate criteria for all contaminants. However, most jurisdictions have standards associated with the criteria contaminants, including particulate matter, sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and ozone (O_3).

YG has established ambient air standard for TSP and $PM_{2.5}$, as well as other criteria contaminants. In BC, up to three objective values have been recommended using the categories "desirable", "acceptable", and "tolerable" (Levels A, B, and C, respectively); "desirable" being the most stringent. Ontario has a number of ambient air quality criteria introduced as part of Ontario Regulation 419. With that regulation, Ontario developed standards for a number of pollutants that previously had no standard, and reduced many existing standards to reflect a greater understanding of the health and vegetative effects of some pollutants.

Typically, an air quality standard is meant to connote a legal limit for a pollutant numerical concentration (i.e. part of a provincial or territorial regulation), while objectives and guidelines are meant to connote a desirable concentration of a pollutant but not necessarily legally binding with respect to air permitting or environmental assessment purposes.

3.2 Air Quality Standards and Guidelines

Predictions of the maximum ground level concentrations for each averaging period are compared to the corresponding air quality standards or guidelines from Yukon, BC, or Ontario, as shown in Table 7A-8. Preferentially, Yukon standards were used for the contaminants when available, in this case TSP for 24-hour and annual averages, and 24-hour average $PM_{2.5}$ concentrations. If Yukon standards were not available and more than one provincial standard exists for a particular contaminant or averaging period, the most stringent of them was used for comparison. For 24-hour PM_{10}, the "desirable" objective from BC was used, while for the metals, Ontario 24-hour average standards and guidelines were used. Governments use ambient air quality criteria to make decisions about acute exposure to air contaminants. Although some criteria were from other jurisdictions outside of the Yukon, the use of criteria from other provinces helps to put the concentrations determined in this assessment into context and gauge acceptability and significance.

Standards and guideline concentration units are in micrometres per cubic metre ($\mu g/m^3$) unless otherwise noted.

TABLE 7A-8
Summary of Ambient Air Quality Standards for All Modelled Contaminants µg/m³
Faro Mine Interim Works

	Avg. Period		
Contaminant	**24-hour**	**Annual**	
Total Particulate (TSP)	120	60	Yukon AAQS
PM_{10}	50		BC AAQO
$PM_{2.5}$	30		Yukon AAQS
Antimony	25		Ontario Standard
Arsenic	5		Ontario Standard
Barium	10		Ontario Guideline
Beryllium	0.01		Ontario Standard
Boron	120		Ontario Standard
Cadmium	0.025		Ontario Standard
Chromium	1.5		Ontario Guideline
Cobalt	0.1		Ontario Guideline
Copper	50		Ontario Standard
Iron	4		Ontario Standard
Lead	0.5		Ontario Standard
Manganese	2.5		Ontario Guideline
Molybdenum	120		Ontario Guideline
Nickel	2		Ontario Standard
Selenium	10		Ontario Guideline
Silver	1		Ontario Standard
Strontium	120		Ontario Guideline
Tellurium	10		Ontario Standard
Tin	10		Ontario Standard
Titanium	120		Ontario Standard
Vanadium	2		Ontario Standard
Zinc	120		Ontario Standard

AAQO: Ambient Air Quality Objective
Yukon AAQS: Yukon Ambient Air Quality Standards

SECTION 4

4 Modelling Results

4.1 Introduction

The FMC was assessed quantitatively by modelling the estimated emissions that will result from construction and maintenance activities that are or will occur at the site over the next 10 years. The individual activities constituting the IW were initially qualitatively assessed to determine whether there existed a feasible pathway whereby air quality in the study region could potentially be affected. The activities that were deemed to likely affect air quality were quantified in terms of emissions and were then modelled to conservatively estimate the extent of the effects of those emissions.

The air quality effects from the identified emissions sources at the FMC are presented in this section. The activities chosen for quantitative assessment were previously summarized in Section 2 of this Appendix.

Ambient air standards are generally compared against a total pollutant concentration in air. Therefore, the assessment of effects was performed by adding existing background concentrations of particulate matter and metals with those estimated by the air dispersion modelling of construction and maintenance activity emissions. The background concentrations for particulate matter and metals were presented in *Air Quality Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2013a), and were measured at the FMC during 2008 when care and maintenance activities and road traffic associated with those activities occurred. It is likely that this will result in a "double counting" of emissions associated with road dust resuspension and tailings area wind erosion. Therefore, concentrations predicted in this assessment are likely to be conservatively high. The cumulative total of the modelled plus background were then compared to the applicable ambient air quality criteria as listed in Table 7A-8 to determine magnitude, extent, and frequency and overall significance of predicted effects, if any.

Effects of various components of the IW on air quality are summarized in the following sections.

4.2 Results

The maximum predicted 24-hour and annual average ground level concentrations were calculated using the CALPUFF dispersion model for each contaminant and applicable averaging period. Table 7A-2 in Section 2, provides a complete emissions summary.

4.2.1 Particulate Matter

A summary of the predicted maximum off-property ground level concentrations for each particulate contaminant and the applicable Air Quality Objective (AQO)/Point of Impingement (POI) are presented in Table 7A-9. Also presented in this table are the coordinates of the location where the maximum concentration occurs and the comparison of the predicted concentration with the applicable AQO or POI. Background concentrations for the contaminants have been listed and added to the modelled results to show an estimated total concentration for each contaminant and averaging period, as applicable.

A summary of the predicted maximum ground level concentrations for all receptors for each contaminant and the applicable AQO/POI are presented in Table 7A-10. These predictions include receptors that are very close to proposed construction activities, resulting in higher maximum concentrations.

TABLE 7A-9
Summary of CALPUFF Dispersion Modelling Results for Particulate Matter – Off Property
Faro Mine Interim Works

Contaminant	Maximum GLC (µg/m³)	UTM Easting (km) [b]	UTM Northing (km) [b]	Background Concentration (µg/m³)	Combined Maximum Concentration (µg/m³)	Air Quality Standard (µg/m³)	Percentage of Air Quality Standard (%)	Frequency of Exceedance (%)
24–Hour Average Concentration								
TSP	48	577.770	6915.105	11.7[a]	60	120	50	0
PM_{10}	33	577.494	6914.854	7.1[a]	40	50	81	0
$PM_{2.5}$	3	577.494	6914.854	7	10	30	35	0
Annual Average Concentration								
TSP	5	578	6916	11.7	16.7	60	27.8	0

[a]75th Percentile
[b] Location of Maximum Impact

TABLE 7A-10
Summary of CALPUFF Dispersion Modelling Results for Particulate Matter – All Receptors
Faro Mine Interim Works

Contaminant	Maximum GLC (µg/m³)	UTM Easting (km) [b]	UTM Northing (km) [b]	Background Concentration (µg/m³)	Combined Maximum Concentration (µg/m³)	Air Quality Standard (µg/m³)
24–Hour Average Concentration						
TSP	513	580.257	6914.177	11.7[a]	525	120
PM_{10}	490	580.257	6914.177	7.1[a]	497	50
$PM_{2.5}$	49	580.257	6914.177	7	56	30
Annual Average Concentration						
TSP	102	582.257	6913.177	11.7	114	60

[a]75th Percentile
[b] Location of Maximum Impacts

Maximum 24-hour, and annual average Ground Level Concentrations (GLCs) for each modelled contaminant during the IW activities are below the applicable air quality standards when considering off-property receptors. Maximum off-property concentrations for particulate matter are occurring in the northwest part of the mining tenure border, west of the area where DVIHU construction is to take place.

Concentration isopleths showing the maximum 24-hour concentrations of TSP for off-property receptors are shown in Figure 7A-4. The same isopleths for PM_{10} and $PM_{2.5}$ are shown in Figures 7A-5 and 7A-6.

Concentration isopleths showing the maximum 24-hour concentrations of TSP for all receptors including on-property are shown in Figure 7A-7. The same isopleths for PM_{10} and $PM_{2.5}$ are shown in Figures 7A-8 and 7A-9. These figures show the modelled concentrations at each receptor predicted over the modelling period (2010). Figures 7A-10 through 7A-12 shows the number of days that an ambient air standard was exceeded as determined through dispersion modelling for TSP, PM_{10}, and $PM_{2.5}$, respectively. These figures show that exceedances of ambient air standards and guidelines are highly localized to the immediate construction area and to a lesser extent the tailings area.

Considering only off-property receptors, the maximum 24-hour and annual average concentrations for TSP, PM_{10}, and $PM_{2.5}$ are all predicted to be below the applicable standards at all times.

4.2.2 Metals

A summary of the predicted maximum off-property ground level concentration for each metal contaminant (contained within particulate matter) and the applicable standards or guidelines is presented in Table 7A-11. It should be noted that the metals standards and guidelines are from Ontario since no applicable Yukon standards exist for these contaminants. The comparison against Ontario standards is made to help assess the significance of the modelled concentrations.

TABLE 7A-11
Summary of CALPUFF Dispersion Modelling Results for Metals – Off Property
Faro Mine Interim Works

Contaminant	Maximum Ground Level Concentration (µg/m³)	Background Concentration (µg/m³)	Combined Maximum Concentration (µg/m³)	Air Quality Criteria (µg/m³)	Percentage of Air Quality Objective/Standard (%)
Antimony	MDL	MDL	MDL	25	n/a
Arsenic	0.0088	0.0049	0.0137	5	0.3%
Barium	0.0208	0.0460	0.0668	10	0.7%
Beryllium	MDL	MDL	MDL	0.01	n/a
Boron	MDL	MDL	MDL	120	n/a
Cadmium	0.0012	0.0025	0.0037	0.025	14.7%
Chromium	0.3628	0.2600	0.6228	1.5	41.5%
Cobalt	MDL	MDL	MDL	0.1	n/a
Copper	0.0547	0.4800	0.5347	50	1.1%
Iron	0.7562	1.3900	2.1462	4	53.7%
Lead	0.0269	0.0840	0.1109	0.5	22.2%
Manganese	0.0106	0.0210	0.0316	2.5	1.3%
Molybdenum	0.0016	0.0011	0.0027	120	<0.1%
Nickel	0.0081	0.0090	0.0171	2	0.9%
Selenium	MDL	MDL	MDL	10	n/a
Silver	0.0012	0.0009	0.0021	1	0.2%
Strontium	0.0037	0.0042	0.0079	120	<0.1%
Tellurium	MDL	MDL	MDL	10	n/a
Tin	0.0083	0.0150	0.0233	10	0.2%
Titanium	0.0286	0.0270	0.0556	120	<0.1%
Vanadium	MDL	MDL	MDL	2	n/a
Zinc	0.0569	0.1000	0.1569	120	0.1%

Notes:
MDL = less than Method Detection Limit (not detectable during monitoring program)
µg/m³ = micrograms of contaminant per cubic metre
n/a = Not applicable or Not Available

Table 7A-12 shows a summary of the predicted maximum ground level concentration for each metal contaminant (contained within particulate matter) and the applicable standards or guidelines from all receptors including onsite receptors.

Maximum 24-hour average GLCs of metals during the IW are well below the applicable objectives/standards for all off-property receptors. All metal concentrations are predicted to be less than their applicable standard and most are less than 1 percent of the standard or were not detectable during the SENES 2008 monitoring program. The maximum predicted concentration of metals is only 54 percent of the applicable standard. No off-property exceedances are predicted.

For all receptors, only two metals (chromium and iron) show highly localized exceedances in and near the construction area. It should be noted that metals concentrations were estimated by using a ratio of metal to PM_{10} concentrations developed from data supplied by SENES (2009). Emission estimates of fugitive particulate matter are difficult to develop and are subject to considerable uncertainty, and therefore the metals estimated are subject to the same uncertainty. The modelling shows that particulate matter decreases to below applicable standards beyond the property line and the modelled effects are highly localized.

TABLE 7A-12
Summary of CALPUFF Dispersion Modelling Results for Metals – All Receptors
Faro Mine Interim Works

Contaminant	Maximum Ground Level Concentration (µg/m³)	Background Concentration (µg/m³)	Combined Maximum Concentration (µg/m³)	Air Quality Criteria (µg/m³)
Antimony	MDL	MDL	MDL	25
Arsenic	0.13	0.0049	0.13	5
Barium	0.31	0.0460	0.35	10
Beryllium	MDL	MDL	MDL	0.01
Boron	MDL	MDL	MDL	120
Cadmium	0.017	0.0025	0.020	0.025
Chromium	5.34	0.2600	**5.62**	1.5
Cobalt	MDL	MDL	MDL	0.1
Copper	0.81	0.4800	1.29	50
Iron	11.2	1.3900	**12.6**	4
Lead	0.40	0.0840	0.48	0.5
Manganese	0.16	0.0210	0.18	2.5
Molybdenum	0.024	0.0011	0.025	120
Nickel	0.12	0.0090	0.13	2
Selenium	MDL	MDL	MDL	10
Silver	0.017	0.0009	0.018	1
Strontium	0.054	0.0042	0.059	120
Tellurium	MDL	MDL	MDL	10
Tin	0.12	0.0150	0.14	10
Titanium	0.42	0.0270	0.45	120
Vanadium	MDL	MDL	MDL	2
Zinc	0.84	0.1000	0.94	120

Notes:
MDL = less than Method Detection Limit (not detectable during monitoring program)
µg/m³ = micrograms of contaminant per cubic metre
n/a = Not applicable or Not Available

4.3 Assessment Limitations

The assessment of the air quality effects of the FMC during construction and maintenance are subject to some limitations. The fugitive dust analysis is subject to significant uncertainties because of the inherent challenge in accurately estimating emissions inventories and in properly modelling their concentrations. The dust estimates were based on 2010 meteorological observations from the Faro Dump meteorological monitoring station. Estimates of PM_{10} and $PM_{2.5}$ were based on general particle size distributions consistent for that type of emission as per USEPA AP-42 guidance (USEPA, 1995).

Deposition loss from the suspended particulate matter would be expected in the near field but because of the lack of information regarding particle sizes within the dust. Because the model does not account for depositional loss of crustal dust which was not included in the modelling, the model will likely predict higher ambient concentrations of particulate matter and metals than what would actually be predicted if deposition were included.

The IW activities did not include an analysis of criteria contaminants, other than particulate matter, for two reasons:

- The emissions of other criteria contaminants are expected to be very small and no significant effect on ambient concentrations of those pollutants is expected. Also, there would be significant uncertainties associated with modelling of mobile equipment such as work schedule, number of vehicles, location of vehicles, as well as uncertainties in the emissions factors and estimates themselves.
- The property line for the IW activities analysis was based on the boundary of the existing mineral staking withdrawal and is therefore a large area. The concentrations at the edges of the mining tenure are expected to be very small and localized to near the edge of the property. Modelled concentrations because of IW activities at these locations are expected to be indistinguishable from the natural variability of contaminant background concentrations.

Emissions from roadways were determined from estimates of daily traffic as supplied by onsite personnel, including security guards and managers familiar with traffic flow into and out of the site. Since traffic patterns were not known with certainty, it was assumed that vehicle traffic on the haul roads would travel on all FMC and Vangorda/Grum mine site roads as well. This is an inherently conservative assumption.

All of the expected particulate matter sources were modelled simultaneously for each of the identified activities in order to determine a worst case scenario. In reality, only infrequent occurrences of simultaneous tailing emissions, construction emissions, and roadway emissions are likely to occur on a consistent basis.

A 60-percent reduction in fugitive dust emissions was assumed to account for dust mitigation because of the anticipated application of tackifiers, water, and dust mitigation BMPs throughout the site. In reality, these activities will likely be more effective and reductions larger than the 60 percent (Hayden, 2005) are likely for both unpaved roads and the tailings area.

The modelling also assumed year-round emissions from the tailings area, which would likely not occur when there is snow cover. However, winter emissions were included in the study since dusting from the tailings area is known to occur when temperatures are cold but when there is not yet snow cover.

SECTION 5

5 Assessment of Air Quality Effects

5.1 Introduction

The IW activities have the potential to emit particulate matter and metals within particulate matter because of material handling, wind erosion, and resuspension of road dust because of onsite traffic. The overall assessment of significance of the air quality effects was determined by the direction of the effect, the magnitude and probability of the effect, the reversibility of the effect with consideration of timing and requirement of mitigation, and the geographic extent of the change. These will be discussed in more detail in the following sections.

Section 5.2 discusses the significance of possible cumulative effects that may occur in the study region as a result of IW emissions.

An assessment of the overall significance of the air quality effects are presented in Section 5.3 and includes the considerations and rationale used for determining significance and definitions of the ratings scale for each.

5.2 Cumulative Effects Assessment

A cumulative effects assessment extends what is normally in an environmental impact assessment to include effects over a larger area and a longer time period. Cumulative impacts can occur when more than one disturbance affects a resource, when one action results in multiple effects on a resource, or when similar small-scale events occur repeatedly in time or space, thereby causing a magnified impact (Hegmann, 1999).

This section considers the cumulative effects of the IW activities in the study area.

5.2.1 Interim Works Emissions with Existing Emission Sources

The modelling impact analyses presented previously include existing background concentrations for particulate matter. It is expected that these background levels are representative of the impacts from existing contaminant sources in the area surrounding the FMC.

The area surrounding the FMC is isolated and, therefore, the background levels of each of the contaminants are expected to be relatively small. The Town of Faro is located about 12 km south of the FMC and 6 km southwest of the Vangorda/Grum side of the complex. There is also an access road leading from the Robert Campbell Highway, through the Town of Faro and up to the FMC. Therefore, some contribution to background levels would be expected from mobile source combustion products such as nitrogen oxides, particulate matter, and carbon monoxide as well as contributions to particulate from residential heating and wood burning. The model predictions are conservative, especially with respect to particulate matter from construction activities at the site. The actual incremental impact from the FMC emissions are expected to be less than those presented in the modelling analyses provided, especially when a dust/particulate matter BMP plan is implemented.

The cumulative effects of criteria contaminants from the FMC with other emissions from nearby access road, highways, and the Town of Faro are expected to be minimal.

5.2.2 Secondary Particulate from Interim Works Emissions

A long-range assessment of secondary formation of ammonium sulphate and ammonium nitrate from the precursor gases of sulphur dioxide and nitrogen oxides was not performed in this study. This is because of the minimal amount of SO_2 and NO_x that is expected to be generated at the FMC because of the IW. Further, it is expected that in the field where the highest concentrations are expected to be found, secondary particulate formation will be insignificant compared to primary particulate matter from the various fugitive sources.

No significant cumulative effects from the IW with respect to secondary particulate formation from precursor emissions are expected to occur.

5.2.3 Long Range Transport of Interim Works Emissions

Based on the modelling results for particulate matter, and the likely insignificance of secondary particulate formation from SO_2 and NO_x precursor emissions, the IW emissions are not expected to have a measurable effect on air quality in the Town of Faro. The effects are therefore expected to be indistinguishable from background levels.

5.3 Residual Effects and Effects Assessment

This section describes the results of the detailed analysis of the potential effects on air quality from the IW. The air quality assessment considers the effect of all activities that may adversely affect the air quality of the region.

The model predictions presented in Section 4 are conservative and the incremental contribution to ambient contaminant levels is expected to be moderate to high within the construction and tailings area but low or no effect outside of the area withdrawn from mineral staking.

5.3.1 Air Quality Pathways of Effects

The pathways of effects are the activities that were identified as having the ability to affect air quality. These pathways include dust resuspension from the tailing area, general construction activities, and dust resuspension from vehicle traffic on unpaved roadways within the FMC. All of these activities have the potential to affect air quality and are assessed together through emission estimates and air dispersion modelling to quantify their potential effects.

5.3.2 Air Quality Indicators

The indicators used to assess air quality included the change in concentration of particulate matter in air, specifically TSP, PM_{10}, $PM_{2.5}$, and metals. The changes in air concentrations for these contaminants were estimated using emission estimates and air dispersion modelling for each of the potential pathways. Also, previous monitoring programs at the site (SENES, 2009) measured ambient air concentrations of a number of metals as shown in Table 7A-5. The concentrations of these metals were estimated based on the correlation of the observed ratio of metals to PM_{10} during the monitoring program and the model estimates for PM_{10} from this study. These indicators were chosen because of the IW activities being assessed as pathways; particulate matter and the (possible) metals within them were expected to show the greatest change in ambient air compared to background.

The possible interactions of each of the main sources that could potentially affect air quality were assessed individually in Table 7A-14.

5.3.3 Air Quality Ecological Objectives

A description of the standards and guidelines used to assess effects was presented in Section 3, specifically Table 7A-8. The ambient air standards and guidelines used were taken preferentially from Yukon, but were supplemented with objectives and standards from BC and Ontario, as necessary. These standards are generally used within each jurisdiction to provide regulators with a sense of the magnitude of the effect that an emitting source or group of sources has on the surrounding ambient air. It should be noted that usually concentrations at off-property receptors are compared against the ambient air standards and guidelines. In this study these standards were used to compare both on-property and off-property concentrations. As a result, they are an inherently conservative comparison metric.

5.3.4 Analysis of Potential Effects

The maximum 24-hour and annual averages (for TSP only) of ambient air concentrations predicted by the air dispersion modelling assessment was compared to ambient air standards in order to determine the magnitude of the total ambient air concentration for each contaminant. For all of the effects considerations, magnitude ratings were assigned “low”, “medium” or “high” where “low” means that there is minimal effect, and “high” means the effect was substantial. Table 7A-13 summarizes the significance criteria used in this air quality effects assessment.

The assessment of the magnitude and likelihood of the changes to ambient air concentrations were based on a comparison to standards and the frequency of occurrence or duration of predicted exceedances of standards at any of the modelled receptors. There was no consideration of whether the predicted exceedances were on-property or off-property, as this was considered in the geographic extent consideration discussed in the following section. A designation of "high" in this category was defined as having any one model receptor showing an exceedance of a contaminant air standard for more than 25 percent of the modelled days. It should be noted that there were several receptors in the immediate vicinity of the construction zone and the tailings area where predicted exceedances were expected.

The geographic extent effects assessment was defined by considering whether the exceedance areas occurred on or in close proximity to the emission sources, whether there were any exceedances off-property of the mineral staking withdrawal area, or whether there was a wide-spread area of exceedance off-property. For this category, a "low" designation was assigned when there was no off-property exceedance of ambient air standards for any of the contaminants and averaging periods.

The reversibility effects assessment was defined by considering whether the ambient air concentrations affected by the various sources were reversible or irreversible. A "low" designation for this attribute means that the effect was reversible without mitigation, medium means reversible with mitigation and time, while high means irreversible even with mitigation.

5.3.5 Air Quality Mitigation

A summary of the proposed mitigation is provided in Table 7A-14 but more details of the anticipated best management practices for the construction area and other aspects of the dust mitigation measures to be employed are presented in Section 4.3 of the *Faro Mine Interim Works Project Proposal* (CH2M HILL, 2014a).

5.3.6 Air Quality Significance of Effects

The effects classifications are presented in Table 7A-13. The assessment includes a level of concern with each Project potential interaction on the air quality component. Also, if a residual effect is noted, an evaluation of the residual effect will include an assessment of magnitude and frequency, geographic extent of effect, and overall significance of effect.

For the effects assessment, it was assumed that all potential pathways affected air quality in a negative sense, and therefore direction of effects was not explicitly included in the summary tables. The magnitude and frequency of effect was based on whether the total ambient air concentrations were less than or greater than applicable standards or guidelines, and if so, what percentage of the days were the concentrations greater than the applicable standards. The geographic extent of the effect differentiated between the on-property receptors and the off-property receptors, and whether receptors in those areas showed exceedances. Finally, reversibility considered whether the air quality effect was reversible, was reversible with time and mitigation, or was irreversible.

It should be noted that under the magnitude and frequency columns, these considerations are based on concentrations relative to a standard or guideline. There were several modelled contaminants for this assessment and these considerations were allocated based on the worst-case pollutant concentrations relative to their applicable standards or guidelines.

Table 7A-14 summarizes the air quality effects assessment for the IW activities after the proposed mitigation. A summary of the proposed mitigation is also shown in Table 7A-14 for each of the three areas.

5.3.7 Air Quality Monitoring

The dispersion modelling analysis has shown that on-property effects are moderate when using conservative emission estimates and dust mitigation methods for the three emission source areas. Overall significance is considered none to low off-property; therefore, no monitoring is proposed for air quality.

A brief discussion and context of the ambient air quality effects on particulate matter, metals, and dust is provided in the following sections.

Table 7A-13

Definitions for Evaluating Significance

Faro Mine Interim Works

VC	Indicator	Rationale for Selection	Measurements	Effects Attributes	Significance Ranking	Ranking Criteria
Air Quality	Contaminant Air Concentrations affected by Tailings Area, Construction, and Unpaved road traffic	Elevated pollutant concentrations can be harmful to humans, wildlife and vegetation. Ambient air quality standards will be used to assess significance of effects and these standards and guidelines are measured in terms of contaminant concentrations in air.	Modelled changes in Air concentrations for TSP, PM10, PM2.5, and metals	**Magnitude and Likelihood**	Low	Air concentrations less than applicable standards on-property, throughout the modelled year
					Medium	Air concentrations less than applicable standards off-property, throughout the year, but above on-property < 25% of modelled days at any receptor
					High	Air concentrations more than standards on-property, more than 25% of days in modelled year at any receptor
				Geographic Extent	Low	Air concentrations greater than standards only on-property
					Medium	Air concentrations greater than standards off-property
					High	Air concentrations greater than standards on a regional basis (greater than 1 km from site boundary)
				Reversibility	Low	Effects are completely reversible
					Medium	Effects are reversible but with mitigation and it may takes months or years for reversal to occur
					High	Effect is non-reversible despite mitigation.

Table 7A-14

Projected Air Quality Effects From IW Activities After Mitigation

Faro Mine Interim Works

IW Activity	Potential Interaction	Reversibility	Magnitude	Frequency/ Probability	Extent	Overall Level of Significance	Mitigation Plan Summary
Tailing area	Wind erosion from dried tailings material	Medium	Low	Medium	Low	Medium	Application of a chemical dust suppression compound on an annual basis or more frequently as required.
Intermediate Dam Construction	Emissions from various activities associated with vehicles, material handling, blasting etc.	Low	Medium	High	Low	Medium	Apply water spray during dry periods to disturbed areas, control of vehicle access and speeds, work stoppage under high wind events, minimize material drop distance, periodic washing of vehicles to reduce load out of dust.
FMC Access and Hauls Roads	Emissions from road dust resuspension caused by traffic	Low	Low	Low	Low	Low	Fuel efficient vehicles, environmental awareness, proactive identification of emission sources, maintenance programs, reduced idling times, water application to roads during dry periods, snow grading on top of roads, posting and enforcement of speed limits.

Particulate matter emissions from the FMC are expected to result in no offsite exceedances of applicable TSP, PM_{10}, $PM_{2.5}$ or metal standards. It should be noted that because of the low release height of the fugitive emission sources resulting from IW activities, all of the highest off-property concentrations are located at the mining boundary limits west of the DVIHU construction area. Also, the model predictions are conservative in that all emission sources were modelled simultaneously and it is unlikely that this will occur in practice. Dust suppression BMPs will be used wherever feasible to reduce on-property and off-property effects. Dust control techniques and their effectiveness are difficult to accurately quantify, but a conservative estimate of 60 percent was used in the modelling consistent with water spray control of fugitive emissions sources. This is consistent with what was shown by other investigators (Cowherd, 1988).

It is expected that after the appropriate dust control techniques are employed at the tailings area, construction area, and unpaved roadways, the residual effects of particulate matter emissions (including metals) at off-property locations will be negligible and concentrations will be indistinguishable from those measured during the previous monitoring campaigns. The geographic extent and reversibility of air quality effects are low, and although the magnitude and likelihood of effects can be high within and close to the emission sources, a negligible effect is expected at the property line and in the neighbouring Town of Faro.

It is noted that “dust” is a more general term associated with particulate matter but it typically refers to any form of particulate matter that is considered to be visible and therefore includes larger particles that settle relatively quickly to the ground. There is no ambient air quality standard for “dust.” The primary air pollutant from the FMC will be dust generated from construction activities. The main potential sources of dust will be tailings dust, haul truck operations including loading, vehicle traffic, grading, and other types of material handling.

A dust management plan has been developed and can be found in the *Environmental Management Plan, Faro Mine Interim Works* (CH2M HILL, 2014b). The influence of the dust management plan on the residual impacts of dust and particulate matter will be to lower the amount of particulate being generated, such that the significance of the residual impacts is low.

SECTION 6

6 Summary of Air Quality Assessment and Effects

A comprehensive modelling assessment was completed for several contaminants that are expected to be emitted as a result of IW activities. The contaminants assessed included particulate matter, as well as metals within particulate matter. All modelled contaminants have an applicable Yukon, BC, or Ontario air quality criterion.

The dispersion model used to evaluate the effects of particulate matter emissions resulting from IW activities was the USEPA CALPUFF dispersion model, which is ideal for long-range transport of contaminants and particularly suited for complex terrain, as is the case of the FMC. Meteorological data from two meteorological surface stations located at the FMC and one Environment Canada station located in the Town of Faro were used in the dispersion model. Additional MM5 prognostic meteorological data for the year 2010 was used. The effects were calculated with a higher resolution of receptors within 12 km from a point central to the FMC, as well as a less dense resolution of receptors for a larger 100 km by 100 km area centered on the site. The emission rates used for 24-hour and annual averaging periods for the modelling were maximum 24-hour emissions from the tailing area, the unpaved onsite roads, and the Intermediate Dam construction work.

The results show modest off-property concentrations for the particulate matter, but all off-property concentrations were predicted to be less than all applicable ambient air quality standards. Modelling of metals and particulate matter (TSP, PM_{10}, and $PM_{2.5}$) for IW showed the highest offsite concentrations were downwind of the construction area along the northwestern part of the mineral staking withdrawal area. All property line concentrations were less than applicable criteria. Emission control factors were used consistent with water spraying and other dust management practices to reduce predicted fugitive dust emissions for the sources considered in this assessment.

There were highly localized onsite areas where particulate matter is expected to be higher than applicable ambient air standards. These areas were restricted to the immediate vicinity of the DVIHU construction zone and to a lesser extent the tailings area. The air quality effect from these activities will be mitigated by the proposed BMPs and dust suppression compound application. The overall significance of the activities is expected to be low to medium during the construction period, and then will become low to none afterwards. Any short-term effects on ambient air quality are expected to be reversible. Off-property the overall significance of effect to air quality is estimated to be low to none.

Because of modest concentrations and the limited geographic extent of particulate matter effects, no particulate monitoring is proposed. Regular visual checks for dusting and fugitive dust emissions will occur subsequent to dust suppression applications to confirm the effectiveness of the measures and to help guide the frequency of the applications. For more details of the dust management plan, a comprehensive dust and particulate matter mitigation plan is included in Section 4.3 of the *Faro Mine Interim Works Project Proposal* (CH2M HILL, 2014a).

SECTION 7

7 Works Cited

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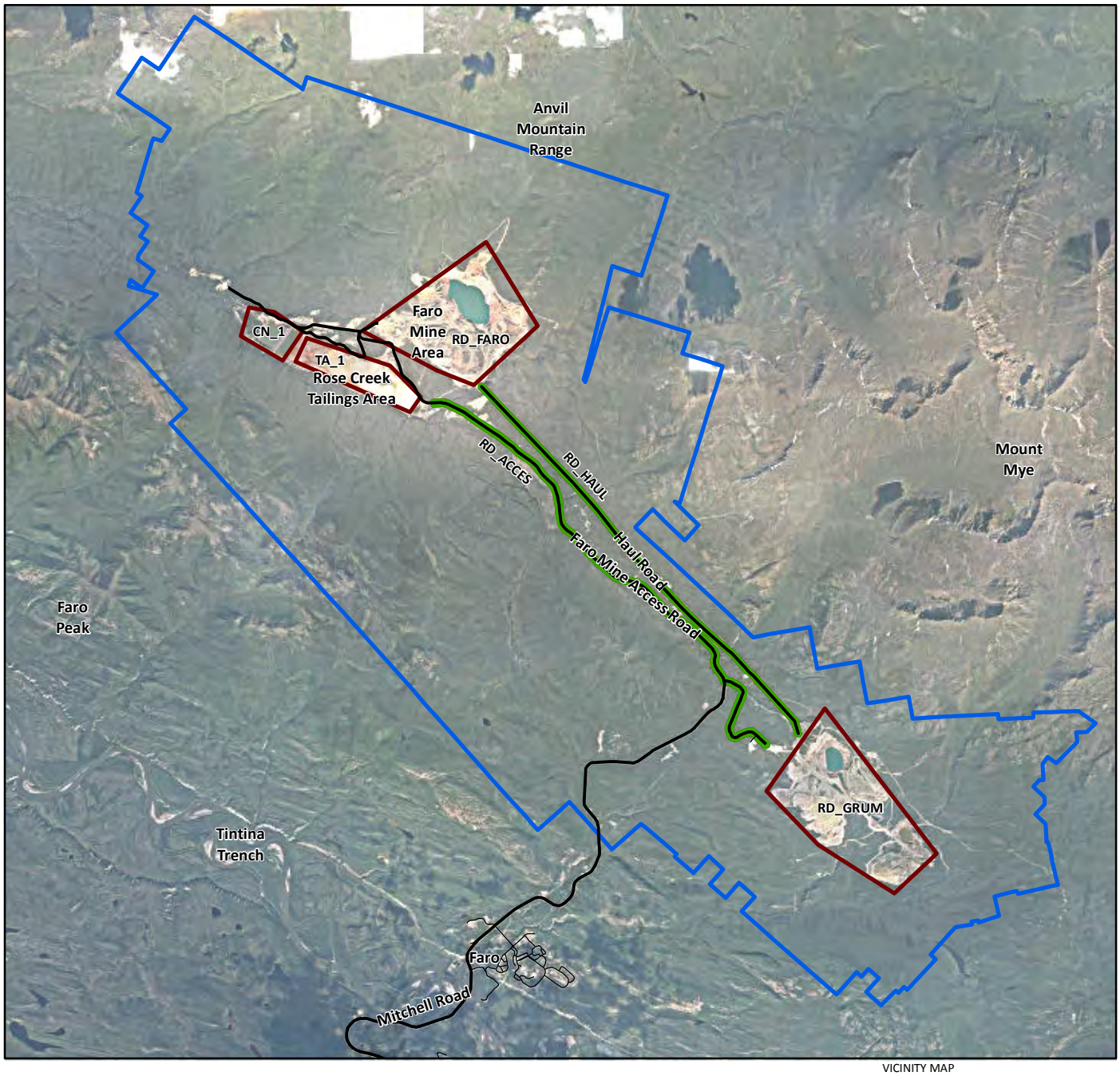
Figures



LEGEND

- Area Source
- Area Line Source
- Property Boundary

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.

VICINITY MAP



N

0 1,500 3,000

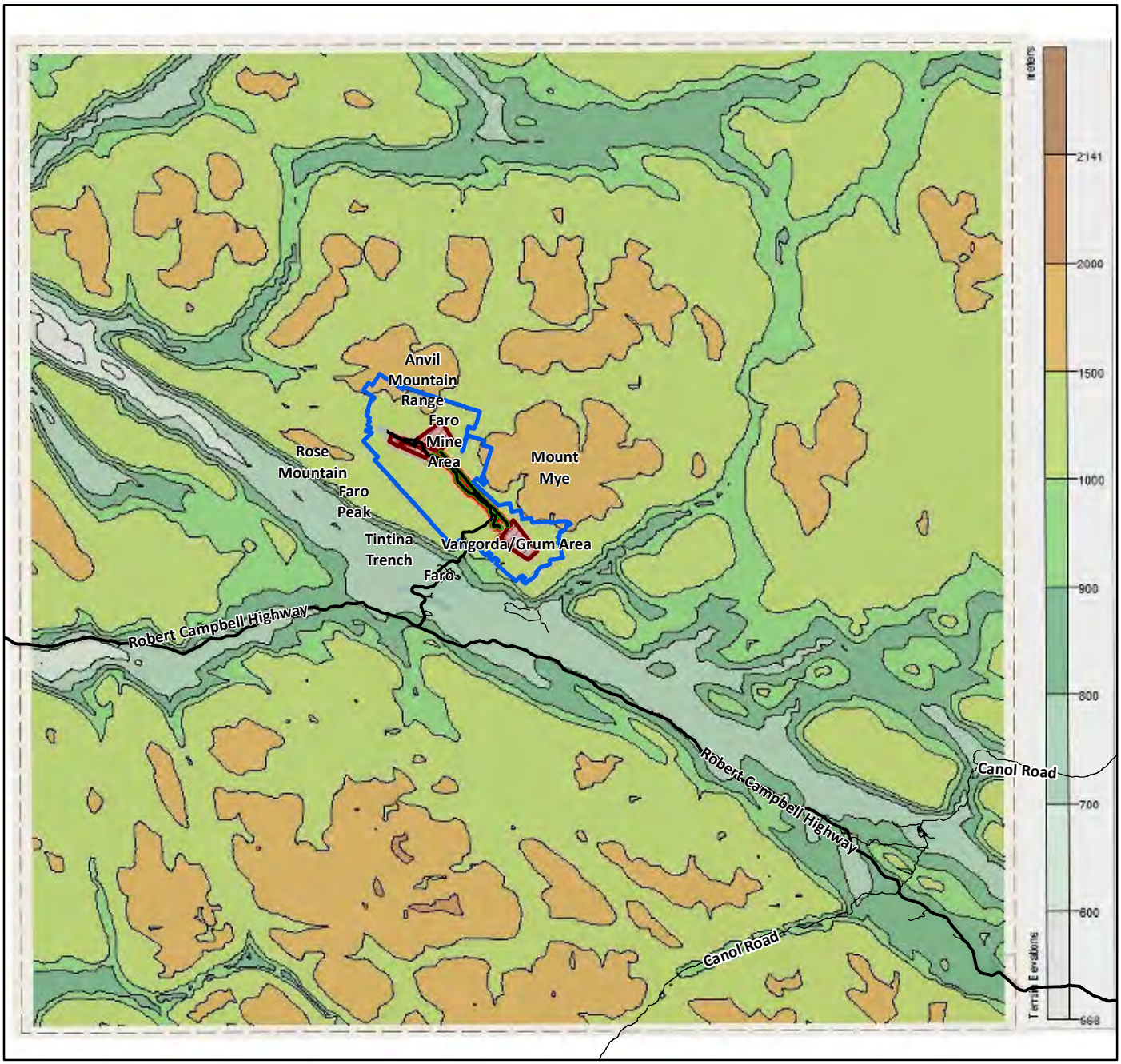
Metres

Created by: CRITIGEN

FIGURE 7A-1

Locations of Emission Sources Used in the Effects Assessment

Faro Mine Interim Works



LEGEND

- Area Source
- Area Line Source
- Property Boundary

VICINITY MAP



N

0 8,000 16,000

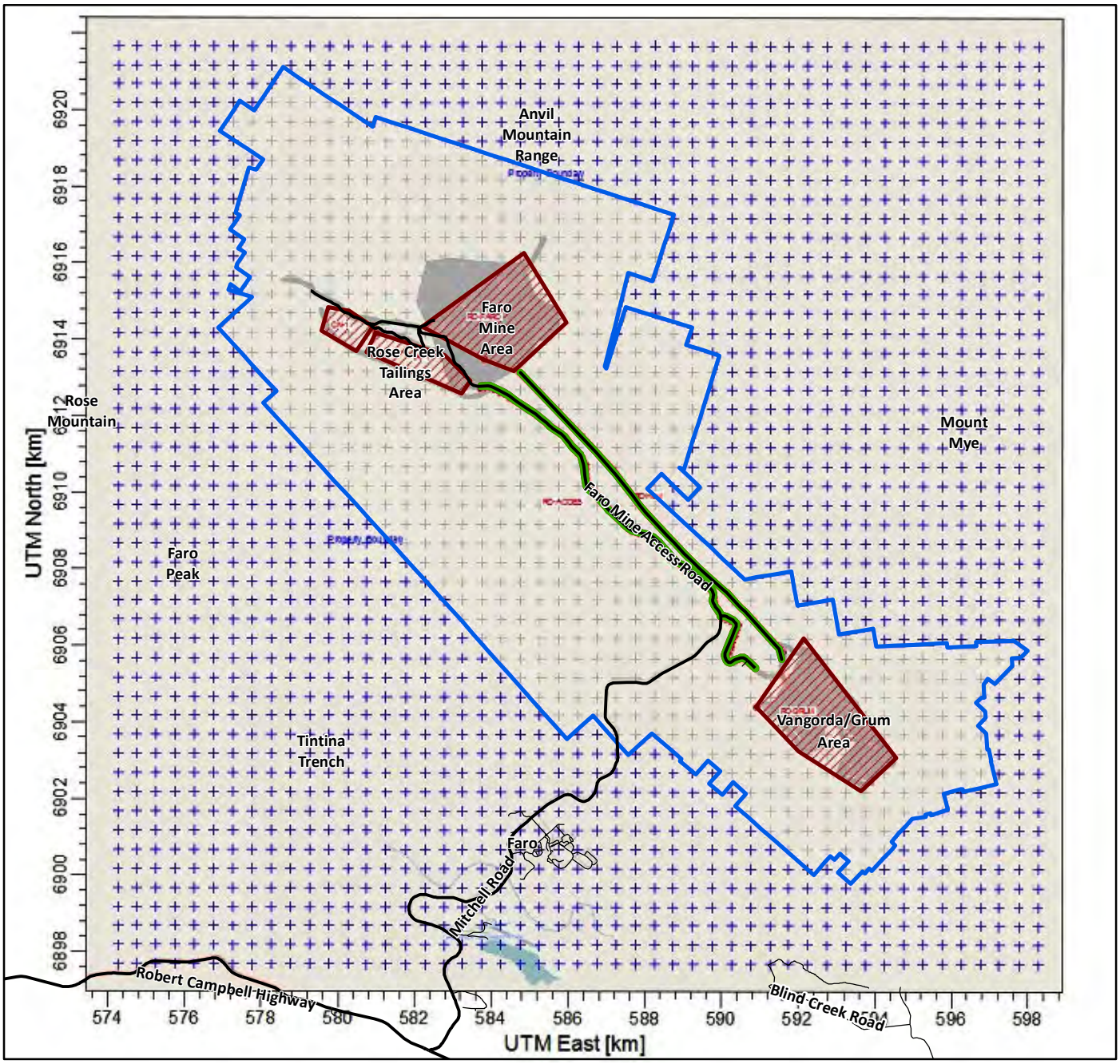
Metres

Created by:
CRITIGEN

FIGURE 7A-2

Terrain Elevations near the Faro Mine Complex

Faro Mine Interim Works



LEGEND

- Area Source
- Area Line Source
- Property Boundary

Note:
UTM = Universal Transverse Mercator projected coordinate system .

VICINITY MAP



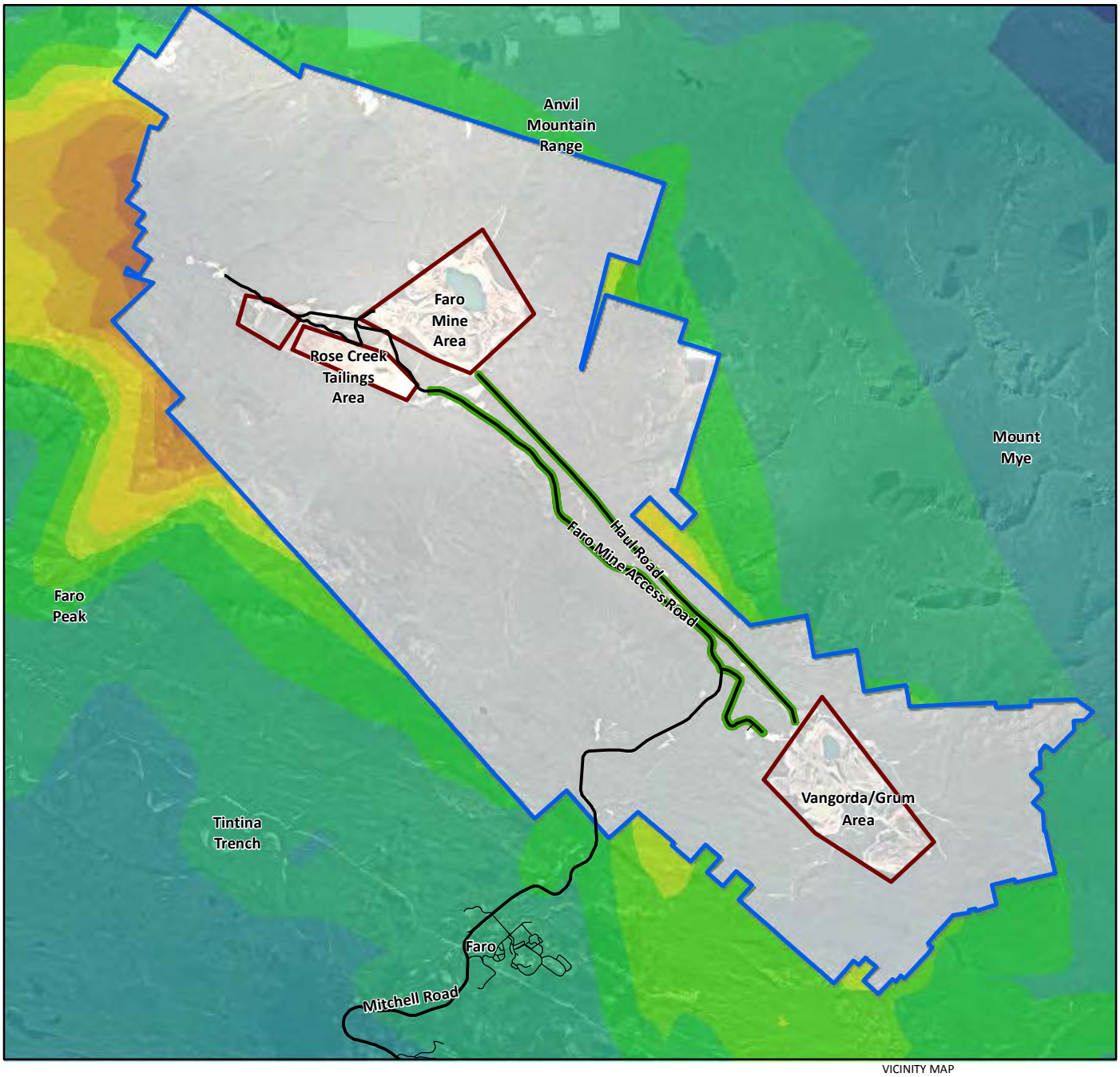
N

0 2,000 4,000
Metres

Created by:
CRITIGEN

FIGURE 7A-3
Near-field Receptors Used in Air Dispersion Modelling
Faro Mine Interim Works

CH2MHILL



LEGEND

- Area Source
- Area Line Source
- Property Boundary

HIGHEST 24-HOUR AVERAGE CONCENTRATION (TSP)

µg/m³

- 0-0.8
- 0.8 - 1
- >1 - 2
- >2 - 4
- >4 - 6
- >6 - 8
- >8 - 10
- >10 - 15
- >15 - 20
- >20 - 30
- >30 - 40
- >40 - 48.4

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. µg/m³ = micrograms per cubic metre
4. TSP = total suspended particulate.

VICINITY MAP



N

0 1,500 3,000

Metres

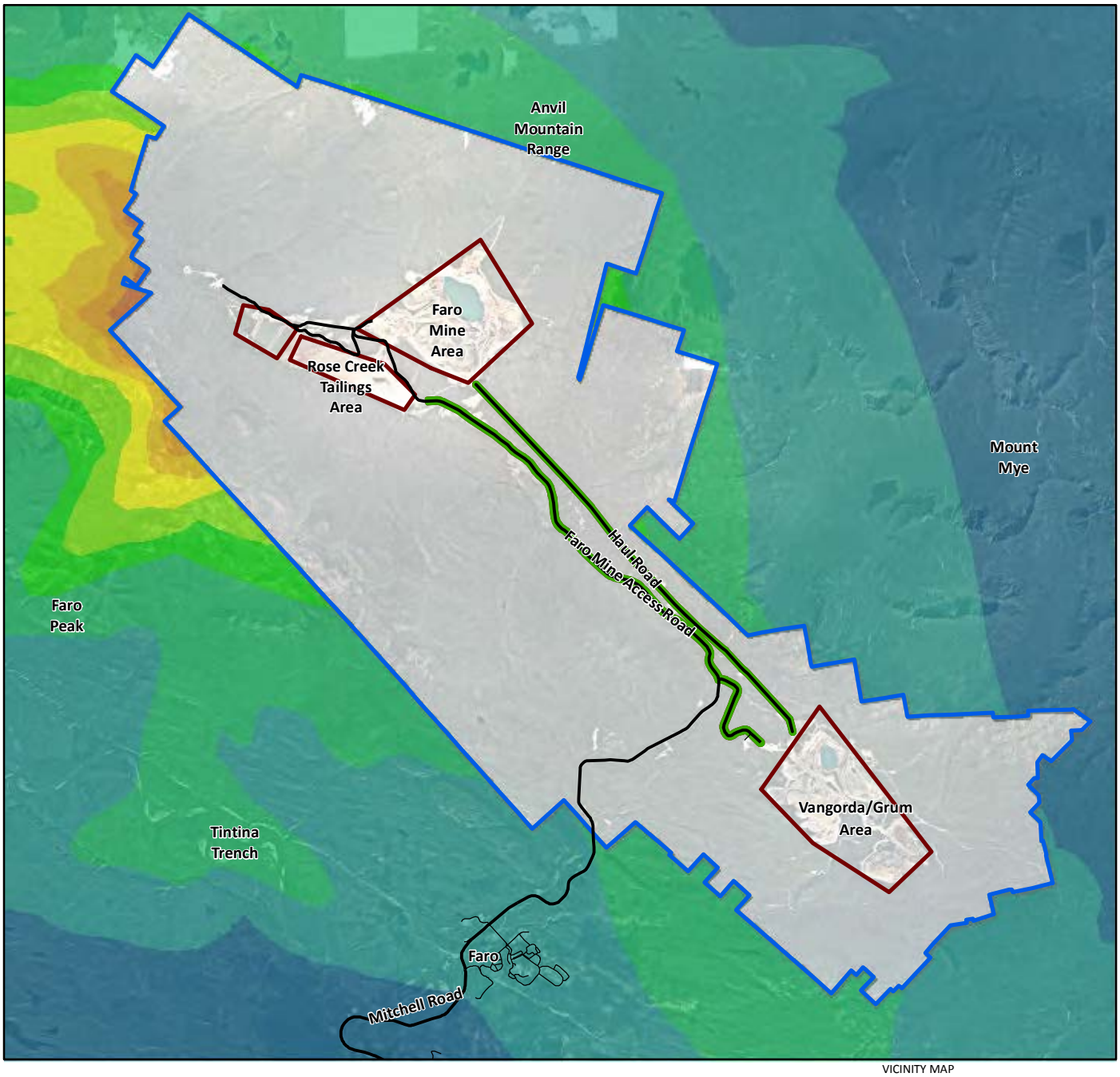
Created by: CRITIGEN

FIGURE 7A-4

Maximum Concentrations Isopleths of TSP – Off-Property – 24-Hour Averages

Faro Mine Interim Works

CH2MHILL



LEGEND

- Area Source
- Area Line Source
- Property Boundary

HIGHEST 24-HOUR AVERAGE CONCENTRATION (PM_{10})

µg/m³

- 0-0.5
- 0.5 - 1
- >1 - 2
- >2 - 4
- >4 - 6
- >6 - 10
- >10 - 15
- >15 - 20
- >20 - 25
- >25 - 30
- >30 - 35

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. µg/m³ = micrograms per cubic metre
4. PM_{10} = particulate matter less than 10 microns in aerodynamic diameter.

VICINITY MAP



N

0 1,500 3,000

Metres

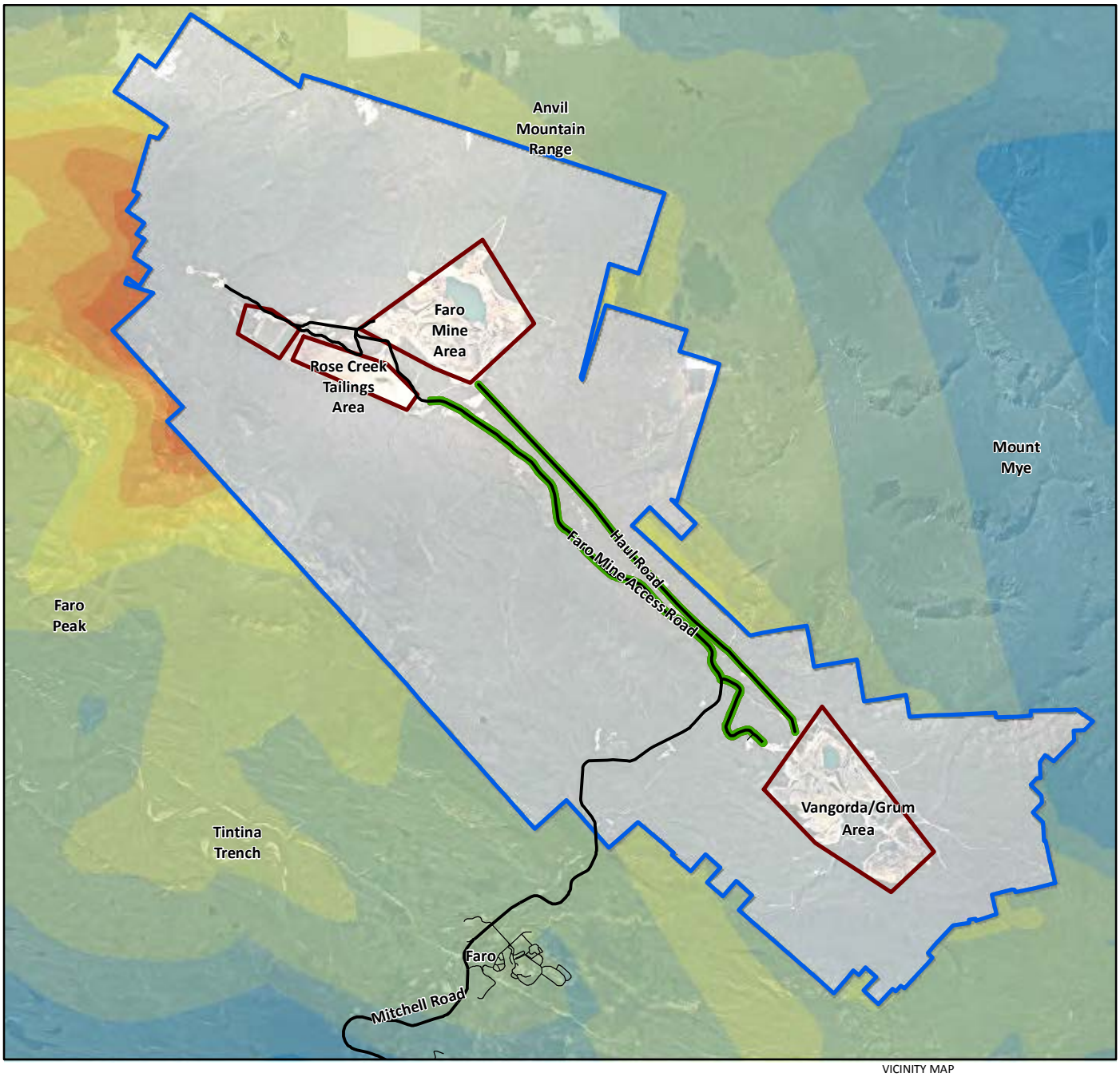
Created by: CRITIGEN

FIGURE 7A-5

Maximum Concentrations Isopleths of PM_{10} – Off-Property – 24-Hour Averages

Faro Mine Interim Works

CH2MHILL



LEGEND

- Area Source
- Area Line Source
- Property Boundary

HIGHEST 24-HOUR AVERAGE CONCENTRATION ($PM_{2.5}$)

µg/m³

- < 0.05
- > 0.05 - 0.07
- > 0.07 - 0.1
- > 0.1 - 0.2
- > 0.2 - 0.4
- > 0.4 - 0.6
- > 0.6 - 1
- > 1.0 - 1.5
- > 1.5 - 2.0
- > 2.0 - 3.0
- > 3.0 - 3.44
- > 3.44

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. µg/m³ = micrograms per cubic metre
4. $PM_{2.5}$ = particulate matter less than 2.5 microns in aerodynamic diameter.

VICINITY MAP



N

0 1,500 3,000

Metres

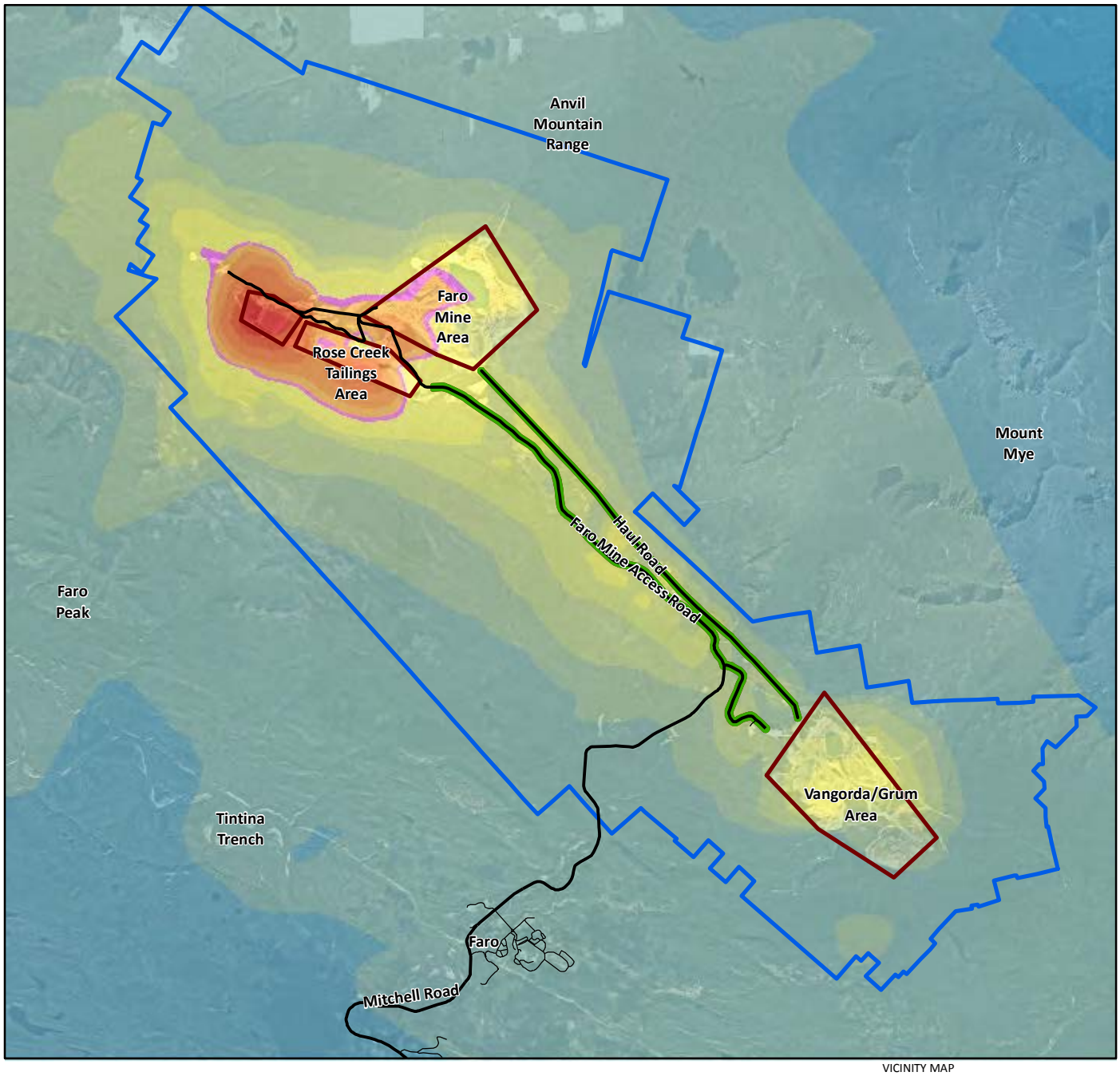
Created by: CRITIGEN

FIGURE 7A-6

Maximum Concentrations Isopleths of $PM_{2.5}$ – Off-Property – 24-Hour Averages

Faro Mine Interim Works

CH2MHILL



LEGEND

- Area Source
- Area Line Source
- Property Boundary

HIGHEST 24-HOUR AVERAGE CONCENTRATION (TSP)

µg/m³

- > 0.5 - 1
- > 1 - 2
- > 2 - 10
- > 10 - 20
- > 20 - 40
- > 40 - 60
- > 60 - 108
- > 108 - 120
- > 120 - 150
- > 150 - 200
- > 200 - 300
- > 300 - 400
- > 400 - 513

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. µg/m³ = micrograms per cubic metre
4. TSP = total suspended particulate.

VICINITY MAP



N

0 1,500 3,000

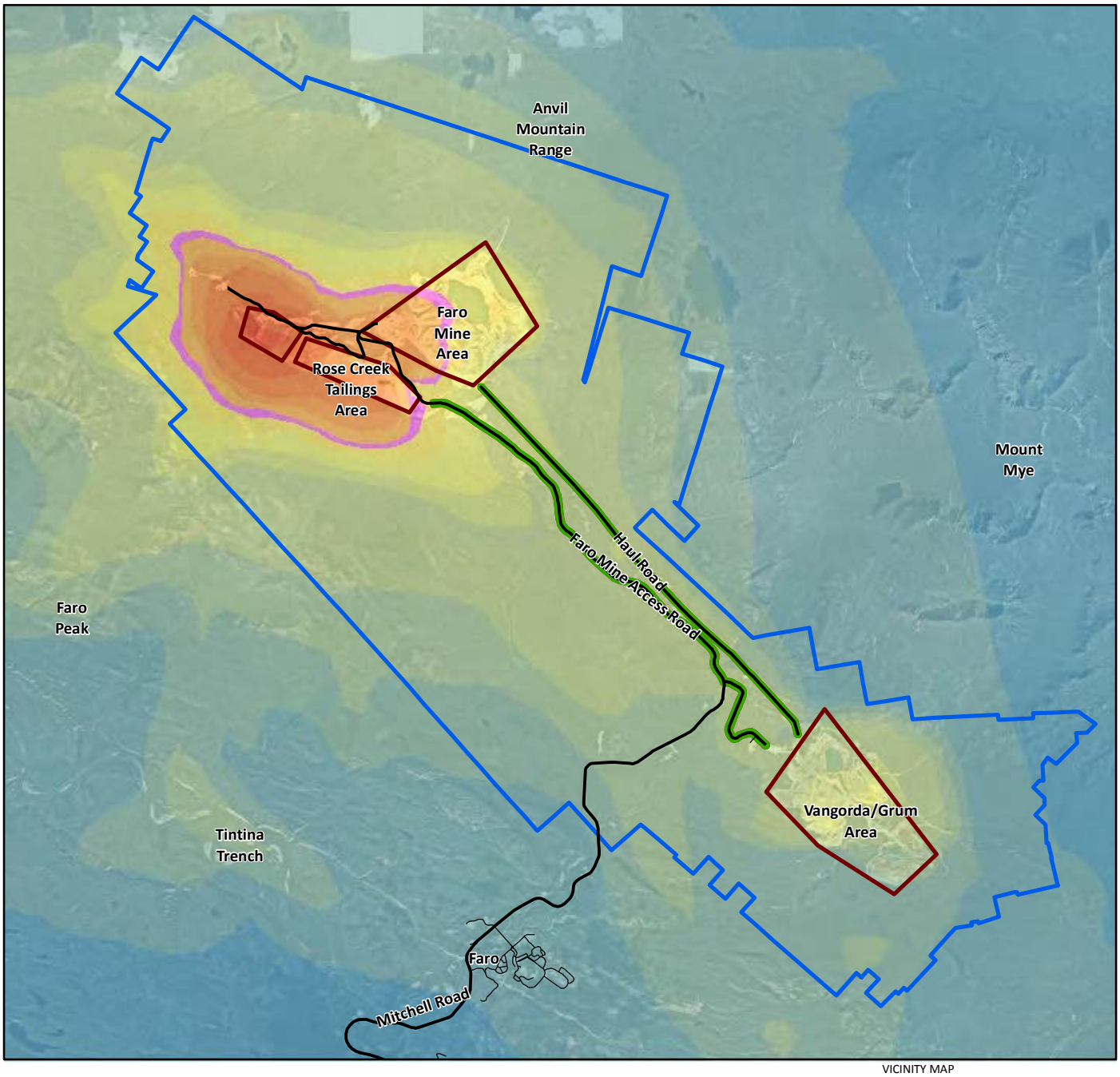
Metres

Created by: CRITIGEN

FIGURE 7A-7

Maximum Concentrations Isopleths of TSP – All Receptors – 24-Hour Averages

Faro Mine Interim Works



LEGEND

24-HOUR AVERAGE CONCENTRATION (PM_{10})

µg/m³

- < 0.5
- > 0.5 - 1
- > 1 - 2
- > 2 - 3
- > 3 - 5
- > 5 - 15
- > 15 - 20
- > 20 - 30
- > 30 - 42.9
- > 42.9 - 50
- > 50 - 70
- > 70 - 100
- > 100 - 200
- > 200 - 400
- > 400 - 490
- > 490 - 500

- Area Source
- Area Line Source
- Property Boundary

VICINITY MAP



Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. µg/m³ = micrograms per cubic metre
4. PM_{10} = particulate matter less than 10 microns in aerodynamic diameter

N

0 1,500 3,000

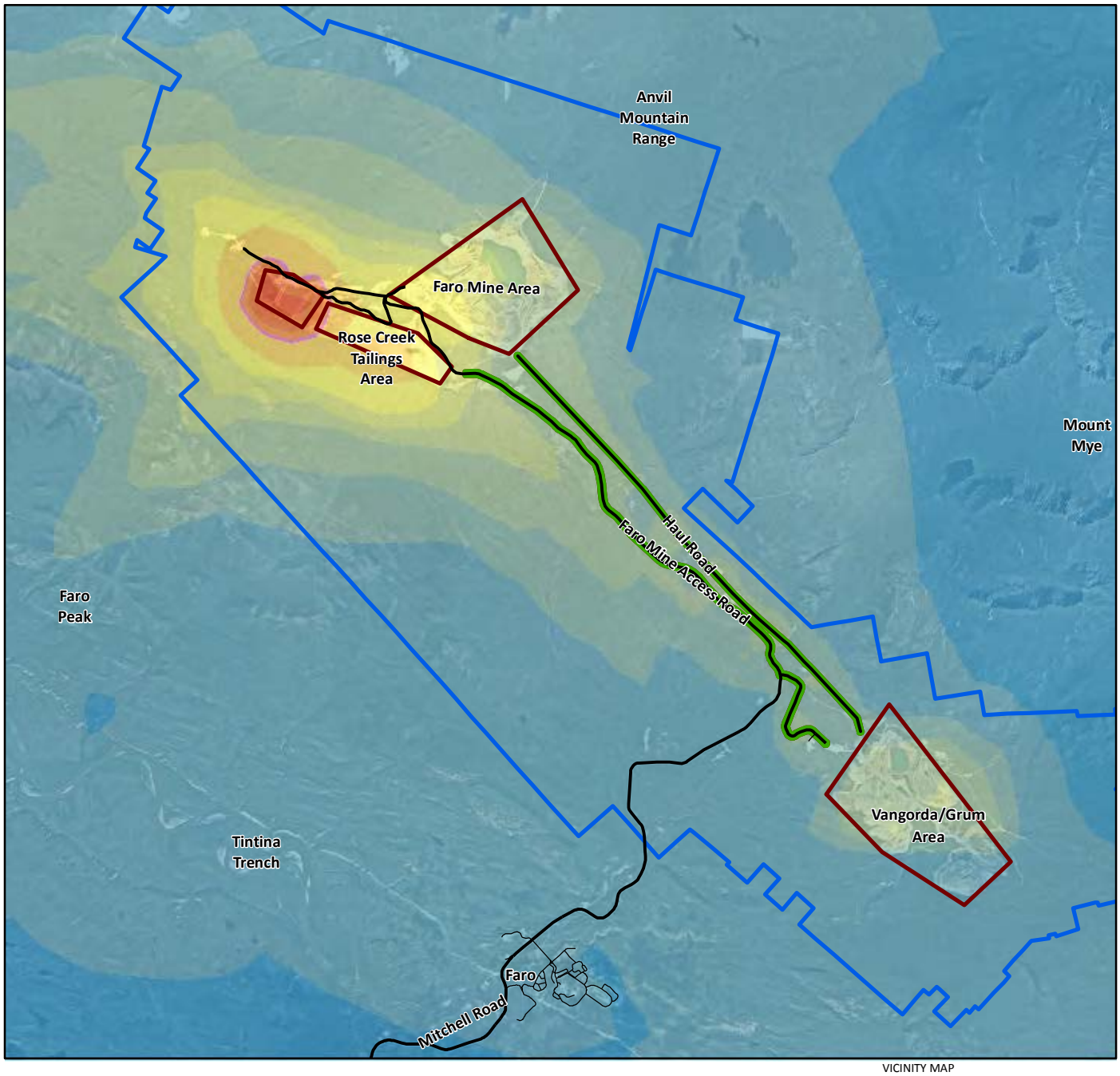
Metres

Created by: CRITIGEN

FIGURE 7A-8

Maximum Concentrations Isopleths of PM_{10} – All Receptors – 24-Hour Averages

Faro Mine Interim Works



LEGEND

- Area Source
- Area Line Source
- Property Boundary

HIGHEST 24-HOUR AVERAGE CONCENTRATION ($PM_{2.5}$)

µg/m³

- 0.03 - 0.1
- > 0.1 - 0.5
- > 0.5 - 1
- > 1.0 - 2.0
- > 2.0 - 3.0
- > 3.0 - 5.0
- > 5.0 - 10.0
- > 10.0 - 23.0
- > 23.0 - 25.0
- > 25.0 - 30.0
- > 30.0 - 40.0
- > 40.0 - 48.97
- > 48.97

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. µg/m³ = micrograms per cubic metre
4. $PM_{2.5}$ = particulate matter less than 2.5 microns in aerodynamic diameter

VICINITY MAP



N

0 1,500 3,000

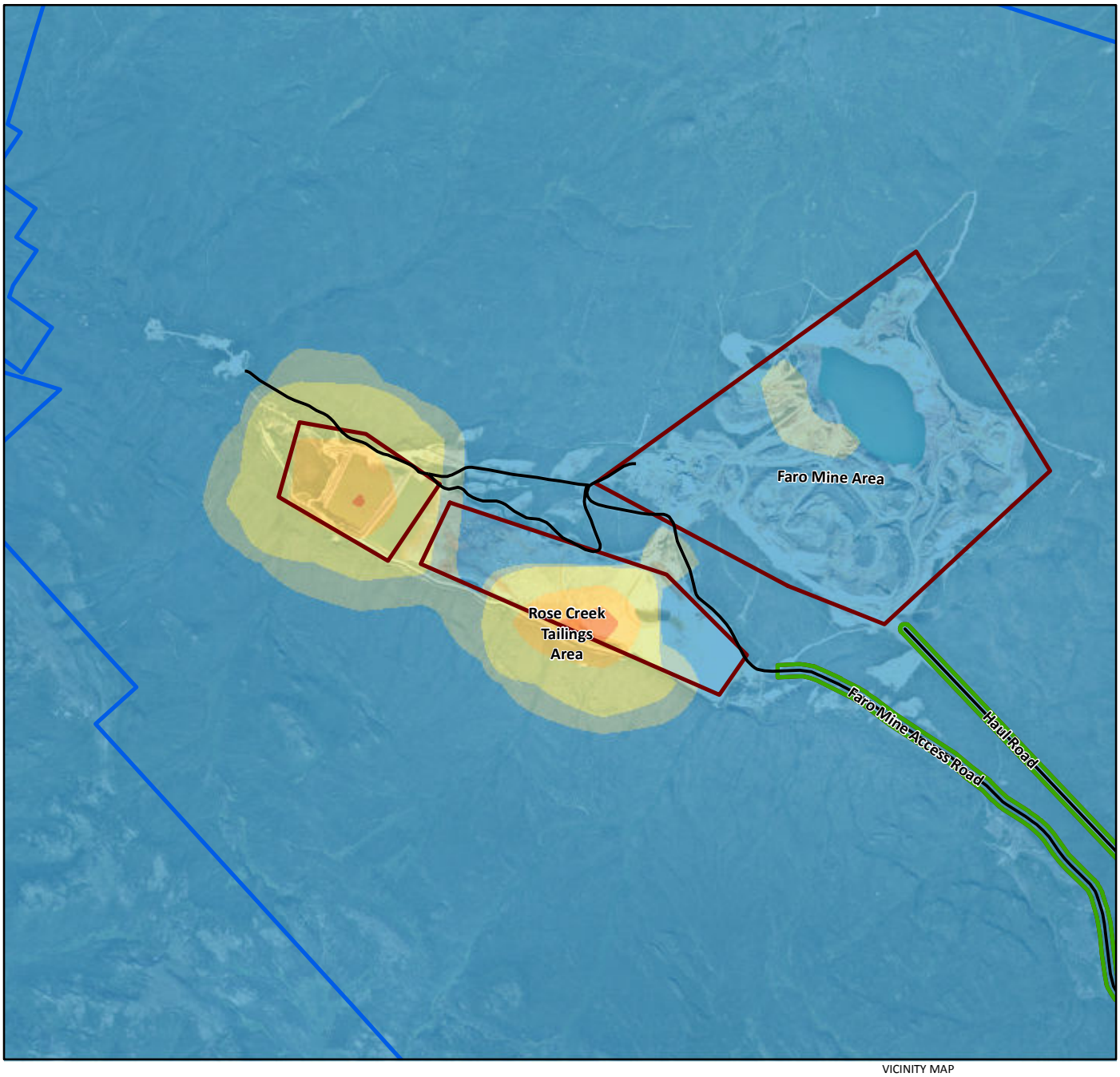
Metres

Created by: CRITIGEN

FIGURE 7A-9

Maximum Concentrations Isopleths of $PM_{2.5}$ – All Receptors – 24-Hour Averages

Faro Mine Interim Works



LEGEND

- Area Source
- Area Line Source
- Property Boundary

COUNTS OF 24-HOUR AVERAGE CONCENTRATION EXCEEDANCES (TSP)

- < 5
- > 5 - 10
- > 10 - 50
- > 50 - 100
- > 100 - 138
- > 138

VICINITY MAP



Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. $\mu g/m^3$ = micrograms per cubic metre
4. TSP = total suspended particulate

N

0 750 1,500

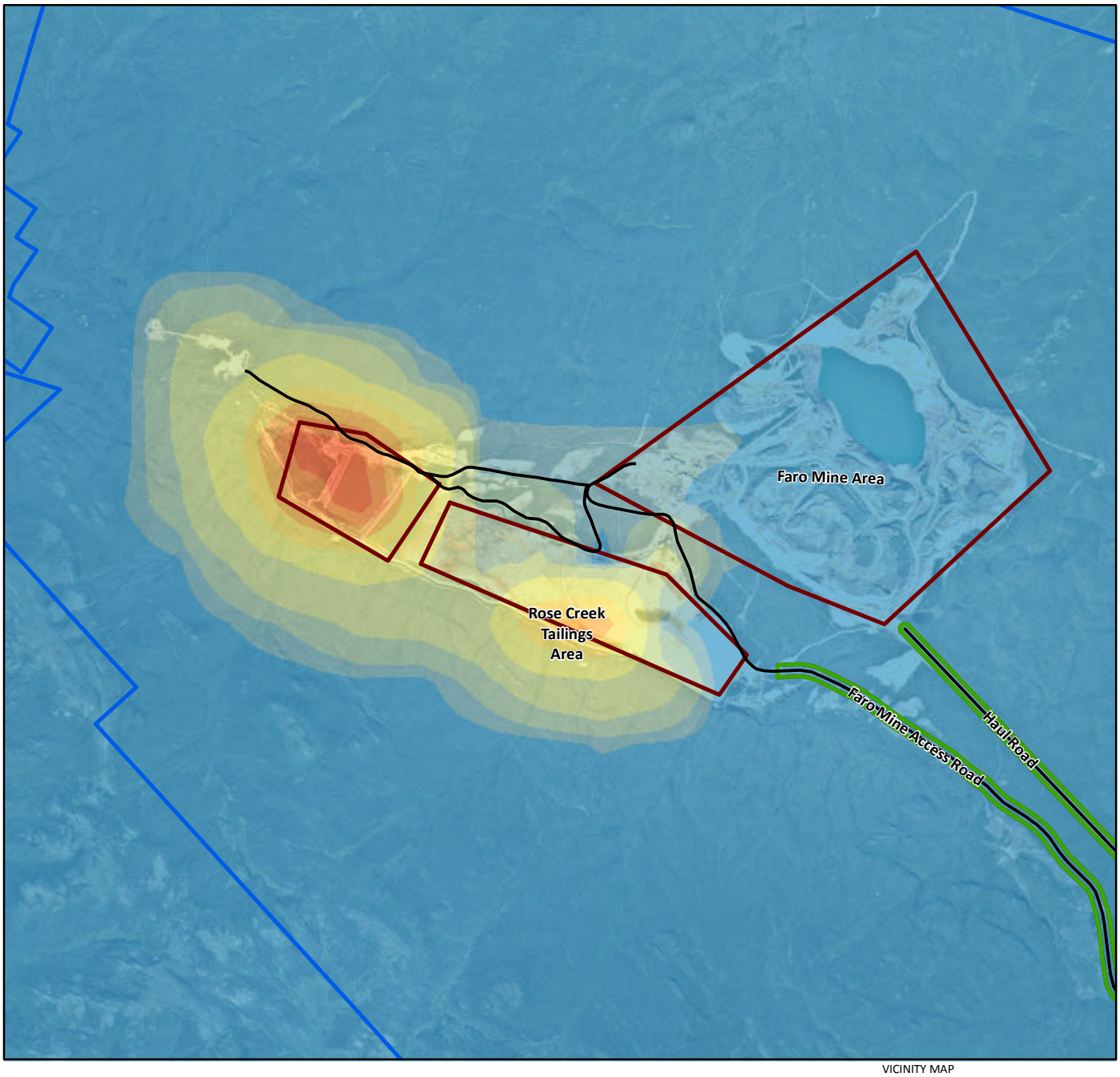
Metres

Created by: CRITIGEN

FIGURE 7A-10

Exceedance Counts for TSP – All Receptors – 24-Hour Averages

Faro Mine Interim Works



LEGEND

- Area Source
- Area Line Source
- Property Boundary

COUNTS OF 24-HOUR AVERAGE CONCENTRATION (PM_{10})

- < 5
- > 5 - 10
- > 10 - 20
- > 20 - 50
- > 50 - 100
- > 100 - 150
- > 150 - 200
- > 200 - 250
- > 250 - 291
- > 291

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. $\mu g/m^3$ = micrograms per cubic metre
4. PM_{10} = particulate matter less than 10 microns in aerodynamic diameter

VICINITY MAP



N

0 750 1,500

Metres

Created by: CRITIGEN

FIGURE 7A-11

Exceedance Counts for PM_{10} – All Receptors – 24-Hour Averages

Faro Mine Interim Works



VICINITY MAP



LEGEND

- Area Source
- Area Line Source
- Property Boundary

COUNTS OF 24-HOUR AVERAGE CONCENTRATION EXCEEDANCES ($PM_{2.5}$)

- > 0 - 1
- > 1 - 2
- > 2 - 3
- > 3 - 5
- > 5 - 10

Notes:
1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. $PM_{2.5}$ = particulate matter less than 2.5 microns in aerodynamic diameter.

N

0 700 1,400
Metres

Created by: CRITIGEN

FIGURE 7A-12
Exceedance Counts for $PM_{2.5}$ – All Receptors – 24-Hour Averages
Faro Mine Interim Works

Attachment 7A-1
Emission Estimates Calculations

7A-1-1
Emissions from Construction

Fugitive Emission Estimates for Heavy Construction Operations
Reference:

1) US EPA AP-42 Section 13.2.3 - Heavy Construction Operations
2) Industrial Wind Erosion, US EPA AP-42 Section 13.2.5

1. Emission Factor Source: US EPA AP-42 Section 13.2.3 - Heavy Construction Operations

1.1 TSP Emission Estimates

E_{TSP} = 2.69 megagrams (Mg) / hectare/ month of activity

Since the AP-42 emission factor was based on the month-round construction activities, a scaling factor is applied to reflect the day-time construction nature in Faro.

scaling 12 hours / 24 hours = 0.5

E_{TSP} = Scaling factor x 2.69
= 0.5 x 2.69
= 1.345 (megagrams (Mg) / hectare/ month of activity)

Convert to grams per square meter per day
= 1.345*1000,000 g/10,000 m^2/30 day =
= 4.48 (g/m^2/day)

Convert to grams per square meter per second (24 hour average emissions)
= 4.48 / 24 / 3600
= 5.19E-05 $g/m^2/s$

1.2 PM_{10} Emission Estimates

Using a PM_{10}/TSP ratio of 0.5 to calculate PM_{10} emission ra (AP-42 Section 13.2.5)

E_{PM10} = 5.19E-05 x 0.5
= 2.59E-05 ($g/m^2/s$)

1.3 $PM_{2.5}$ Emission Estimates

Due to a limited amount of information available for $PM_{2.5}$ ratio over PM_{10} for construction, a ratio of 0.1, calculated from onsite unpaved roads $PM_{2.5}$ and PM_{10} emissions was used.

$E_{PM2.5}$ = 2.59E-05 x 0.1
= 2.59E-06 ($g/m^2/s$)

1.4 Dust Control Efficiency

Dust control is required for construction operations, conservatively assume a basic control efficiency of 60% for using watering applications.

Details will be discussed in Environmental Management Plan.
Sample calculation for TSP emissions after control:

$E_{TSP\ w\ control}$ = 5.19E-05 x (1-60%) = 2.08E-05 ($g/m^2/s$)

2. Total Construction Emission Summary

Construction Area ID	Construction Area Description	Area (m^2)	Emission Rate ($g/s.m^2$)			Control Efficiency	Emission Rate after control ($g/s.m^2$)		
			TSP	PM_{10}	$PM_{2.5}$	(%)	TSP	PM_{10}	$PM_{2.5}$
CN_1	Constructio	2175059	5.189E-05	2.595E-05	2.595E-06	60%	2.08E-05	1.04E-05	1.04E-06

7A-1-2
Emissions from Tailings

Fugitive Emission Estimates for Tailing Areas
Reference:

1) An Inventory of Particulate Emissions from Open Sources, John S. Evans and Douglas W. Cooper, 1980
2) Industrial Wind Erosion, US EPA AP-42 Section 13.2.5

1. Method Description: The milling of ores results in solid waste which leaves the mill as a slurry. This slurry is channeled to a tailings pond, where solids are allowed to settle out of suspension. After the separation of water and solids, a dried pile of mill tailings remains. These piles are subject to wind erosion.

The emission factor were calculated using a equation suggested by Reference 1 and 2010 climate factors at on-site Faro Dump Station.

EF_{PM} *(ton/year.acre)* = *0.133 C*

where:

C = climate factors

$$C = 0.345(\bar{\upsilon}_{30})^3 / (PE)^2$$

where:

$\bar{u}_{30}$ = average annual wind speed (mph) at 30 ft above the ground,

PE = Thornwaite's PE index

$$PE = 10 \times \sum_{i=1}^{12} \left[11.5 \times (P_i / (T_i - 10))^{10/9} \right]$$

where:

P_i = monthly precipitation (inches of rain)

T_i = mean monthly temperature (°F) or 28.4 °F, whichever is less.

Total emissions (ton/year) = E_{PM} x A

where:

A = acres of tailing areas

2. Calculations:

2010 monthly precipitation and mean temperature at on-site Faro Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pi (mm)	20	4.1	8.9	25.6	41.3	36.7	21.2	30.2	38.8	17.7	22.1	21	
Pi (in)	0.79	0.16	0.35	1.01	1.63	1.44	0.83	1.19	1.53	0.70	0.87	0.83	
Ti (°C)	-12.41	-7.28	-6.64	0.27	6.76	9.68	12.32	11.41	4.51	-1.73	-9.13	-18.52	
Ti (°F)	9.66	18.89	20.05	32.49	44.16	49.42	54.17	52.54	40.12	28.89	15.57	-1.34	
$(Pi/(Ti-10))^{(10/9)}$	0.03	0.01	0.01	0.03	0.03	0.03	0.01	0.02	0.04	0.03	0.03	0.03	
$11.5*(Pi/(Ti-10))^{(10/9)}$	0.35	0.06	0.14	0.37	0.39	0.29	0.14	0.22	0.42	0.29	0.39	0.37	
$\bar{u}_{30}$ *(m/s)*													5.59
$\bar{u}_{30}$ *(mph)*													12.50

PE = 34.17

C = 0.345 x 12.5/34.17^2 = 0.577

2.1 Calculation of annual emissions:

Annual EF_{PM} = 0.133 X 0.577

= 7.68E-02 (ton/year. acre)

= 4.21E-01 (lb/day.acre)

= 1.75E-02 (lb/hr.acre)

Convert to grams per second per square meter:

$$= \frac{7.68\text{E-}02 \text{ ton} * 2000 \text{ lb} * 454 \text{ g} * \text{year} * \text{day} * \text{hour} * \text{acre}}{\text{year.acre} \quad \text{ton} \quad \text{lb} \quad 365 \text{ day} \quad 24 \text{ hour} \quad 3600 \text{ sec} \quad m^2}$$

= **5.46E-07** **g/s/m^2**

Annual EF_{PM10} = **2.73E-07** **g/s/m^2** [using PM_{-10} to PM ratio of 0.5 from AP-42 Section 13.2.5]

2.2 Calculation of 24-hr average emissions.

As the method used above is for the estimate of annual emission from tailings, to obtain a 24-hour average emission, a conversion factor recommended by the Ontario MOE for conversion of annual POI concentration to 24-hr POI concentration was used to obtain the 24-hr average emission

$EF_{24\text{-hr}} = EF_{annual} \times (8760/24)^{0.28} = EF_{annual} \times 5.217$

24-hr EF_{PM} = 5.46E-07 x 5.217

= **2.851E-06** **g/s/m^2**

2.3 PM_{10} Emission Estimates

Using a PM_{10}/TSP ratio of 0.5 to calculate PM10 e (AP-42 Section 13.2.5)

E_{PM10} = 2.85E-06 x 0.5

= 1.43E-06 ($g/m^2/s$)

2.4 $PM_{2.5}$ Emission Estimates

Due to a limited amount of information available for PM2.5 ratio over PM10 for construction, a ratio of 0.1, calculated from onsite unpaved roads PM2.5 and PM10 emissions was used.

$E_{PM2.5}$ = 1.43E-06 x 0.1

= 1.43E-07 ($g/m^2/s$)

2.5 Dust Control Efficiency

Dust control is required for construction operations, conservatively assume a basic control efficiency of 60% for using watering applications. Details will be discussed in Environmental Management Plan.
Sample calculation for PM emissions after control:

$E_{PM\ w\ control}$ = 2.85E-06 x (1-60%) 1.14E-06 ($g/m^2/s$)

$E_{PM10\ w\ control}$ = 1.43E-06 x (1-60%) 5.70E-07 ($g/m^2/s$)

$E_{PM2.5\ w\ control}$ = 1.43E-07 x (1-60%) 5.70E-08 ($g/m^2/s$)

Emission rate after control = 1.14E-06 **$g/s/m^3$**

24-hr EF_{PM10} = **1.425E-06** **$g/s/m^2$** [using PM_{-10} to PM ratio of 0.5 from AP-42 Section 13.2.5]

Emission rate after control = 5.702E-07 **$g/s/m^3$**

3. Emission Summary for Tailings

Source ID	Source Name	Tailing Area size (m^2)	Uncontrolled Emissions ($g/m^2/s$)			Control Efficiency (%)	Controlled Emissions ($g/m^2/s$)		
			PM	PM10	PM2.5		PM	PM10	PM2.5
TA-1	Tailings Area	1710520	2.85E-06	1.43E-06	1.43E-07	60%	1.14E-06	5.70E-07	5.70E-08

Notes:
Area for Tailing Area calculated from CALPUFF view

7A-1-3
Emissions from Onsite Unpaved Roads

Calculation of Road Dust Emissions from Unpaved Roadways:

1. Environment Canada's "Unpaved Industrial Road Dust Calculator" spreadsheets were used for road dust estimate.

Emission Summary for Road Segments Calculation using EC Spreadsheets.

Source ID	Description	Modelled Source Type	Area (m^2)	Emission Rate (g/s)					
				24-hr average			Annual		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
RD_HAUL	Haul Road	Area Line Source	153600	9.256	2.450	0.245	2.612	0.691	0.069
RD_ACCES	Access Road	Area Line Source	172530	6.863	1.816	0.182	1.937	0.513	0.051
RD_Faro	Roads in Faro Site	Area source	5888607	14.391	3.809	0.381	4.061	1.075	0.107
RD_Grum	Roads in Grum Site	Area source	6667147	10.558	2.795	0.279	2.980	0.789	0.079

2. Calculate emission rate in per square meter basis by dividing the total emissions by the total area of the applicable road segments.
Sample calculations:

RD_Haul 24-hr TSP emission = 9.256 (g/s) / 153600 (m^2)
= 6.03E-05 ($g/m^2/s$)

Emission Summary:

Source ID	Description	Modelled Source Type	Area (m^2)	Emission Rate ($g/s.m^2$)					
				24-hr average			Annual		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
RD_HAUL	Haul Road	Area Line Source	153600	6.03E-05	1.59E-05	1.595E-06	1.700E-05	4.501E-06	4.501E-07
RD_ACCES	Access Road	Area Line Source	172530	3.978E-05	1.053E-05	1.053E-06	1.122E-05	2.971E-06	2.971E-07
RD_Faro	Roads in Faro Site	Area source	5888607	2.444E-06	6.469E-07	6.469E-08	6.896E-07	1.825E-07	1.825E-08
RD_Grum	Roads in Grum Site	Area source	6667147	1.584E-06	4.192E-07	4.192E-08	4.469E-07	1.183E-07	1.183E-08

3. Dust Control Efficiency
Dust control is required for construction operations, conservatively assume a basic control efficiency of 60% for using watering applications.
Details will be discussed in Environmental Management Plan.
Sample calculation for Haul Road TSP emissions after control:

Haul Road $E_{TSP\ w\ control}$ = 6.03E-05 x (1-60%)
= 2.41E-05 ($g/m^2/s$)

Emission Summary After Control:

Source ID	Description	Modelled Source Type	Area (m^2)	Emission Rate ($g/s.m^2$) after control					
				24-hr average			Annual		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
RD_HAUL	Haul Road	Area Line Source	153600	2.41E-05	6.38E-06	6.38E-07	6.80E-06	1.80E-06	1.80E-07
RD_ACCES	Access Road	Area Line Source	172530	1.59E-05	4.21E-06	4.21E-07	4.49E-06	1.19E-06	1.19E-07
RD_Faro	Roads in Faro Site	Area source	5888607	9.78E-07	2.59E-07	2.59E-08	2.76E-07	7.30E-08	7.30E-09
RD_Grum	Roads in Grum Site	Area source	6667147	6.33E-07	1.68E-07	1.68E-08	1.79E-07	4.73E-08	4.73E-09

Environment Canada Environnement Canada

Canada

UNPAVED INDUSTRIAL ROAD DUST CALCULATOR

Purpose

This spreadsheet was designed to assist with estimating the releases of NPRI substances from unpaved road dust. The substances of concern in this activity are TPM (Total Particulate Matter), PM10 (Particulate matter with aerodynamic diameter less than 10 µm) and PM2.5 (Particulate matter with aerodynamic diameter less than 2.5 µm).

Considerations on preparing unpaved road dust estimates

Due to the high degree of variability in the silt content measurements, applicability of weather observations to the site and many other similar influencing factors, it is generally accepted that these methodologies give orders of magnitude results for indicative purposes. In consideration of these factors it is expected that facilities estimating their releases will use average type information, not highly detailed daily traffic monitoring or other means to try and arrive at a theoretically precise emissions estimate.

How to Use the Estimation Tool

The reporting threshold for including TPM, PM10 and PM2.5 emissions from road dust is 10 000 Vehicles Kilometres Traveled (VKT) on unpaved surfaces within the facility in a given year. Before estimating emissions, check if you meet first the requirement of 10 000 VKT on unpaved surfaces within a facility per year.

This spreadsheet is used for the estimation of road dust emission from a given unpaved surface road within the facility. The calculation should be repeated for the other unpaved surface roads within the facility and the total emission should be obtained by summing the emissions from each unpaved segment road.

Cells highlighted in yellow are required values. Once you have entered all the required values you can view the generated adjusted emission factors and release estimates, which will appear in red bold font.

Since the NPRI reporting thresholds are for the facility as a whole, the air releases calculated from the unpaved road surfaces must be added to the NPRI releases from other sources (air releases) and activities at the facility.

Sources of Information

Emission factors are from the US EPA's AP-42 Chapter 13.2.2- Unpaved Roads (Industrial Roads). Last update November 2006. http://www.epa.gov/ttn/chief/ap42/ch13/index.html

Environment Canada Weather information website: http://www.climate.weatheroffice.ec.gc.ca/Welcome_e.html

Additional Information

Read the instructions under the tab "Instructions" for more information about the technical terms and simplifications about the reduction of dust emissions due to precipitation and other weather conditions.

The tab "Dust Control Methods" in the calculator includes corrections for a number of dust suppression methods.

The following instructions (and guidance) describe the data that is required on the "Facility Information" sheet

(There are additional instructions and guidance for use on other sheets. Please refer to each sheet for specific instructions)

Definition - Unpaved road

The common types of unpaved road surfaces include:

gravel road surfaces, thin membrane bituminous, surface treatments and bituminous cold mix surfaces.

If a dust suppressant is applied to an unpaved road, this segment of road is still considered unpaved road surface.

Note that winter roads, though classed as unpaved roads are made on frozen ground, snow and ice and typically have negligible dust emissions. Therefore winter roads will not be considered when reporting road dust to the NPRI.

Facility Information

Segment Road Length

It is the length in **km** of the segment road

Number of operating Days per Year

Enter the number of days (in the calendar year) that the traffic volume uses the road segment. If the volume is entirely different on the weekends, consider a second calculation for weekend traffic or add in the number of days which would be the equivalent number of days (eg. weekend traffic is generally 1/3 that of weekday traffic, there are 110 weekend days, equivalent days would be 110/3 or about 36 days)

Silt content

Use facility test data or representative test data from other sites. If this information is unavailable, please refer to the *Typical Silt Content AP-42* sheet reproduced from the US EPA. If roads are graded frequently this will generally change silt content on the running surface so a representative value must be chosen which will yield an average for the year. Do not use the silt content of the aggregate used in the construction of the road as due to compaction of the running surface - a significant proportion of this may not be available to generate dust.

Vehicle Class

Utilize general vehicle classes of similar Gross Vehicle Weight (GVW) ranges. The equations were developed for such and using specific weights will increase the reporting burden for little increase in accuracy.

If more than 20 classes of vehicles are being entered please contact the NPRI regional office.

Average daily traffic

The average daily traffic is the total count of vehicle passes over the segment roads per day. This value is used in the calculation of the fleet average weight and VKT calculation

Empty weight

The equations are based on the fleet average weight for all traffic. Estimate the typical unloaded weight for each class of vehicles which would include the fuel, equipment, operator, etc.

Full weight

The equations are based on the fleet average weight for all traffic. Estimate the typical loaded weight for each class of vehicles which would include the fuel, equipment, operator, etc. as well as the payload.

Mean weight
This is the calculated average weight of each vehicle class, considering the empty and full weights. This value will be used in the calculation of the fleet average weight.

Calculated VKT
Based on the road length, number of vehicles, the days of operation, the kilometres travelled by each class of vehicle. This calculation is used when the actual VKT is unknown.

Annual VKT from other methods
This section is used when the actual VKT value is known for each vehicle class, or estimated using an alternative method. This value can be obtained from odometer readings of the vehicles, actual annual vehicle counts or alternative methods. This value will be used preferentially over the Calculated VKT (it must be left empty if the Calculated VKT is used) in the calculation of the Fleet average weight and the Total VKT

Percentage of traffic on the segment road
This is the calculated percentage of traffic on the road based on the entered VKT information. This value will be used in the calculated of the weighted Fleet Average Weight.

W * P
This is the calculated Mean weight multiplied by the Percentage of Traffic on the road segment for use in the calculation of the Weighted Fleet Average Weight.

Annual Total Vehicle Kilometres Travelled on the segment road (VKT)
This is the sum of the Calculated and Actual VKT. If all of the formulas are properly in place there will be no duplication of information, please verify after entering information that everything is in place properly. This value will be used in the emissions calculation.

Wfleet: Fleet average weight for vehicle classes on the segment road (metric tonnes)
This is the calculated, weighted Fleet Average Weight considering the average vehicle weights and the VKT. This value will be used in the emissions calculation.

Precipitation

Means the sum of the rainfalls and snow falls.

Estimated working days when roads were frozen or snow covered and wet for Winter+Estimated working days with precipitation exceeding 0.2 mm

	2009		total	2010		total
Station	Days < 0 ℃	Precipitation>2mm (May to Sep)	days	Days < 0 ℃	Precipitation>2mm (May to Sep)	days
Grum	56	206	262	192	92	284
Faro	61	204	265	190	83	273

Roads length	Road length			
RD_HAUL: Haul road	10240	m	10.24	km
RD_ACCES: Employee access road	11502	m	11.502	km
total				
Roads on Faro Site				
R-3_south of tailing	5052	m		
R-4_north of tailing and surounding main pit	7902	m		
R-5	10438	m		
R-6	5274	m		
R-7	3177	m		
total	31843	m	31.843	km
Roads on Grum Site				
R-8	7012	m		
R-9	3729	m		
R10	3227	m		
R11	2129	m		
R12	4202	m		
R13	3064	m		
total	23363	m	23.363	km

Vehicle Summary

Type of Vehicle	# of vehicle	Description	Using frequency
class 2 light duty	20	employee used vehicles	daily
class 2 light duty	7	management vehicles	daily
class 2 light duty	2 - 4	visitor's vehicles	daily in summer months
class 7 heavy duty	10 - 15	heavy equipment	daily
class 2 light duty	6	CH2M vehicles/truck	daily, Each vehicle made trip up and back to Town each day and made 2 to 4 trips on site.
class 2 light duty	2	CH2M sub vehicles	daily, Each vehicle made trip up and back to Town each day and made 2 to 4 trips on site.

TYPICAL SILT CONTENT VALUES OF SURFACE MATERIAL ON INDUSTRIAL UNPAVED ROADS

Industry	Road Use Or Surface Material	Silt Content (%)
Copper smelting	Plant road	17
Iron and steel production	Plant road	6
Sand and gravel processing	Plant road	4.8
	Material storage area	7.1
Stone quarrying and processing	Plant road	10
	Haul road to/from pit	8.3
Taconite mining and processing	Service road	4.3
	Haul road to/from pit	5.8
Western surface coal mining	Haul road to/from pit	8.4
	Plant road	5.1
	Scraper route	17
	Haul road (freshly graded)	24
Construction sites	Scraper routes	8.5
Lumber sawmills	Log yards	8.4
Municipal solid waste landfills	Disposal routes	6.4

Source:
http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0202.pdf

This information is provided for entry on the **Facility Information** sheet in the **Silt Content section**.

Site specific testing information should be used preferentially over these values if available.

This is the silt content of the loose material on top of the packed running surface of the road in the vehicle tracks., Generally no direct correlation to the silt content of the unpaved road strata.

RD_HAUL

ROAD SEGMENT TRAFFIC DETAILS

This calculation is done for a given unpaved segment road in the facility. If the facility has other segment roads, save the calculation for this given segment road and do the other calculations segment by segment. The meteorological data will remain unchanged.

Unpaved Segment Road Length	**20.48**	**Km**
Number of operating days per year	**365**	**Days/Year**
Silt Content	**5.8**	**%**
Estimated working days when roads were frozen or snow covered and wet for Winter + Estimated working days with precipitation exceeding 0.2 mm	**262**	**Days (*)**

(*) Data can be taken from Environment Canada National Climate Data, Ensure that the cell value C7 is less or equal than cell C5. For more details, refer to the example scenario in the guiadance on estimating Road dust emissions from industrial unpaved surfaces.
http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html
http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Fleet information Should you have more vehicle types travelling this segment, please contact the NPRI Regional Office

Vehicle class	Vehicle type	Average daily traffic	Empty Weight	Full Weight	W	Calculated VKT	Annual VKT using other methods	P	W * P
					Mean Weight			Percentage of traffic on the segment road	
	Units	[#/day]	[metric tonnes]	[metric tonnes]	[metric tonnes]	[km]	[km]	[%]	[metric tonnes]
	1				0	0		0.00	0.000
management vehicles and / Sub vehicles	2	15	2	4.54	3.27	112128		50.00	1.635
	3				0	0		0.00	0.000
	4				0	0		0.00	0.000
	5				0	0		0.00	0.000
	6				0	0		0.00	0.000
Class 7 Heavy Duty Trucks	7	15	8	15	11.5	112128		50.00	5.750
	8				0	0		0.00	0.000
	9				0	0		0.00	0.000
	10				0	0		0.00	0.000
	11				0	0		0.00	0.000
	12				0	0		0.00	0.000
	13				0	0		0.00	0.000
	14				0	0		0.00	0.000
	15				0	0		0.00	0.000
	16				0	0		0.00	0.000
	17				0	0		0.00	0.000
	18				0	0		0.00	0.000
	19				0	0		0.00	0.000
	20				0	0		0.00	0.000
Totals / Overall Means						224256	0		7.385

Annual Total Vehicle Kilometres Travelled on the segment road (VKT)	**224256**	**VKT**
Wfleet: Fleet average weight for vehicle classes on the segment road (metric tonnes)	**7.385**	**tonnes**

RD_HAUL ANNUAL UNCONTROLLED EMISSIONS FOR AN UNPAVED SEGMENT ROAD WITHOUT RAIN AND SNOW CORRECTION

Constant	PM2.5	PM10	TPM
k (kg/VKT)	0.042	0.423	1.381
a	0.9	0.9	0.7
b	0.45	0.45	0.45

EF = k (s/12)^a (Wfleet/2.72)^b

E = EF*VKT

EF = size-specific emission factor (kg/VKT)

s = surface material silt content (%)

Wfleet = Fleet average weight of vehicle classes on the segment road (Metric tonnes)

VKT : Vehicle Kilometres Traveled

E = Uncontrolled size specific emissions (kg)

Note: the equation has been modified (from (W/3) to (W/2.72)) to allow for the use of metric information

Substance Name	CAS Number	EF Uncontrolled	EF (Units)	VKT	VKT Units	Total Release	Units
TPM	*	1.302	kg/VKT	224256	km	291.884	tonnes
PM10	*	0.345	kg/VKT	224256	km	77.260	tonnes
PM2.5	*	0.034	kg/VKT	224256	km	7.726	tonnes

Reference

EPA (2006) *Unpaved Roads-Chapter 13.2.2, AP-42, Compilation of Air Pollutant Emission Factors* , Volume 1, Stationary Point and Area Sources, USEPA, USA.

RD_HAUI **ANNUAL EMISSIONS FOR AN UNPAVED SEGMENT ROAD**

Emissions	Annual uncontrolled emissions (tonnes)	Adjustment factor ADJ for natural mitigations	Annual adjusted emissions for natural mitigation (tonnes)	Dust control methods adjustement	Total Release (*)	Units	24-hr emission rate (g/s)	annual emission rate (g/s)
Total Particulate Matter TPM	291.884	28%	82.367	100%	82.367	**tonnes**	9.256	2.612
Particulate matter less than 10 µm PM_{10}	77.260	28%	21.802	100%	21.802	**tonnes**	2.450	0.691
Particulate Matter less than 2.5 µm $PM_{2.5}$	7.726	28%	2.180	100%	2.180	**tonnes**	0.245	0.069

(*) The total release take in account the natural mitigations and any other applied dust control methods.

RD_ACCES

ROAD SEGMENT TRAFFIC DETAILS

This calculation is done for a given unpaved segment road in the facility. If the facility has other segment roads, save the calculation for this given segment road and do the other calculations segment by segment. The meteorological data will remain unchanged.

Unpaved Segment Road Length	**23**	**Km**
Number of operating days per year	**365**	**Days/Year**
Silt Content	**5.8**	**%**
Estimated working days when roads were frozen or snow covered and wet for Winter + Estimated working days with precipitation exceeding 0.2 mm	**262**	**Days (*)**

(*) Data can be taken from Environment Canada National Climate Data, Ensure that the cell value C7 is less or equal than cell C5. For more details, refer to the example scenario in the guiadance on estimating Road dust emissions from industrial unpaved surfaces.
http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html
http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Fleet information Should you have more vehicle types travelling this segment, please contact the NPRI Regional Office

Vehicle class	**Vehicle type**	**Average daily traffic**	**Empty Weight**	**Full Weight**	**W** **Mean Weight**	**Calculated VKT**	**Annual VKT using other methods**	**P** **Percentage of traffic on the segment road**	**W * P**
	Units	[#/day]	[metric tonnes]	[metric tonnes]	[metric tonnes]	[km]	[km]	[%]	[metric tonnes]
Class 1 light duty trucks	**1**	**20**	**1.5**	**2.72**	**2.11**	**167900**		**62.50**	**1.319**
Class 2 light duty	**2**	**12**	**2**	**4.53**	**3.265**	**100740**		**37.50**	**1.224**
	3				**0**	**0**		**0.00**	**0.000**
	4				**0**	**0**		**0.00**	**0.000**
	5				**0**	**0**		**0.00**	**0.000**
	6				**0**	**0**		**0.00**	**0.000**
	7				**0**	**0**		**0.00**	**0.000**
	8				**0**	**0**		**0.00**	**0.000**
	9				**0**	**0**		**0.00**	**0.000**
	10				**0**	**0**		**0.00**	**0.000**
	11				**0**	**0**		**0.00**	**0.000**
	12				**0**	**0**		**0.00**	**0.000**
	13				**0**	**0**		**0.00**	**0.000**
	14				**0**	**0**		**0.00**	**0.000**
	15				**0**	**0**		**0.00**	**0.000**
	16				**0**	**0**		**0.00**	**0.000**
	17				**0**	**0**		**0.00**	**0.000**
	18				**0**	**0**		**0.00**	**0.000**
	19				**0**	**0**		**0.00**	**0.000**
	20				**0**	**0**		**0.00**	**0.000**
Totals / Overall Means						**268640**	**0**		**2.543**

Annual Total Vehicle Kilometres Travelled on the segment road (VKT)	**268640**	**VKT**
Wfleet: Fleet average weight for vehicle classes on the segment road (metric tonnes)	**2.543**	**tonnes**

RD_ACCES ANNUAL UNCONTROLLED EMISSIONS FOR AN UNPAVED SEGMENT ROAD WITHOUT RAIN AND SNOW CORRECTION

Constant	PM2.5	PM10	TPM
k (kg/VKT)	0.042	0.423	1.381
a	0.9	0.9	0.7
b	0.45	0.45	0.45

EF = k (s/12)^a (Wfleet/2.72)^b

E = EF*VKT

EF = size-specific emission factor (kg/VKT)

s = surface material silt content (%)

Wfleet = Fleet average weight of vehicle classes on the segment road (Metric tonnes)

VKT : Vehicle Kilometres Traveled

E = Uncontrolled size specific emissions (kg)

Note: the equation has been modified (from (W/3) to (W/2.72)) to allow for the use of metric information

Substance Name	CAS Number	EF Uncontrolled	EF (Units)	VKT	VKT Units	Total Release	Units
TPM	*	0.806	kg/VKT	268640	km	216.418	tonnes
PM10	*	0.213	kg/VKT	268640	km	57.285	tonnes
PM2.5	*	0.021	kg/VKT	268640	km	5.728	tonnes

Reference

EPA (2006) *Unpaved Roads-Chapter 13.2.2, AP-42, Compilation of Air Pollutant Emission Factors* , Volume 1, Stationary Point and Area Sources, USEPA, USA.

RD_ACCES **ANNUAL EMISSIONS FOR AN UNPAVED SEGMENT ROAD**

Emissions	Annual uncontrolled emissions (tonnes)	Adjustment factor ADJ for natural mitigations	Annual adjusted emissions for natural mitigation (tonnes)	Dust control methods adjustement	Total Release (*)	Units	24-hr emission rate (g/s)	annual emission rate (g/s)
Total Particulate Matter TPM	216.418	28%	61.071	100%	61.071	tonnes	6.863	1.937
Particulate matter less than 10 µm PM_{10}	57.285	28%	16.165	100%	16.165	tonnes	1.816	0.513
Particulate Matter less than 2.5 µm $PM_{2.5}$	5.728	28%	1.617	100%	1.617	tonnes	0.182	0.051

(*) The total release take in account the natural mitigations and any other applied dust control methods.

RD_FARO

ROAD SEGMENT TRAFFIC DETAILS

This calculation is done for a given unpaved segment road in the facility. If the facility has other segment roads, save the calculation for this given segment road and do the other calculations segment by segment. The meteorological data will remain unchanged.

Unpaved Segment Road Length	**31.843**	**Km**
Number of operating days per year	**365**	**Days/Year**
Silt Content	**5.8**	**%**
Estimated working days when roads were frozen or snow covered and wet for Winter + Estimated working days with precipitation exceeding 0.2 mm	**262**	**Days (*)**

(*) Data can be taken from Environment Canada National Climate Data, Ensure that the cell value C7 is less or equal than cell C5. For more details, refer to the example scenario in the guiadance on estimating Road dust emissions from industrial unpaved surfaces.
http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html
http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Fleet information Should you have more vehicle types travelling this segment, please contact the NPRI Regional Office

Vehicle class	**Vehicle type**	**Average daily traffic**	**Empty Weight**	**Full Weight**	**W** **Mean Weight**	**Calculated VKT**	**Annual VKT using other methods**	**P** **Percentage of traffic on the segment road**	**W * P**
	Units	[#/day]	[metric tonnes]	[metric tonnes]	[metric tonnes]	[km]	[km]	[%]	[metric tonnes]
	1				**0**	**0**		**0.00**	**0.000**
management vehicles and / Sub vehicles	**2**	**15**	**2**	**4.54**	**3.27**	**174340.425**		**50.00**	**1.635**
	3				**0**	**0**		**0.00**	**0.000**
	4				**0**	**0**		**0.00**	**0.000**
	5				**0**	**0**		**0.00**	**0.000**
	6				**0**	**0**		**0.00**	**0.000**
Class 7 Heavy Duty Trucks	**7**	**15**	**8**	**15**	**11.5**	**174340.425**		**50.00**	**5.750**
	8				**0**	**0**		**0.00**	**0.000**
	9				**0**	**0**		**0.00**	**0.000**
	10				**0**	**0**		**0.00**	**0.000**
	11				**0**	**0**		**0.00**	**0.000**
	12				**0**	**0**		**0.00**	**0.000**
	13				**0**	**0**		**0.00**	**0.000**
	14				**0**	**0**		**0.00**	**0.000**
	15				**0**	**0**		**0.00**	**0.000**
	16				**0**	**0**		**0.00**	**0.000**
	17				**0**	**0**		**0.00**	**0.000**
	18				**0**	**0**		**0.00**	**0.000**
	19				**0**	**0**		**0.00**	**0.000**
	20				**0**	**0**		**0.00**	**0.000**
Totals / Overall Means						**348680.85**	**0**		**7.385**

Annual Total Vehicle Kilometres Travelled on the segment road (VKT)	**348680.85**	**VKT**
Wfleet: Fleet average weight for vehicle classes on the segment road (metric tonnes)	**7.385**	**tonnes**

RD_FAR **ANNUAL UNCONTROLLED EMISSIONS FOR AN UNPAVED SEGMENT ROAD WITHOUT RAIN AND SNOW CORRECTION**

Constant	PM2.5	PM10	TPM
k (kg/VKT)	0.042	0.423	1.381
a	0.9	0.9	0.7
b	0.45	0.45	0.45

EF = k (s/12)^a (Wfleet/2.72)^b

E = EF*VKT

EF = size-specific emission factor (kg/VKT)

s = surface material silt content (%)

Wfleet = Fleet average weight of vehicle classes on the segment road (Metric tonnes)

VKT : Vehicle Kilometres Traveled

E = Uncontrolled size specific emissions (kg)

Note: the equation has been modified (from (W/3) to (W/2.72)) to allow for the use of metric information

Substance Name	CAS Number	EF Uncontrolled	EF (Units)	VKT	VKT Units	Total Release	Units
TPM	*	1.302	kg/VKT	348680.85	km	453.831	tonnes
PM10	*	0.345	kg/VKT	348680.85	km	120.126	tonnes
PM2.5	*	0.034	kg/VKT	348680.85	km	12.013	tonnes

Reference

EPA (2006) *Unpaved Roads-Chapter 13.2.2, AP-42, Compilation of Air Pollutant Emission Factors* , Volume 1, Stationary Point and Area Sources, USEPA, USA.

RD_FARO **ANNUAL EMISSIONS FOR AN UNPAVED SEGMENT ROAD**

Emissions	Annual uncontrolled emissions (tonnes)	Adjustment factor ADJ for natural mitigations	Annual adjusted emissions for natural mitigation (tonnes)	Dust control methods adjustement	Total Release (*)	Units	24-hr emission rate (g/s)	annual emission rate (g/s)
Total Particulate Matter TPM	453.831	28%	128.067	100%	128.067	tonnes	14.391	4.061
Particulate matter less than 10 µm PM_{10}	120.126	28%	33.899	100%	33.899	tonnes	3.809	1.075
Particulate Matter less than 2.5 µm $PM_{2.5}$	12.013	28%	3.390	100%	3.390	tonnes	0.381	0.107

(*) The total release take in account the natural mitigations and any other applied dust control methods.

RD_GRUM

ROAD SEGMENT TRAFFIC DETAILS

This calculation is done for a given unpaved segment road in the facility. If the facility has other segment roads, save the calculation for this given segment road and do the other calculations segment by segment. The meteorological data will remain unchanged.

Unpaved Segment Road Length	**23.363**	**Km**
Number of operating days per year	**365**	**Days/Year**
Silt Content	**5.8**	**%**
Estimated working days when roads were frozen or snow covered and wet for Winter + Estimated working days with precipitation exceeding 0.2 mm	**262**	**Days (*)**

(*) Data can be taken from Environment Canada National Climate Data, Ensure that the cell value C7 is less or equal than cell C5. For more details, refer to the example scenario in the guiadance on estimating Road dust emissions from industrial unpaved surfaces.
http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html
http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Fleet information

Should you have more vehicle types travelling this segment, please contact the NPRI Regional Office

Vehicle class	Vehicle type	Average daily traffic	Empty Weight	Full Weight	W	Calculated VKT	Annual VKT using other methods	P	W * P
					Mean Weight			Percentage of traffic on the segment road	
	Units	[#/day]	[metric tonnes]	[metric tonnes]	[metric tonnes]	[km]	[km]	[%]	[metric tonnes]
	1				0	0		0.00	0.000
management vehicles and / Sub vehicles	2	15	2	4.54	3.27	127912.425		50.00	1.635
	3				0	0		0.00	0.000
	4				0	0		0.00	0.000
	5				0	0		0.00	0.000
	6				0	0		0.00	0.000
Class 7 Heavy Duty Trucks	7	15	8	15	11.5	127912.425		50.00	5.750
	8				0	0		0.00	0.000
	9				0	0		0.00	0.000
	10				0	0		0.00	0.000
	11				0	0		0.00	0.000
	12				0	0		0.00	0.000
	13				0	0		0.00	0.000
	14				0	0		0.00	0.000
	15				0	0		0.00	0.000
	16				0	0		0.00	0.000
	17				0	0		0.00	0.000
	18				0	0		0.00	0.000
	19				0	0		0.00	0.000
	20				0	0		0.00	0.000
Totals / Overall Means						255824.85	0		7.385

Annual Total Vehicle Kilometres Travelled on the segment road (VKT)	**255824.85**	**VKT**
Wfleet: Fleet average weight for vehicle classes on the segment road (metric tonnes)	**7.385**	**tonnes**

RD_GRUM **ANNUAL UNCONTROLLED EMISSIONS FOR AN UNPAVED SEGMENT ROAD WITHOUT RAIN AND SNOW CORRECTION**

Constant	PM2.5	PM10	TPM
k (kg/VKT)	0.042	0.423	1.381
a	0.9	0.9	0.7
b	0.45	0.45	0.45

EF = k (s/12)^a (Wfleet/2.72)^b
E = EF*VKT

EF = size-specific emission factor (kg/VKT)
s = surface material silt content (%)
Wfleet = Fleet average weight of vehicle classes on the segment road (Metric tonnes)
VKT : Vehicle Kilometres Traveled
E = Uncontrolled size specific emissions (kg)

Note: the equation has been modified (from (W/3) to (W/2.72)) to allow for the use of metric information

Substance Name	CAS Number	EF Uncontrolled	EF (Units)	VKT	VKT Units	Total Release	Units
TPM	*	1.302	kg/VKT	255824.85	km	332.972	tonnes
PM10	*	0.345	kg/VKT	255824.85	km	88.136	tonnes
PM2.5	*	0.034	kg/VKT	255824.85	km	8.814	tonnes

Reference

EPA (2006) *Unpaved Roads-Chapter 13.2.2, AP-42, Compilation of Air Pollutant Emission Factors* , Volume 1, Stationary Point and Area Sources, USEPA, USA.

RD_GRU ANNUAL EMISSIONS FOR AN UNPAVED SEGMENT ROAD

Emissions	Annual uncontrolled emissions (tonnes)	Adjustment factor ADJ for natural mitigations	Annual adjusted emissions for natural mitigation (tonnes)	Dust control methods adjustement	Total Release (*)	Units	24-hr emission rate (g/s)	annual emission rate (g/s)
Total Particulate Matter TPM	332.972	28%	93.962	100%	93.962	**tonnes**	10.558	2.980
Particulate matter less than 10 µm PM_{10}	88.136	28%	24.871	100%	24.871	**tonnes**	2.795	0.789
Particulate Matter less than 2.5 µm $PM_{2.5}$	8.814	28%	2.487	100%	2.487	**tonnes**	0.279	0.079

(*) The total release take in account the natural mitigations and any other applied dust control methods.

Attachment 7A-2
CALMET and CALPUFF Parameters and Switches

TABLE 7A-2-1
Input Parameters for CALMET
Faro Mine Interim Works

Option	Parameter	Value	Explanation and Justification
Wind field model selection variable	IWFCOD	1	Use diagnostic wind module (allows 2-step approach)
Compute Froude number adjustment effects?	IFRADJ	1	Used to evaluate thermodynamic blocking effects of the terrain on the wind flow and are described using the critical Froude number
Compute kinematic effects?	IKINE	0	No, do not calculate a terrain-forced vertical velocity in the initial guess wind field DIVLIM, NITER and ALPHA do not need to be specified
Use O'Brien procedure for adjustment of the vertical velocity?	IOBR	0	No adjustment to the vertical velocity profile at top of model domain
Compute slope flows?	ISLOPE	1	Slope flow calculated as a function of sensible heat flux, distance to the crest or valley bottom, and slope angle
Extrapolate surface wind observations to upper layers?	IEXTRP	1	No surface wind extrapolations to upper layers
Extrapolate calm winds aloft?	ICALM	0	No surface wind calm extrapolation
Layer-dependent biases	BIAS	0	No bias of MM5 and surface winds
Minimum distance between upper air station and surface station for which extrap of surface winds will be allowed	RMIN2	4	
Gridded prognostic wind field model output fields	IPROG	14	MM5 Prognostic data introduced as initial guess field
Use varying radius of influence?	LVARY	F	No. Sparse surface data available.
Maximum radius of influence over land of the surface layer	RMAX1	10	
Maximum radius of influence over land aloft	RMAX2	50	
Maximum radius of influence over water	RMAX3	50	NA
Minimum radius of influence used in the wind field interpolation	RMIN	0.1	NA
Radius of influence of terrain features	TERRAD	5	
Distance from a surface station at which the station observations and first guess field are equally weighted	R1	1	
Distance from an upper air station at which the observation and first guess field are equally weighted	R2	5	
Relative weighting of the prognostic wind field data	RPROG	N/A	Not used
Maximum acceptable divergence in the divergence minimum procedure	DIVLIM	$5x10^{-6}$	Not used since IKINE = 0
Maximum number of iterations in the divergence min. procedure	NITER	50	Not used since IKINE = 0

TABLE 7A-2-1
Input Parameters for CALMET
Faro Mine Interim Works

Option	Parameter	Value	Explanation and Justification
Number of passes in the smoothing procedure	NSMTH	2	2 in lowest layer, 4 in higher layers
Maximum number of stations used in each layer for the interpolation of data to a grid point	NINTR2	99	Default
Critical Froude number	CRITFN	1	If Froude number is less than CRITFN, wind has an uphill component and direction is changed to be tangent to the terrain; If Froude number is greater than CRITFN, no adjustment is made
Empirical factor controlling the influence of kinematic effects	ALPHA	0.1	Not used since IKINE = 0
Multiplicative scaling factor for extrapolation of surface observations to upper layers	FEXTR2	N/A	Not Used
Number of barriers to interpolation of the wind fields	NBAR	0	Not Used
X and Y coordinates of barriers	XBBAR, YBBAR, XEBAR, YEBAR	N/A	Not Used
Diagnostic module surface temperature option	IDIOPT1	0	Usually surface temperatures are computed internally
Diagnostic module sfc. met station to use	ISURFT	-1	Default
Diagnostic module domain-averaged lapse rate option	IDIOPT2	0	Usually lapse rate computed internally.
Diagnostic module upper air station to use for lapse rate	IUPT	N/A	Not Used
Depth through which the domain-scale lapse rate is computed	ZUPT	N/A	Not Used
Initial guess field wind components	IDIOPT3	0	Usually computed internally from upper air observations
Upper air station to use for domain-scale winds	IUPWND	N/A	Not Used
Bottom and top of layer though which the initial guess winds are computed	ZUPWND	N/A	Not Used

TABLE 7A-2-2
Input Parameters for CALPUFF
Faro Mine Interim Works

Option	Parameter	Value	Explanation & Justification
Vertical distribution used in the near field	MGAUSS	1	Gaussian
Terrain adjustment method	MCTADJ	3	Partial plume path adjustment (allows plume penetration into elevated inversions)
Sub grid-Scale complex terrain flag	MCTSG	0	Usually 0, but allows for CTDM-like treatment of sub grid-scale hills
Near-field puffs modelled as elongated?	MSLUG	0	Slug model not used
Transitional Plume Rise modelled?	MTRANS	1	Yes, transitional rise computed
Method used to simulate building downwash?	MBDW	1	No downwash used, area sources only
Stack-tip downwash?	MTIP	1	Not used
Vertical wind shear modelled above stack top?	MSHEAR	0	No, vertical wind shear above stack top not modelled; if this option is chosen, a power law wind speed extrapolation is done above stack top
Puff splitting allowed?	MSPLIT	0	No, splitting not allowed
Chemical Transformation Scheme	MCHEM	0	Chemical transformations not modelled
Aqueous phase transformation flag (only used if MCHEM = 1 or 3)	MAQCHEM	0	Aqueous phase not modelled
Wet removal modelled?	MWET	0	Deposition was not modelled
Dry deposition modelled?	MDRY	0	Deposition was not modelled
Methods used to compute dispersion coefficients	MDISP	3	PG dispersion coefficients; default
Sigma measurements used?	MTURBVW	N/A	Used only if MDISP = 1 or 5
Back-up method used to compute dispersion when measured turbulence data are missing	MDISP2	N/A	Used only if MDISP = 1 or 5
PG sigma y,z adjusted for roughness	MROUGH	0	Default
Partial plume penetration of elevated inversion?	MPARTL	1	Yes, partial plume penetration; default
Strength of temp inversion provided in PROFILE.DAT extended records?	MTINV	0	Typically computed from measured/default gradients; depends on whether PROFILE.DAT contains extended records
Probability Distribution Function used for dispersion under convective conditions?	MPDF	0	No, default
Sub-grid TIBL module used for shore line?	MSGTIBL	0	Not used
Boundary conditions (concentration) modelled?	MBCON	0	Boundary concentrations not modelled
Configure for FOG Model output?	MFOG	0	FOG model usually not run unless condensed plume assessment is required
Test options specified to see if they conform to regulatory values?	MREG	0	No checks made regarding conformity to USEPA values

Appendix 7B
Description of Water Modelling & Results

Draft

Description of Water Modelling & Results, Faro Mine Remediation Project

Prepared for

Government of Yukon and the Government of Canada as represented by Aboriginal Affairs and Northern Development Canada

March 2014

CH2MHILL®

309 Strickland Street, Suite 301
Whitehorse, Yukon Y1A 2J9

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Acronyms and Abbreviations

Ca	calcium
Cd	cadmium
Co	cobalt
COC	constituent of concern
CVD Pond	Cross Valley Pond
FMC	Faro Mine Complex
HEP	Hydrological Effective Precipitation
IW	Interim Works
km	kilometre
km^2	square kilometre
L/s	litres per second
LCD	Little Creek Dam
m	metre
m^2	square metre
m^3	cubic metre
Mg	magnesium
mg/L	milligram per litre
mm	millimetre
Mn	manganese
NFRC	North Fork Rose Creek
OLS	Ordinary Least Square
Pb	lead
RCAA	Rose Creek Alluvial Aquifer
RCTA	Rose Creek Tailings Area
SO_4	sulphate
USgpm	United States gallon per minute
Zn	zinc

SECTION 1

Introduction

This appendix presents the methodology and results for the near-term (January 2014 through December 2023) prediction of water quality discharged from the Faro Mine Complex (FMC). The following water quality parameters relevant to the aquatics effects assessment were chosen for this evaluation (Minnow, 2014a):

- Hardness (calculated using calcium [Ca] and magnesium [Mg])
- Cadmium (Cd)
- Cobalt (Co)
- Lead (Pb)
- Manganese (Mn)
- Sulphate (SO_4)
- Zinc (Zn)

Results are presented in terms of percentiles from a range of stochastic simulations, and show the likelihood of having concentrations exceeding guideline values at the following key locations (presented in Figure 7B-1):

- North Fork Rose Creek (NFRC) upstream from North Fork Rock Drain (NFRD) at NF1
- North Fork Rose Creek upstream from mine access road at X2
- Rose Creek below confluence of South and North Fork Rose Creek at X3A
- Rose Creek downstream from mine site discharges at X14
- Rose Creek upstream from confluence with Anvil Creek at R4
- Anvil Creek downstream from confluence with Rose Creek at R5
- Anvil Creek near confluence with Pelly River at A1
- Pelly River downstream from Anvil Creek at P4
- Vangorda Creek upstream from confluence with Pelly River at V8

The near-term water quality predictions presented in this appendix assume that the recent concentration trends will remain the same for the next 10 years; therefore, whenever a trend in water quality was verified, it was extrapolated for 10 years. The assumptions presented in this document were conservative. More accurate predictions of water quality will be possible when results from ongoing modelling efforts (geochemistry, groundwater and surface water) are concluded to support the development of the Faro Mine Remediation Plan (FMRP), yielding a better understanding of the generation of loads from waste rock dumps and the processes that might attenuate those loads before they reach streams.

Recent surface water quality data for the NFRC and Rose Creek indicate an increase in zinc concentration in late 2013, likely originating in the area of NFRD. This deterioration may be due to a change in seepage water geochemistry from a nearby waste rock dump. The modelling work described in this appendix does not include this recent change in water quality as it is assumed that this development will be addressed through Adaptive Management processes and the new source will be managed to remove its impact on NFRC. Hence, the trends in water quality for the NFRC predicted by this model will include only longer-term trends observed for this reach of the creek and not the shorter-term influx of contamination observed starting the winter of 2013.

As presented in *Assessment of Effects of the Faro Mine Interim Works on Surface Water Quality and Resulting Effects on Fish and Fish Habitat* (Minnow, 2014a), none of the above water quality parameters are likely to be above guideline thresholds at the most downstream location (P4). However, consistent with past results, predictions indicate that certain parameters at some locations upstream of P4 in the Rose Creek, Anvil Creek, and Vangorda Creek drainages may exceed the determined guidelines.

SECTION 2

Background

The overall water modelling objective is the prediction of the effects of the Interim Works on water quality in the receiving environment; these predictions will be used in the environmental assessment for the project.

The model predicts water quality at key locations in the aquatic receiving environment as a result of the contaminant loads from the FMC, specifically seepage from the waste dumps and the Rose Creek Tailings Area (RCTA), and the discharge of treated water from the Interim Works Treatment System and Vangorda Water Treatment Plant (WTP). This model was developed using a similar framework to that being used for the long-term model currently under development to support the ongoing closure planning process (CH2MHILL, 2013a), with differences in the approach used for waste rock source terms: the Interim Works version of the model fixes source load concentrations at key mine locations based on actual site conditions and current trends in seepage water quality. A detailed description of this adapted model version is presented in Section 5, Model Assumptions.

A key challenge in predicting water quality at the FMC stems from the high level of uncertainty about the waste dump seepage water quality over time and hydrological variability. The uncertainties are addressed in the model with the use of stochastic elements in GoldSim, which are described in detail in Section 5.

The long-term model was refined as follows for the Interim Works modelling effort:

- Refined the water balance components on the Vangorda/Grum Area, a task not yet completed for the long-term model
- Compared historical model results against measured data (pit elevations, flows and water quality for key chemical constituents)

Fixed key water quality parameters at model boundaries based on recent measured water quality values. In this Report, Section 3, Methodology, describes in detail how water quality concentrations for the next 10 years were estimated. Section 4, Input Data, describes the available data used to calibrate the model water balance and to support the development of the water quality trends and estimates of uncertainty. Section 5, Model Assumptions, describes the flow and water quality assumptions. Section 6, Calibration, describes the calibration process for various model components. Finally, Section 7, Results, summarizes the model results; additional analysis and interpretation of these results is presented in Prediction of Water Quality Effects, Faro Mine Interim Works Minnow (2014a).

SECTION 3

Methodology

The study methodology is divided into three separate but connected elements: system representation, system flows, and system water quality. Section 3.1, System Representation, illustrates how the model elements are connected, including how catchments and waste dumps are connected and how and where they drain through the system. Section 3.2, System Flows, describes the procedures used to account for all the flow components that could affect water quality. Section 3.3, System Water Quality, describes the procedures used to estimate future water quality based on observed concentrations at key locations and changes in the recent past.

3.1 System Representation

The adapted FMC GoldSim model v2 predicts flows and water quality conditions for three sub-areas within the FMC:

1) Anvil Creek and Rose Creek drainages downstream of the FMC
2) Vangorda Creek drainage downstream of the Vangorda/Grum Area
3) Pelly River between its confluences with Vangorda Creek and Anvil Creek and immediately downstream of Anvil Creek.

The Faro Mine Area drains to the Pelly River via Rose Creek and then Anvil Creek, whereas the Vangorda/Grum Area drains to the Pelly River via Vangorda Creek. The Pelly River downstream of the Anvil Creek confluence is the farthest downstream model prediction point (Figure 7B-1). Figure 7B-1 also presents the site-wide stream network, key locations for which historical flow and water quality data are available, locations of the Faro and Vangorda/Grum Areas, and names of the major streams considered in the model.

Figures 7B-2 and 7B-3 provide more detail, showing the Faro and Vangorda/Grum Areas, respectively, along with modelled catchment boundaries and the waste dump configurations. Pre-mining topography of the mine site was used to delineate model catchment for waste dump/groundwater seepage through the system. Current site topography defines the routing of surface water runoff and flows.

Figure 7B-2 shows eight catchment areas within the Faro Mine Area, and Figure 7B-3 shows five catchment areas within the Vangorda/Grum Area, all represented in the FMC GoldSim model v2. The modelled catchments associated with the Faro Mine Area are as follows:

- Faro Main Pit (MP)
- NFRC
- Zone II (ZII)
- Catchment that drains to the X2 monitoring location (X2)
- Rose Creek Valley (RCV)
- Upper Guardhouse (GHU)
- Lower Guardhouse (GHL)
- RCTA, also referred to as Down Valley Tailings (DVT) Area

The modelled catchments associated with the Vangorda/Grum Area are as follows:

- Catchment that drains to the V1 monitoring location (V1)
- Catchment that drains to the V27 monitoring location (V27)
- Catchment that drains to the V8 monitoring location (V8)
- Vangorda Pit
- Grum Pit (GP_Area)

The proportion of waste dump seepage that reports to the modelled catchments is outlined in Table 7B-1 for the Faro Mine Area and Table 7B-2 for the Vangorda/Grum Area. Figure 7B-4 illustrates the general routing of flows through the system from the waste dump or contaminated site to the downstream receiving environment.

Figures 7B-5 and 7B-6 depict the general geographic connectivity of the elements included in the GoldSim model v2 for the Faro and Vangorda/Grum Areas, respectively, whereas Figures 7B-7 and 7B-8 show a more-detailed model schematic including connections among catchments, storage elements, and collection systems, including seepage interception systems(SIS), in the GoldSim model v2. Figures 7B-7 and 7B-8 are referred to as "model schematics" and illustrate the overall direction of flows in the system.

Figures 7B-7 and 7B-8—together with Tables 7B-1 and 7B-2— graphically depict how catchments, flows, waste dumps, and WTP operations could affect the receiving environment. For example, Table 7B-1 shows that 83 percent of the Intermediate Dam (ID) Waste Dump is in the X2 catchment and Figure 7B-7 shows that the X2 catchment has a direct contribution to the receiving environment. On the other hand, a waste dump contained in the MP catchment (e.g., Faro Valley North) will have to flow to the Faro Pit first, then to the WTP where it will be treated, then discharged to the CVD Pond and finally discharged to the environment at X14. Figures 7B-7 and 7B-8 show the catchments that are contributing and eventually affecting water quality concentrations for the receiving environment in the Faro Mine Area and Vangorda/Grum Area respectively. System Flows

The system flows are generated from Hydrological Effective Precipitation (HEP) values, which are expressed in millimetres (mm) per year and defined as the total annual precipitation minus losses to satisfy the soil moisture deficit and evapotranspiration (Younger et al., 2002). HEP values were estimated in previous FMC reports (RGC, 1996; AECOM, 2009) and the values obtained for the FMC catchments are based on a regional analysis comparing HEP and elevations. Several HEP values were estimated for the FMC based on the correlation curve between HEP and elevation developed by RGC (2009) and the different median elevations of the FMC drainage catchments. The catchments and correspondent values for HEP, Area, and Average Annual Flow Volume are presented on Table 7B-3.

The HEP values were developed for average precipitation conditions, and the model scales them up or down proportionally to the annual precipitation used in each stochastic run. The current closest and best precipitation record available is from the Faro Airport Station. The Faro Airport Station is located approximately 14 kilometres (km) from the Faro Valley Waste Dump area at an elevation of 717 metres (m), approximately 457 m lower than the FMC. The monthly precipitation data are presented in Section 4. The assumptions regarding the use of this dataset, including the adjustment of precipitation based on elevation, are presented in Section 5.

Annual average flows from catchments are estimated by multiplying the HEP value by the catchment area and the precipitation scale adjustment as presented in Equation 1, as follows:

$$1. \quad Q=A*HEP*coef$$

where:

Q = total annual flow from unimpaired area (seepage plus runoff) (cubic metres [m^3]/year)
A= total area of the unimpaired catchment (square metres [m^2])
HEP = HEP value for the catchment (m/year)
coef= coefficient that adjusts the HEP based on the current annual precipitation, or the annual precipitation (Faro or Vangorda) divided by 357 mm for catchments in the Faro Mine Area and 369 mm for catchments in the Vangorda/Grum Area (unitless)

For the waste dump areas, it was necessary to separate the seepage and runoff components of the HEP. Sections 3.2.1 and 3.2.2 describe the equations used to estimate the seepage and runoff annual average flows. Section 3.2.3 describes how the annual average flows are converted to monthly average flows.

Once flows were generated at the model boundaries (model boundaries represented as undisturbed catchments and waste dumps), flows are routed through the system. The flow through the system is mainly determined by seepage collection systems efficiency (when available), pump and reservoir operations, and water treatment season and capacity. A more detailed description of the flow routing from upstream to downstream is presented in Section 5.

3.1.1 Seepage

Annual seepage volume is calculated as a function of waste dump area, precipitation, and an infiltration factor that converts precipitation into seepage (function of the cover type). Seepage volumes from each waste dump were computed according to Equation 2, as follows:

$$2. \quad S_{w,c} = A_w * D_{w,c} * I_w * P$$

where:

$S_{w,c}$ = total annual seepage for waste dump "w" located in catchment "c" (m^3)
A_w = total area of waste dump "w" (m^2)
$D_{w,c}$ = fraction of waste dump "w" that drains to catchment "c"
I_w = infiltration factor for waste dump "w" (unitless, 0 to 1 depending on the waste dump cover type)
P = annual precipitation (m)

Seepage volumes generated by the waste dump sources are grouped by catchments, and a monthly factor is applied to the aggregated runoff to distribute the annual volumes into monthly flows. The seepage is then routed through the system according to operational assumptions.

3.1.2 Surface Runoff

The system runoff is computed as a function of the infiltration factor used in Equation 2 to compute seepage and the HEP value for each catchment. The surface runoff is computed according to Equation 3, as follows:

$$3. \quad R_{w,c} = A_w * D_{w,c} * (HEP_c - I_w * P)$$

where:

$R_{w,c}$ = total annual runoff for waste dump "w" located in catchment "c" (m^3)
HEP_c = annual HEP for catchment "c" (m entered as mm in the model)

Waste dumps are then grouped by catchments and a monthly factor is applied to the aggregated runoff to distribute the annual flows into monthly flows. The total annual runoff for a waste dump can also be described as the total annual HEP minus the total annual seepage computed for a specific waste dump within a specific catchment.

The sum of the annual volumes from Equations 2 and 3, plus the boundary condition flows, represent all the inflows to the modelled system and are balanced with all computed outflows, change in storage volume, or losses from the system for a given time step.

3.1.3 Monthly Flow Patterns

The annual average runoff and seepage flows from undisturbed and waste dump areas are converted into monthly flows by monthly flow patterns, or distributions, representing fractions of the annual volume. Several monthly flow patterns are used in the model depending on the location where the flows are being generated and depending if the flows are runoff or seepage. The following bullets provide a description of how the monthly flow patterns were generated. Figures 7B-1, 7B-2 and 7B-3 show the locations of the places described in this subsection; Table 7B-4 presents the actual patterns as a fraction of the annual volume.

- Faro Surface: This monthly flow pattern was developed from historical flows at R7 and it is applied to NFRC inflows, Upper Faro Creek flows, and runoff flows originating from waste dumps located in the X23, RCV, Upper and Lower Guardhouse, Faro Pit, X2, and NFRC catchments.
- Faro WR Seep: This monthly flow pattern was developed based on the assessment of historical flows measured at X23, a well-defined seep at the toe of the Main dump. This distribution is applied to seepage flows originating on waste dumps located in the X23, RCV, Upper and Lower Guardhouse, Faro Pit, X2, ZII, and NFRC catchments.

- Rose Creek: This monthly flow pattern was developed from historical flows at X14 and it is applied to the runoff and seepage from the RCTA area, Upper South Fork Rose Creek (SFRC) and SFRC, flows from the catchment between Anvil Mouth and R4, and flows from the Upper Anvil catchment.
- Rose Creek R4: This monthly flow pattern is similar to the Rose Creek pattern but with attenuated peaks during the freshet months and increased baseflow during the winter months. The pattern was developed using a calibration parameter for the sulphate dilution measured between X14 and R4 and is described in Section 6. This pattern is applied to the flows originating between X14 and R4.
- Vangorda Surface: This monthly flow pattern was developed from historical flows at V8 and it is applied to all creek and surface water flows in the Vangorda/Grum Area except for flows originating at the Vangorda Waste Dump.
- Vangorda WR Seep: This monthly flow pattern was developed from flows measured at the toe of the Grum Dump and it is applied to all seepage flows in the Vangorda/Grum Area except for the Vangorda dumps.
- Little Creek Dam LCD): The monthly flow pattern was developed from estimated inflows into Little Creek Dam and it is applied to all seepage and runoff flows from the Vangorda dumps that drain into LCD.

Monthly flow patterns are important model parameters as they represent the seasonal variations in the magnitude of expected flows during a year, which directly affects the water quality results.

3.2 System Water Quality

The methodology applied to estimate near-term water quality concentrations for the FMC takes into account recently measured water quality concentrations and trends at key locations of the FMC. In this case, 'near-term' refers to the period over about the next 10 years and 'recent' indicates up to the past 9 years, but is generally limited to the past 5 to 6 years. As Section 3.3.2 describes, the period used to fix water quality for each of the source terms was selected based on operational (e.g., S-Wells began to operate in 2009), or data quality considerations. Available water quality concentrations from the key locations were used to generate monthly water quality patterns, incorporating observed trends, where applicable, to represent source terms in the model. Water quality was predicted for the duration of the Faro Mine Interim Works (IW) (2014 through 2023) at key locations in the aquatic receiving environment within and downstream of the FMC. Locations within the model where water quality was predicted include: NF1, X2, X3A, X14, R4, R5, A1, P4 and V8. Based on the analysis performed in the *Aquatic Baseline Characterization Report, Faro Mine Interim Works* (Minnow, 2014b), the following eight constituents of concern (COCs) were identified as the key water quality parameters the model would be used to predict: Ca, Cd, Co, Mg, Mn, Pb, SO_4, and Zn. Hardness is calculated from the predicted Ca and Mg concentrations.

At specific source locations, the water quality concentrations were fixed with a monthly time-series from January 2013 to January 2024 (a longer period than the period reported in the results from January 2014 to December 2023), reflecting the observed monthly pattern and annual trend, if any, to represent the near-term site conditions.

The term "fixed" is used to describe water quality for some of the source locations. The term means that a fixed time-series was developed that includes a monthly pattern and an annual trend, if the available data exhibited a trend.

The fixed time-series of concentrations used as model inputs were created using a four-step process. First, the locations where fixed water quality was applied were chosen based on their potential to impact the receiving environment. Second, monthly patterns for the concentrations were created based on recent observed data. Third, an Ordinary Least Square (OLS) fitting procedure was used on annual concentration values to determine if there were any trends in the concentrations at the defined locations where water quality is fixed. The OLS fitting procedure was then confirmed with a more robust statistical test described under Section 3.3.3.1. Finally, monthly variability was applied to the trended time-series based on the variability observed in the recent past. The following sections explain in detail each one of these four steps.

3.2.1 Locations where Water Quality was fixed

Water quality source terms are fixed at the following three locations within the Faro Mine Area:

- Rose Creek Alluvial Aquifer (RCAA) underlying the RCTA
- S-Wells bypass discharge to NFRC
- Groundwater discharge to NFRC from waste dumps upstream of the Haul Road

Water quality discharge from the Faro WTP is also fixed. The Faro WTP discharge water quality used as model input was generated from expected future performance and past performance. Specifically, concentrations of As, Cu, Ni, Pb, and Zn in the Faro WTP discharge were fixed to expected future WTP performance. Concentrations of Ca, Co, Mg, Mn, and SO_4 were fixed based on water quality in Cross Valley Dam Pond (CVD Pond) discharge (X5) between 2011 and 2012. This period was chosen because site operations changed in 2011, which resulted in shifts in CVD Pond water quality. Concentrations of Cd were also fixed based on water quality in the X5 discharge. Cd concentrations in the CVD Pond were conservatively assumed to be unimpacted by operational changes discussed; therefore, the maximum observed concentration between 2002 and 2012 was selected to represent Cd discharge to Rose Creek. Data through 2013 was not included, because the CVD Pond had been operated differently during the summer of 2013 (i.e., it did not receive inflow of lime-treated effluent). The 2013 site operations are expected to be unique to 2013 and do not represent future conditions.

During the latter part of 2013, elevated Zn concentrations were identified in Rose Creek, sourced from the vicinity of the Haul Road. Beyond incorporating observed trends from groundwater discharge to NFRC from waste dumps upstream of the Haul Road through 2012, these recent Zn concentration increases are not included in model water quality input since it is an unforeseen deviation from current trends and currently being addressed through adaptive management. Additional discussion and consideration of these elevated Zn concentrations and associated potential effects on the receiving environment are presented in Minnow (2014a) and Chapter 6.1 of the *Faro Mine Interim Works Project Proposal* (CH2M HILL, 2014).

For the Vangorda/Grum Area, water quality source terms are fixed at the following seven locations:

- Shrimp Creek (V4)
- Sheep Pad Ponds (V25 BSP)
- V15 (seasonally collected Grum Waste Dump Runoff and Seepage)
- Grum Waste Dump runoff (uncollected)
- Grum Waste Dump seepage (uncollected)
- Vangorda Waste Dump (runoff and seepage)
- West Fork Vangorda Creek (V5)

The discharge water quality from the Vangorda WTP is also fixed. Vangorda WTP discharge quality used as model input was generated from expected future performance and measured past performance.

Table 7B-5 presents the locations and the period of record used to fix water quality. Figures 7B-2 and 7B-3 present the locations referred to in Table 7B-5**.** Table 7B-6 presents the median and maximum water quality for the Faro Interim Works Treatment System and Vangorda WTP discharges, along with discharges downstream of the WTPs from the CVD Pond at X5 and from Sheep Pad Ponds at V25 BSP.

Runoff and seepage from waste dumps located in catchments other than the X2 and NFRC catchments (Figure 7B-2) either report to an intermediate area where water is collected and routed for treatment (e.g., X23 and GDL Waste Dumps drain to ID Pond and MP Waste Dump drains to Faro Pit), or have gradual geochemical changes that are not expected to cause appreciable increases in contaminant loading during the period of the IW (e.g., GHU to Upper Guardhouse Creek).

The GHU Waste Dump catchment (Figure 7B-2) was assigned a background water quality, specifically seepage water quality was assigned based on background groundwater quality (monitoring well TH86-17). Water from the GHU catchments flows to the receiving environment at X14.

Waste dumps located in the GHL, X23 and MP catchments (Figure 7B-2) have also been assigned a background water quality based on background groundwater quality represented by monitoring well TH86-17. These waste dumps are located at areas internal to the Faro Mine Area, which means that the water from these catchments is collected for treatment prior to being released. Collected water from these waste dumps is accounted for in WTP discharge volumes and loads. This simplifying assumption is considered a reasonable approach that does not impact the predicted water quality for the short duration of the IW. This approach was used since load that by-passes collection is expected to require longer travel time for break-through to the receiving environment than the duration of the IW.

Runoff from all waste dumps is assigned a water quality equal to 10 percent of the seepage water quality. The 10 percent of seepage water quality is a simplified assumption used in the long-term model and based on previous water quality observations

Background surface water quality data was generated from reference stations V1, VR, USFR, R7, FC, R6, and W10 (Figure 7B-1) from 2008 through 2012, with pooled background water quality from these stations applied as background surface water quality input at the same locations represented in the model. Key background water quality parameters (mean, minimum, and standard deviation) used as model inputs are consistent with the background reference conditions determined in the Minnow (2014b) and are presented in Table 7B-7.

Background groundwater quality data is generated from the available data from 2004 through 2012 at monitoring well TH86-17, located upgradient of the RCTA.

3.2.2 Water Quality Monthly Patterns

Monthly water quality patterns were developed because the surface water (and, to a lesser extent, groundwater) at the FMC, exhibits monthly and seasonal water quality variation in response to changes in stream discharge, loads from mined material, and WTP discharge. Monthly concentration patterns were developed using the available data from the period of interest for each source term. The period used to fix water quality for each of the source terms is indicated on Table 7B-5. The period used for each source term is based on operational considerations (e.g., S-Wells began operation in 2009), or data quality considerations. Data quality considerations included data gaps or elevated detection limits in historical data. Where data quality issues affected monthly or annual source term water quality, the selected period relied on more recent data (i.e., since 2008 or 2009). Where the period was focused to more recent data, it was done to provide data more representative of current conditions and provides for more conservative estimates of future water quality. Using the commercial software package Tableau (Version 8.0.5, www.tableausoftware.com), the median monthly concentration for each COC from all years within the selected period of interest was selected from the time-series. Figures 7B-9 to 7B-19 present the monthly pattern for the key water quality parameters at the eleven source term locations.

The water quality monthly pattern for each fixed surface water location is generated from a single site location (e.g., Shrimp Creek input water quality generated from measurement data collected at V4). For surface water locations, the spatial scale at which the hydrology data and water quality data are measured is the same. Source terms used to represent groundwater quality discharge to the receiving environment rely upon multiple monitoring locations (Table 7B-5). Water quality data from the group of monitoring locations is pooled and then a median monthly value is selected from the pooled time-series. Multiple locations are grouped to generate an average water quality value to represent water quality over the broad areas the source term represents in the model. For these locations, the hydrology component is generated based on the catchment area; however, at a different spatial scale over which water quality data is collected.

While grouping the data is intended to provide a representative average water quality over the source term area, the water quality likely overestimates the concentrations over the broad area of interest because the groundwater monitoring wells have been installed to target areas receiving deteriorated water from the waste dumps. They will therefore have bias to identifying areas with the highest concentrations, and applying this over the broad area for which the hydrology component of the model applies. This approach provides a conservative estimation of load from the source area to the receiving environment.

As will be discussed in greater detail in Section 4, there are data limitations to developing a monthly pattern at the source term locations. For months without data or with a minimal sample size, an average value of the median monthly concentration from adjacent months is used instead. Sparse data limits development of monthly patterns for groundwater source terms more than for surface water source terms.

3.2.3 Water Quality Trends

Observed site water quality data through 2012 was used in the development of annual water quality trends. The input water quality time-series, beginning January 2013, was developed based on the annual trend applied to the monthly pattern. The median annual concentration was selected from the compiled time-series for each source term location. The annual concentration is selected to reflect long-term changes in water quality. Using the Tableau software package, a linear regression model is applied to the median annual concentration for all years within the selected period of interest for each time-series. The software package uses an OLS fitting procedure to develop a linear trend line for each key water quality parameter at all 11 source term locations.

This linear trend is projected (beginning in 2013 and extending over the 10-year duration of the IW) to develop the source term water quality input concentration time-series. The projected annual concentration increases are added to the monthly pattern to create an input time-series that includes both a monthly pattern and annual trend. The annual trend is directly applied to the individual months. For example, if there is a 0.025 mg/L annual increase for Zn and the initial January concentration is 0.10 mg/L and February concentration is 0.12, Year 2 January concentration is 0.125 mg/L and February concentration is 0.145 mg/L. If no trend is determined from the historical data, or if the trend indicates decreasing concentrations, the median monthly pattern developed is applied consistently to each year of the source term input water quality time-series. Decreasing trends are not applied to the input water quality time-series. Additional discussion about the inclusion of trends is provided in Section 3.3.4.

Projecting the linear trend into the future relies upon the principal assumptions that recent observed changes in water quality data will represent near-term future water quality changes and that fitting the observed data to a linear trend, as opposed to, for example, a power-series, is representative of field conditions. This ignores potential non-linear changes such as would happen if the attenuation capacity for a specific constituent was exceeded or from changes in response to depletion of neutralizing potential that had previously been buffering geochemical changes. Future water quality changes inconsistent with recent observed trends will not be predicted by this model. Instead, those types of changes will be identified through routine environmental monitoring programs during the IW and managed through the Adaptive Management Plan in response to specific changes identified during monitoring.

Figures 7B-20 to 7B-30 present the annual trend for each COC for all source term locations. Table 7B-8 summarizes the parameters for each source term for which trends are applied based on the observed data.

3.2.4 Seasonal-Kendall Statistical Test

The Tableau software package used to reduce the data and generate model inputs includes limited statistical analyses capability. Following the development of the annual trend using the OLS fitting procedure, a check was made on the statistical significance of the trend direction. The Seasonal–Kendall statistical test (Hirsch et al., 1982) was selected to test whether the apparent trend direction applied to the model water quality inputs was statistically significant. The Seasonal-Kendall test was performed in the statistical analyses software package SAS.

The Seasonal-Kendall test is similar to the more commonly known Mann-Kendall test and was used because it appeared that there are seasonal changes in the data, which can be better accounted for by the Seasonal-Kendall test. The Seasonal-Kendall test ranks each value relative to other values in the sample-set to develop relationships for whether the value is higher or lower; the magnitude of the difference is not considered in whether there is an increasing or decreasing trend. To conduct the Seasonal–Kendall statistical test, the observed data time-series was regrouped from median annual averages to seasonal averages; the three seasons used to group the data are consistent with the three hydrology seasons identified for the FMC (i.e., freshet – May and June, Open Water – July to October, and winter – November to April). Grouping the data on a seasonal basis also provides a more appropriate number of values to conduct the analyses on, as compared to the annual trends considered in

development the water quality model inputs. Table 7B-8 compares the trend direction currently applied to the water quality inputs to the trend direction using a Seasonal-Kendall statistical test.

For all except Co at V15 and Cd at V5, the trends used in the water quality model inputs are more conservative in the trend direction. That is, for trends that are not the same direction, the model input trend is either increasing when the Seasonal–Kendall statistical test indicates that there is no significant trend or there is no model input trend when the Seasonal–Kendall statistical test indicates a significant decreasing trend. For Co at V15 and Cd at V5, the model input has no trend, which contrasts with the Seasonal–Kendall statistical test indicating a significant increasing trend. The model input at V15 represents a collected water source (water conveyed to Vangorda Pit) and does not affect the receiving environment. The increasing trend for Cd at V5 (West Fork Vangorda Creek), would increase the concentration by approximately $2x10^{-6}$ milligrams per litre (mg/L) per year and would therefore not appreciably change the load received at V8.

Based on the data grouping, there were insufficient independent values to calculate the statistical significance of identified trends at X5 (using data from 2011 and 2012 only).

The results of the comparison are consistent with the original approach of relying on increasing trends where observed and on average concentrations in the absence of an apparent increasing trend. Including trends, even if they are not statistically significant, is considered a conservative approach because the modelled key water quality parameters are expected to increase with time. The timing and magnitude of the increases are uncertain; regardless, including a trend, whether statistically significant or not, will add some conservatism to the prediction.

The following paragraphs summarize the comparison presented in Table 7B-8 for each area where water quality is fixed. Locations V15 and LCD are shown on Table 7B-5, however since these represent water quality of collected water conveyed to the Vangorda Pit, they are not described in detail.

RCAA

The Seasonal–Kendall test on the pooled monitoring locations concludes that the key water quality parameters have no statistically significant trend (increasing or decreasing), except for Ca and SO_4. If only the seep at X13 is considered, there is statistically significant increase in all COCs except Pb. The initial OLS approach from the group of monitoring locations (Table 7B-5), which includes increasing trends for Ca, Cd, Co, Mg, SO_4 and Zn, was selected to form the model water input, as this provides a more conservative estimate of mine-influenced water quality from the RCAA, which is expected to continue to degrade over time. The water quality input trends for RCAA match trend directions at X13 (X13 S-K column in Table 7B-8) more closely than for the pooled collection of wells.

S-Wells

The trend direction (no trend) from the two approaches is the same for Pb and SO_4. For the trends developed from the OLS approach, all parameters (except Cd, which is increasing) demonstrated no trend. The Seasonal–Kendall test indicates that the concentrations of Ca, Co, Mg, Mn, and Zn have been following a statistically significant decrease and concentrations of Cd, Pb and SO_4 have no trend. Since 2009, the implementation of the S-Wells collection system continues to have a beneficial effect, reducing loadings. However, it is optimistic to assume that the loads will continue to decrease in the S-Wells area over the duration of the IW. A more conservative approach is to not apply a trend for the parameter concentrations that are indicated to be decreasing, and apply an increasing trend for Cd, as determined from the OLS approach.

NFRC

Consistent with the OLS, the Seasonal–Kendall test demonstrates significantly increasing trends for Ca, Mg, Mn, SO_4, and Zn and no significant trend for Pb. The Seasonal–Kendall test indicates Cd (conservatively included in the model water quality inputs with a constant monthly pattern) is significantly decreasing. The Cd decrease is suspected to be related to absence of data from sampling locations BH2 and BH4 in the Zone II Outwash area over the last couple of years, which apparently has a greater effect on the Seasonal–Kendall test than the OLS. These two locations previously demonstrated the highest Cd concentrations. Co is conservatively included in the model water quality inputs with an increasing trend, rather than applying no trend, as suggested by the Seasonal–Kendall test, as this provides a more conservative prediction of water quality impacts.

V4 (Shrimp Creek)

The Seasonal–Kendall test indicates the increasing trend observed in the SO_4 data is significant, which is consistent with the conclusion reached from the OLS approach. The Seasonal–Kendall test indicates a significant decreasing trend for Cd and Co. Cd and Co are conservatively included in the model water quality inputs with a constant monthly pattern. Based on the OLS approach, the water quality model input for Ca, Mg, Mn, Pb, and Zn includes increasing trends, whereas the Seasonal-Kendall test indicates no statically significant trend.

V25BSP (Below Sheep Pad Pond)

The Seasonal–Kendall test indicates that there is no significant trend in the Ca, Cd and Co data, which is consistent with the conclusion reached from the OLS approach. The Seasonal–Kendall test also indicates no significant trend for Mg, Mn, Pb, SO_4, and Zn; however, these constituents are conservatively included in the model water quality inputs with an increasing trend, based on the OLS approach.

Grum Waste Dump runoff

The Seasonal–Kendall test indicates that there is no significant trend in the Ca, Pb, and Zn data, which is consistent with the conclusion reached from the OLS approach. The Seasonal–Kendall test also indicates no significant trend for Cd, Co, Mg, Mn, and SO_4; however, these constituents are conservatively included in the model water quality inputs with an increasing trend, based on the OLS approach.

Grum Waste Dump seepage

The Seasonal–Kendall test indicates the increasing trend observed in the Co, Mn, Pb, and Zn data is significant, which is consistent with the conclusion reached from the OLS approach. The Seasonal–Kendall test also indicates no significant trend for Cd consistent with the OLS fitting procedure. The Seasonal–Kendall test indicates a significant decreasing trend for Ca, Mg and SO_4; however, these constituents are conservatively included in the model water quality inputs with a constant monthly pattern.

V5 (West Fork Vangorda Creek)

The Seasonal–Kendall test indicates that there is no significant trend in the Co, Mn, Pb, and Zn data, which is consistent with the conclusion reached from the OLS approach. The Seasonal–Kendall test indicates no significant trend for Ca, Mg and SO_4; however, these constituents are conservatively included in the model water quality inputs with an increasing trend, based on the OLS approach.

3.2.5 Water Quality Uncertainty

Because the input water quality source terms are derived from median concentrations, a procedure to incorporate the observed variability was included. The minimum, median, and maximum concentration for each month for all key water quality parameters from the observed data at the source term locations was identified and used in the monthly variability computation. A triangular distribution was developed based on the minimum, median, and maximum concentrations for all key water quality parameters at each source term location.
A minimum +-10 percent variability was assigned to locations, months, and water quality parameters that did not have enough historical data. Figure 7B-31 shows an example of the triangular distribution applied to SO_4 at the S-Wells in January. The figure shows that at the beginning of each stochastic realization, the model samples a value (multiplier on the Abscissa axis) in the triangular distribution, with the highest chance to get 1 (0.36 probability) and no chance to be lower than 0.038 or higher than 5.52. The value sampled is then used as the multiplier of the SO_4 January median concentration that was fixed for the S-wells location. The maximum and minimum values (0.038 and 5.52) show that, historically, SO_4 concentrations in January reached a maximum concentration of 5.52 times the median and a minimum concentration of 0.038 times the median.

For each fixed water quality location, as well as for each month of the year and each water quality parameter, a triangular distribution was created.. As described in Section 5, the model runs for 200 realizations during each time step, and for each realization, a new concentration is selected based on the triangular distribution.

SECTION 4

Input Data

There are two meteorological stations installed at the FMC: one on the top of a waste dump within the Faro Mine Area and one on the top of a waste dump within the Vangorda/Grum Area. These meteorological stations were installed in December 2003; site recorded data is available for a significantly shorter period than from the Faro Airport meteorological station. In addition, according to the *Hydrology Baseline Report, Faro Mine Interim Works* (CH2M HILL, 2014c), the FMC meteorological stations have large data gaps in the precipitation record for 2008 and since 2009. Monthly precipitation data from the Faro Airport Station is the only long-term reliable source available that is close to the mine site. Data from this station is available from 1978 to 2011, and is presented in Table 7B-9.

Flow data used to help calibrate the hydrological portion of the model is available for Faro Creek Diversion, Rose Creek (at stations X2, X10, and X14) and CVD Pond discharge (X5). For the Vangorda/Grum Area, flow data is available for V1, V2, V4, V27, V8, and the Grum Creek Weir. In addition, water transfers are documented from the following locations:

- Faro Pit to the Faro WTP
- ID Pond to the Faro WTP
- Vangorda Pit to the Vangorda/Grum WTP
- Grum Pit to Vangorda Pit
- V15 to Vangorda Pit
- Little Creek Dam Pond to Vangorda Pit
- Discharge from the Sheep Pad Ponds (V25 BSP)

Of these stations, X2, X14, Grum Creek Weir, V1, and V8 have continuous stream flow monitoring gauges installed; however, the X2 continuous flow record is limited to 2011. Data for stations V2, V4, V27, X10, and X5 rely on spot flow measurements. Spot flow measurements are generally collected monthly, although there are gaps in the data record (Figure 7B-32). Locations with continuous stream flow monitoring gauges have a more complete flow record than locations where only spot flow measurements are collected (Figure 7B-32).

Water quality inputs are generated from available data stored in the EQuIS database, maintained as the central data repository for the FMRP. It is necessary to note that, although many efforts have been undertaken to ensure data quality, challenges are presented in the historical data because samples have been collected by different contractors using different sample collection methods and with sample analyses completed by different analytical laboratories. Further, over the period of interest, analyses methods have changed along with detection limits. Additional steps taken to improve the reliability of water quality prediction based on the data availability include reliance on more recent data, selection of median concentrations when averaging to remove the effect of outliers and high detection limits, and the accounting of uncertainty based on the range of historical data to capture the variability in the model water quality predictions.

Data from about 70 monitoring locations (representing 16,477 data points) were relied upon to inform the source term location water quality. Despite the volume of data, there is limited information for some specific areas of the FMC and for specific periods. For locations with no water quality data from specific months, an average concentration was generated from available data in the preceding and subsequent months. For locations with limited water quality data from seasons, typically winter, an average concentration was generated for the entire season based on the available data.

Total metals concentrations are used as input, though groundwater and seeps rely on dissolved metals concentrations. Constituents reported as less than the detection limit were kept in the water quality time-series to inform source term concentrations using half the detection limit value.

Background surface water quality data and analyses used in the model for V1, VR, USFR, R7, FC, R6, and W10 are consistent with the background water quality reported in Minnow (2014b). Variability in background surface water quality is accounted for by including a truncated normal distribution element within the model to generate

background water quality within the range observed at the site during the stochastic simulations. The truncated normal distribution limits the distribution about the mean from producing negative concentrations.

Average concentrations from monitoring well TH86-17 between 2004 and 2012 were used to generate background groundwater input concentrations. This water quality dataset was applied as input data for waste dumps not expected to affect the receiving environment during the IW or those that drain to internal water management systems for collection and treatment, as described in Section 5.

Figure 7B-33 provides a simplified plot of the data availability for all locations used as source term model input. The plot presents the sampling event frequency for each source term location. For source terms that pooled data from more than one location (e.g., S-Wells bypass), the plot indicates a sampling event occurred, regardless of the number of pooled locations sampled.

The groundwater monitoring wells used to inform source term water quality inputs are generally sampled seasonally in the spring and fall (Figure 7B-33). Where no or limited data were available, an average concentration was used based on available data, as follows:

- For the NFRC, observed data were not available from the selection of wells for December through April; therefore, average concentrations from September to November were used to develop the input time-series for these winter months. There were also no data available for July at the NFRC, so the input time-series was created from the average of June and August data.
- For the S-Wells, observed data were not available from the selection of wells for October or from December through April; therefore, average concentrations from September and November were used to develop the input time-series for these winter months. There was only one observation available for the S-Wells for August, so the input time-series was created from the average of concentrations from June, July, and September.
- For RCAA, observed concentrations were available for all months, but there are limited data from a small number of locations over the winter, so average concentrations were used for October through April. In addition, August input concentrations were created from the average of June, July, and September data.
- For the water quality parameters fixed based on recent historical X5 concentrations (Ca, Co, Mg, Mn, and SO_4), no data were available from January, February, and October; therefore an interpolated concentration based on the concentration from the month prior, and month following, the missing month was used to develop the water quality input time-series.
- For LCD input water quality, observed concentrations were not available for November through April, so average concentrations from September and October were used to develop the input time-series for these winter months.

Inconsistent data-sets also presented a data gap. For the NFRC source term, data have not been available since 2006 for the following locations included in the grouping of wells used to develop the input time-series: BH1, BH2, BH4, BH12A, BH12B, and BH13A. Data was only available from one sampling event in 2006 for BH7B. The input water quality time-series for Grum Waste Dump seepage predominantly relies upon data from Moose Seep, as no data have been available for Moose Well since 2009. Similarly, the input water quality time-series for Grum Waste Dump runoff predominantly relies upon data from V2, as available data from Sheep Creek were limited to a total of four observations in 2010 and 2011.

SECTION 5

Model Assumptions

As described in Section 3, the model estimates flows at the FMC as a function of annual HEP and annual precipitation change from an average value. This approach assumes a direct linear correlation between precipitation and HEP values. This is a simplistic approach, yet reasonable given the availability of site data.

Monthly precipitation data from the Faro Airport Station is the only long-term reliable source available. Data from this station are available from 1978 to 2011, and are presented in Table 7B-9. Missing data were filled with the monthly average values. The model assumes that there is an adjustment between the Faro Airport precipitation and the FMC. The adjustment is a function of elevation; AECOM (2009) reported precipitation at the FMC between 7 and 10 percent higher than that occurring at the Faro Airport Station. An FMC precipitation factor that is used to increase the precipitation rates recorded at the Faro Airport Station can be defined in the model by the user. The default FMC precipitation factor is set at a 20 percent increase, based on more recent estimates (CH2M HILL, 2013b). In addition, Vangorda/Grum precipitation is 3.3 percent higher than the Faro Mine area.

When running the model in a stochastic mode, an index sequential methodology is used to loop the 35 years of historical monthly precipitation data. Under stochastic mode, the model will randomly select a year between 1978 and 2011 as the start of the hydrological sequence for each stochastic run (called realization). If the number of years the model is running exceeds the 34 years of hydrology, the model loops back from 2011 to 1978. This methodology incorporates historical precipitation variability to the model, and makes use of the entire available precipitation sequence between 1978 and 2011. The current model runs 200 stochastic realizations.

All the pits and ponds in the system have an elevation-capacity curve that defines the pit volume at a given elevation. The elevation–capacity curve defines the incremental change in elevation for a given change in the volume of the pits, and vice-versa. The model was calibrated with the best currently available elevation –capacity curves, presented on Table 7B-10.

The water quality projections assume that the current site conditions will remain the same and recent trends will continue linearly for the next 10 years. Any major deviation on trends will be addressed by the Adaptive Management Plan. The model assumes mass is conserved for all constituents and no attenuation of load is considered downstream of where loads are being fixed (i.e., there is no reactive mixing included in the model). It is assumed that the past measured concentration monthly patterns will remain the same in the near-term, and the past monthly variability observed around the median are applied for the next 10 years, as described in Section 3.3.3.

The locations chosen to fix water quality are those currently impacting water quality in the receiving environment or expected to over the next 10 years. As described in Section 3.2.1, background groundwater quality, based on TH86-17 concentrations, is used to represent drainage quality from the waste dumps in catchments GHL, GHU, X23 and MP which are not expected to contribute significant load to the receiving environment during the IW. Drainage from these waste dumps is assumed to have water quality similar to background because either the seepage is collected for treatment (and therefore accounted by the WTP discharge) or travel time for the load to reach the receiving environment is greater than the duration of the IW. Undisturbed catchments are assigned with background water quality (see Section 3.3.1).

The seepage and runoff from waste dumps that are not directly connected to the receiving environment are either being collected (by draining into collections systems or pits and ponds) or are being discharged to the RCTA. Concentrations in the discharge from the RCTA are fixed based on a selection of wells downgradient of CVD Pond as presented on Table 7B-5.

The most downstream location considered in the model is the Pelly River downstream of Anvil Creek and Vangorda Creek. Flow in the Pelly River upstream of the confluence with Vangorda Creek averages 192,900 litres per second [L/s]. Intermediate flows (average 830 L/s) join the system between Pelly/Vangorda and Pelly/Anvil confluences. Both upstream Pelly River and intermediate Pelly River flows are estimated from monthly records. The model does not scale these flows for change in precipitation.

Sections 5.1 and 5.2 describe the assumptions particular to the Faro Mine Area and Vangorda/Grum Area, respectively. The description is from upstream to downstream, and includes how the flows are being generated (HEP values, areas, and monthly patterns) and where the inputs are inserted in the model. The description also includes where the water quality is being fixed and the waste dumps upstream of those locations.

5.1 Faro Mine Area Assumptions

The assumptions for the Faro Mine Area are described from upstream (Upper Faro Creek catchment) to downstream (Pelly River). The description includes the origin of the flows, an approximate flow value, the monthly pattern used to convert flows from annual to monthly average flows, and the water quality assigned to the flows. Water flows generated in the model are based on the precipitation received over the individual catchment area. Stream flow, seepage or pumped volumes which are assumed, rather than determined in the model were generated from past studies, site operations or review of available data. Locations with assumed flow volumes are described below and additional discussion on the data availability was provided in Section 4. The catchments and locations mentioned in the assumptions were previously presented on Figure 7B-2; Figure 7B-34 is a simplified schematic containing only the components relevant to this modelling effort. The flows reported here and on Figure 7B-34 are the averages of a stochastic simulation and the result of Equations 1, 2 and 3 previously presented, and consider an annual average precipitation of 370 mm.

5.1.1 Upper Faro Creek to R7

Starting at the Faro Creek Diversion, at the North-end of the system, flows in the Faro Creek Diversion originate in the Upper Faro Creek catchment and are estimated to be on average 177 L/s. Equation 1 can be used to compute the flow with an Upper Faro Creek catchment area of 15.3 square kilometres (km^2), 352 mm of HEP for that catchment and 1.0367 (an annual precipitation value of 370 mm is used for the flow estimates presented below, which is 1.0367 of the average precipitation) as the coefficient to scale HEP.. The annual precipitation varies through the simulation and stochastic run. The Faro Surface monthly flow pattern is applied to the volume at this location to convert it to monthly volumes or average monthly flows. The water quality assumed for Faro Creek Diversion is surface water background.

A portion of the flows from the Upper Faro Creek catchment seep to the Faro Pit. It is estimated that the seepage from Faro Creek Diversion into the Faro Pit is 26 percent of the Faro Creek Diversion flow, or 46 L/s. The current 26 percent value is a result of past water balance calculations (RGC, 1996) and currently used as a calibration parameter, as this value is an estimate. The Faro Creek Diversion Seepage monthly pattern is applied to the volume at this location to convert it to monthly volumes or average monthly flows.

Flows from the Faro Creek Diversion join flows from R7, or NFRC (monitoring location R7). Flows from R7 are calculated following the same assumptions described for Faro Creek Diversion, with a catchment area of 103.5 km^2 and the HEP for that catchment is 325 mm, yielding an average flow of 1,109 L/s. The Faro Surface monthly flow pattern is applied to convert the annual volume into monthly volume based on historical distribution from the R7 location described in Section 3.2.3. The water quality assumed for R7 is surface water background, described in Section 4.

5.1.2 R7 to X2

The first flow contribution from waste dumps and the first location where concentrations are fixed is downstream of the R7 and Faro Creek Diversion junction and upstream of NF1. Portions of the NEU, NEL ZIIE, OHRE, and ID Waste Dumps contribute to the concentrations fixed at this location. The average flow from these waste dumps is 3.4 L/s (seepage plus runoff). A selection of wells and seeps at the base of these waste dump are used to represent the water quality entering NFRC upstream of Haul Road (see NFRC Zone II and NE Waste Dump in Table 7B-5).

S-Wells seepage and runoff that bypasses the collections system enters NFRC between NF1 and X2. Portions of the RD, RZD, MDE, ID, IDSC, OHRW, and OHRE Waste Dumps drain to the S-wells. The average contributing flows to the S-Wells are estimated to be approximately 5.31 L/s, with 4.2 L/s being seepage. The model assumes that the S-Wells collection system has an efficiency between 40 and 80 percent that varies stochastically for each

simulation run. The flows that are not collected (seepage and runoff) end up in the receiving environment, at an average of 2.8 L/s. The water quality from those waste dumps is represented by the average water quality of a selection of wells around the perimeter of the S-Wells collection system, to represent the water quality of water that bypasses the S-Well collection system.

5.1.3 X2 to X14

Between X2 and X3A, the system receives 758 L/s from Upper SFRC (74.25 km^2 and 342 mm of HEP minus 75 L/s considered to be groundwater that enters the RCAA), and 1.6 L/s from runoff originating on undisturbed areas of the RCV catchment. It is believed that water quality from waste dumps in the RCV catchment (MDE and OHRW) will not reach the discharging environment for the next 10 years; therefore, flows from these waste dumps are replaced with undisturbed catchment flows. This is also the reason why the percentage of each waste dump in each catchment does not add to 100 percent for OHRW and MDE on Table 7B-1, the table does not show the percentage of WRD in undisturbed areas. It is believed that RCAA inflows originate in the Upper SFRC, so 75 L/s are subtracted from the Upper SFRC flows and added to the RCAA.

Between X3A and X10 the system receives 174 L/s from SFRC (18 km^2 with 292 mm of HEP)It is also assumed that approximately 205 L/s leave the Rose Creek diversion and enter the ID Pond and CVD Pond in the RCTA. It is believed that 205 L/s leaving RCD into RCTA is overestimated, but only a limited amount of data are available in this area.

Parallel to the Rose Creek Diversion between X3A and X10, the Rose Creek Tailings Area (RCTA) and RCAA drain to the ID Pond and CVD Pond. Inflows to this area comprise 205 L/s from the Rose Creek Diversion, 75 L/s from the Upper SFRC, and 33 L/s from local seepage and runoff, uncollected waste dump seepage, and X23 runoff. The water quality for the Rose Creek Diversion flows are a mix of the different water qualities upstream of X3A. The water quality for the 75 L/s from the Upper SFRC is fixed to the water quality measured from a selection of wells downgradient of the CVD. The water quality from uncollected seepage and runoff is fixed to background from TH86-17 (described in Section 4). The assumption behind the water quality fixes is that the concentrations at X23 or from uncollected waste dumps are not currently showing up at X14 and are not expected to reach X14 in the next 10 years. The CVD Pond receives an annual average of 48 L/s from seepage and 88 L/s from the Faro WTP. The CVD Pond seepage was estimated mainly through pond elevation data during the winter season when there were no discharges or other inflows going to the pond.

The WTP effluent is discharged at the CVD Pond. The model assumes that the maximum WTP capacity will be 378 L/s (6,000 United States gallons per minute [USgpm]) for the next 10 years and the treatment season is assumed to be 5 months, from May to the end of September. Flows from the Faro Pit will be sent to the IWTS to keep the Faro Pit at an elevation target of 1,141 m at the end of the treatment season. The CVD Pond will discharge to X5 to keep elevation below a target of 1,027.9 m at the end of the treatment season and no more than 1,029 m at any time. The CVD Pond discharges to X5 are limited by a maximum siphon capacity of 630 L/s (10,000 USgpm), and the X5 average annual flow is 137 L/s. The water quality at the CVD Pond is a mix of WTP effluent water quality and the mixed water quality entering the RCTA area. However, water quality discharged from the CVD Pond via X5 was fixed based on past performance of the CVD Pond for Ca, Cd, Co, Mg, Mn, and SO_4. This was a conservative approach taking into account the uncertainty related to future water quality entering the CVD Pond from seepage and WTP effluent discharges. Pb and Zn were fixed based on expected future Faro WTP performance and therefore limit discharge concentrations below a maximum of 0.05 and 0.5, respectively for the Faro WTP and below 0.0002 and 0.5, respectively for the Vangorda WTP. Results of an earlier model calibration used fixed WTP quality only, and mixing in the CVD Pond resulted in a poor fit with measured loads for the constituents being represented by the CVD Pond discharge water quality.

The Upper Guardhouse annual average flow is estimated at 1.6 L/s and contributes to the X14 flows. Water quality for Upper Guardhouse Waste Dump is fixed at background.

The next downstream flow location is X14, which receives discharges from X5, flows from X10, RCAA, and Upper Guardhouse Creek. The current model estimates that X14 receives a total of 2,400 L/s on average. Water quality is not fixed and it is a mix of the upstream loads.

5.1.4 Downstream X14

Between X14 and R4 the system receives 882 L/s of natural flows (105 km^2 and 255 mm of HEP). The monthly flow pattern used for these flows was the Rose Creek R4. Water quality is not fixed and it is a mix of the upstream loads.

Between R4 and A1 the system receives 5,629 L/s (643 km^2 and 267mm of HEP). Rose Creek joins the Anvil Creek between these two monitoring locations. The estimated annual volume from HEP was converted into monthly flows with the Rose Creek monthly flow pattern in absence of better data. Anvil Creek then joins the Pelly River.

5.2 Vangorda/Grum Area Assumptions

The assumptions for the Vangorda/Grum Area will be described from upstream (V1) to the most downstream location (V8). The description includes the origin of the flows, an approximate flow value (provided as an annual average), the monthly flow pattern used to convert flows from annual to monthly average flows, and the water quality assigned to the flows. Water flows generated in the model are based on the precipitation received over the individual catchment area. Stream flow, seepage or pumped volumes which are assumed, rather than determined in the model were generated from past studies, site operations or review of available data. Locations with assumed flow volumes are described below and additional discussion on the data availability was provided in Section 4. The catchments and locations mentioned in the assumptions below were previously presented on Figure 7B-3. Figure 7B-35 is a simplified schematic containing only the components relevant to this modelling effort. The flows reported in the following subsections and on Figure 7B-35 are the averages of a stochastic simulation and the result of Equations 1, 2, and 3 previously presented and consider an annual average precipitation of 361 mm.

5.2.1 From V1 to V27

The main flows in the Vangorda /Grum Mine Area come from Vangorda Creek, at V1. The system receives 232 L/s of natural flows (20 km^2 and 374 mm of HEP). The Vangorda Surface monthly flow pattern is applied to the volume at this location to convert it to monthly volumes or average monthly flows. It is assumed that 8.1 L/s or 3.5 percent of the V1 flows seep into Vangorda Pit. The 3.5 percent value was obtained from the model calibration and is close to a previous value estimated to be 4 percent (Bryan, 2012).

Between V1 and the next flow monitoring location V27, there are five other flow contributions: discharges from V25BSP, seepage from Moose Pond, V2 runoff and seepage flows, Grum Overburden Dump flows, and residual undisturbed area flows. The assumption in the model, based on design and current performance of the Vangorda waste dump, is that all the Vangorda waste dump drainage is collected and sent to the Vangorda pit. Water quality is fixed to measured values and trends for inflows to V25BSP (except WTP inflows), Moose Pond inflows (or V15), Moose Pond seepage, and V2. The surface water background concentrations are used for V1 and residual areas.

- **V25BSP, outflow from** Sheep Pad Ponds (SPP) is not modelled as a storage pit, and it is assumed that monthly inflows equal monthly outflows. The pond discharges an average of 47 L/s to Vangorda Creek. The SPP receives Vangorda WTP effluents and flows from the Grum Interceptor Ditch and Grum Overburden catchment. It is assumed that the Grum Interceptor diverts 90 percent of the flows to V25BSP, and the remaining 10 percent flows to the Grum Pit. It is assumed that 73 percent of the Grum Overburden catchment goes to the V25BSP pond and the remaining 27 percent flows to the Grum Pit. The model assumes that the Vangorda WTP has a 2,000 USgpm (126.18 L/s) capacity and will be operating from June through August. Flows are sent from Vangorda Pit to the WTP to keep the Vangorda Pit water surface elevation below 1,083 m at the end of the treatment season.
- The **G3 Overburden** Waste Dump is within the Grum Overburden catchment and it drains straight to V27 with an average flow rate of 2.6 L/s. The overburden material is assumed to contain low leachable concentrations of the key water quality parameters considered and therefore the water quality is fixed to background water quality from TH86-17.

- **Moose Pond** receives inflows from Grum dumps (G1B, G2 and G3O) via Grum Creek and V15. It is assumed that 35 percent of the seepage from G1B, G2 is flows to Moose Pond. The remaining 65 percent drains to V2. It is also assumed that 70 percent of the runoff from G1B, G2, and G3O goes to V15, then to Moose Pond, and the remaining 30 percent flows to V2. Seepage from G3O (2.6 L/s) flows to V27. Moose Pond receives flows from V15. The flows exceeding natural flows to the pond are pumped to Vangorda Pit. Natural monthly flows to Moose Pond were calculated from an estimated catchment area of 0.41 km^2 and 202 mm of HEP. The monthly flow pattern applied was similar to the Vangorda Waste Dump seepage monthly flow pattern with the freshet peak flows in May attenuated and shifted to the following months (July through October). The result of these assumptions yield an average flow pumped from V15 to Vangorda Pit to be 0.75 L/s, with maximum monthly average value at 9 L/s.

  It is assumed that the 2.5 L/s of seepage flows from Moose Pond to Vangorda Creek. It was verified, using measured concentrations, that there is attenuation of some metals, including zinc, from Moose Pond to Vangorda Creek, which is the reason why seepage water quality from Moose Pond was fixed. The water quality from Moose Pond seepage is different than the water quality fixed at the pond, and was fixed based on actual pond seepage water quality data.

- **V2** flows join Vangorda Creek with an average of 4.5 L/s. The V2 location receives 30 percent of the runoff flows from G1B plus G2, and 65 percent of the seepage flows from G1B and G2 Waste Dumps. It is believed that there is some attenuation of concentrations at that location because upstream waste dump concentrations are not currently being observed at V2. Based on this information, the water quality at V2 is fixed based on observed concentrations from V2 and Sheep Creek (see Table 7B-5).

- **Undisturbed areas** are estimated to contribute an extra 17.9 L/s to the Vangorda Creek. The concentrations for these flows are fixed to surface water background.

There are other assumptions on the Vangorda/Grum Area that impact the amount of flow being discharged to Vangorda Creek but do not directly impact the water quality at the stream. Other assumptions impact flows to the Grum or Vangorda pits, or flows being treated at the Vangorda WTP.

The G1-S Waste Dump (i.e., Grum Sulphide Cell) is considered to be covered from the beginning of the simulation; its flows are collected in the lined pond at the toe of the waste dump and sent to Vangorda Pit. The Vangorda Pit receives seepage flows from the Vangorda Creek Diversion (8.4 L/s), local drainage (3.5 L/s), pumped flows from the LCD pond (3.4 L/s), pumped flows from V15 (0.76 L/s),and flows from Grum pit (14.6L/s). Although the water quality in Vangorda Pit is not fixed, the Vangorda WTP effluent is. Flows from the Vangorda Pit are pumped to the Vangorda WTP from June through August at a maximum pumping rate of 2,000 USgpm to keep the Vangorda Pit at a target elevation of 1,083 m at the end of the treatment season.

The Vangorda Waste Dump was constructed on an extensive native till layer with a seepage collection system around the perimeter of the dump to limit seepage/run-off migration to the receiving environment (RGC, 1996). There are limited groundwater monitoring wells downgradient of the Vangorda Waste Dump, however concentrations of the groundwater underlying the Vangorda Waste Dump show signs of moderately-elevated mine impacts (RGC, 2013). Over the duration of the IW it is not anticipated that impacts from the Vangorda Waste Dump will reach Vangorda Creek based on the performance of the containment facility and due to the expected attenuation capacity between the waste dump and Vangorda Creek. The LCD pond is assumed to receive all flows from the Vangorda Waste Dump, seepage and runoff. The model assumption is that LCD flows will be pumped as soon as possible once they reach the pond.

The Grum Pit receives flows from residual areas draining to the pit (7.9 L/s), flows from seepage (3.7 L/s), uncollected flows from the Grum Overburden Dump (27 percent of the Grum overburden or 2.1 L/s), and an assumed 10 percent of the flows collected at the Grum interceptor (1.4 L/s). Flows from the Grum Pit are pumped to the Vangorda Pit at a maximum rate of 1,800 USgpm from May through September, assuming that the target pit elevation at the end of the season is 1,213.4 m. The water quality for the Grum Pit is not relevant to this study as seepage, if any, is assumed to provide an insignificant load to the receiving environment.

5.2.2 From V27 to V8

Downstream of V27, the system receives contributions from undisturbed areas between V27 and V8, Shrimp Creek flows, and V5 flows. Shrimp Creek contributes approximately 81 L/s (13.6 km^2 and 182.2 mm of HEP)) to the V8 flows. V5 contributes approximately 192 L/s to V8 (32 km^2 and 182.2 mm of HEP, plus any other leaks from Grum Waste Dump). Undisturbed areas of the V8 catchment contribute 68 L/s to the V8 location. The Vangorda Creek monthly flow pattern is applied to Shrimp Creek, V5, and undisturbed area flows, to convert them to monthly volumes or average monthly flows. The V8 location (approximately 640 L/s) discharges into the Pelly River upstream of the Pelly/Anvil confluence.

SECTION 6

Calibration

This section describes the differences between the calibration and the predictive model, and presents the comparison between model results and measured data. The section is divided into Flow and Water Quality subsections, which provide a more detailed explanation about what model variables were adjusted and fixed.

Continuous flow and water quality measurements are not available for the site; most of the flow and water quality data are temporally scattered, as presented in Section 4, and most of the locations have had less than 100 measured flow records since 2006. This amount of data does not support a robust model calibration. Therefore, flow data were generally used to identify if modelled results had the right magnitude and monthly pattern. The best historical data available are for water elevations in pits and ponds; therefore, the model calibration process is based mainly on these elevations. The calibration focused on the period between January 2006 and December 2012, because it is a period where pit elevations and some flow data were available.

The assumptions for model calibration are different from the assumptions used for the predictive model. Given the data gaps on measured flow and water quality data, the calibration goal was to make sure all major flows were taken into account and the order of magnitude and seasonal patterns were reasonably close to measured values and differences could be explained.

The calibration assumes that the model starts in January 2006 and runs until December 2011. The annual precipitation for those years is available and was used in this model version.

Flows from pumps with known discharge rates used for seepage collection and water conveyance were fixed in the model. The pump flows fixed were the Emergency Tailings Area to Faro WTP, S-Wells, Zone II, LCD and Vangorda Pit outflows. The Faro Pit outflows were not fixed because of data gaps, but the assumption was that the maximum capacity of the WTP was 5,000 USgpm and the pit was lowered to an elevation of 1,141 m at the end of the treatment season. The treatment season was set to be from May through September. The ID Pond and CVD Pond were set to follow an elevation rule curve based on average monthly historical pit elevations, meaning that releases from those ponds would happen only if the storage was above the rule curve elevation for a given month.

The following subsections show the model versus measured data comparison for flows, storage elevations, and water quality, and describe which parameters were adjusted.

6.1 Flow and Storage Comparison

Figure 7B-36 presents a comparison of the model results versus the measured elevation at all the storage locations modelled in the system. Figure 7B-37 presents a comparison of the model results versus measured flows at key locations at the Faro Mine Area. Figure 7B-38 presents a comparison of the model results versus measured flows at key locations at the Vangorda/Grum Area. It is noteworthy to mention that the measured flows are instantaneous measurements and the model results are monthly averages. The monthly averages do not show daily peak flows recorded at the site but instead average those peak flows throughout the month.

6.1.1 CVD Pond

Figure 7B-36a shows the CVD Pond model versus measured elevation comparison. There weren't enough flow data measurements to fix inflows or outflows to the pond. The assumption is that the pond will receive flows from the WTP (which were not fixed to measured values) and an average of 48 L/s of seepage from the Rose Creek Diversion. Releases from CVD Pond happen when elevation at the pond is above a set monthly target, developed from average historical operations. Figure 7B-36a shows that the model results are within the range of measured values and that some historical operations brought the pond to elevations close to 1027 m. The parameter calibrated for the CVD Pond was the seepage from Rose Creek Diversion. Outside the treatment season, the pond does not receive any inflow except runoff and seepage. Measured elevation data, however, indicate that the pond elevation rises outside of the treatment season (winter). The winter seepage inflows were estimated based on pond elevation-capacity curves and historical change in elevation. Occasional flow discharges from the CVD Pond were measured and are presented on Figure 7B-37a, which shows that modelled discharges are in the order of

magnitude of measured flows and are also matching the seasonal discharge. Additional flow measurement at X5 and WTP effluent discharges could result in a more accurate estimate of the seepage flow from the Rose Creek diversion to the CVD Pond.

6.1.2 ID Pond

Figure 7B-36b shows the ID Pond model versus measured elevation comparison. Pumping out of the pond was not fixed: pump-out of the pond to the WTP happens when elevation at the pond is above a set monthly target and when the WTP is operational. The monthly target elevation was developed from average historical operations. Figure 7B-37c shows a reasonable comparison between modelled and measured pumping out of the pond to the WTP (Intermediate Pond to Faro Mill), with model flows in the same order of magnitude of measured flows. Three measured data points show significantly higher pumping rates, which could be daily peak in pumping operations that is not reflected in the averaged model flows. The inflows to the ID Pond are Emergency Tailings Area- seepage (fixed to measured flows), Lower Guardhouse seepage and runoff, RCTA area runoff, and seepage from the Rose Creek diversion. The calibration parameter adjusted for the ID Pond was the seepage entering the pond, currently estimated to be 21.9 L/s. A more consistent time-series record of pond outflow (pumping to WTP) and Faro WTP total inflows is needed for a more accurate estimate of pond inflows. Figure 7B-36b shows that the assumptions above result in a reasonable comparison of pond elevation between model and measured observations except for an increase in pumping in 2010 and 2011 that brought the ID Pond to lower levels than what is allowed by the model rule curve.

6.1.3 Faro Pit

Figure 7B-36c shows the Faro Pit model versus measured elevation comparison. Water is pumped out of the pit to the WTP when water elevation is above a set monthly target developed from average historical operations, generally intended to have the pit elevation near 1,141 m at the end of the treatment season. The inflows to the pit were fixed to measured flows from the Zone II pumping well and the S-wells collection system. Other inflows to the pit that were not fixed include local seepage and runoff and seepage inflows from the Faro Creek Diversion. The calibration parameter used for the Faro Pit was seepage from the Faro Creek Diversion, estimated to be 26 percent (46 L/s) of the Faro Creek diversion flows. The Faro Pit outflow (Faro Pit to WTP) was not fixed; however, Figure 7B-37b shows a reasonable match of modelled versus available measured flows from the Faro Pit to the WTP. The correlation coefficient between modelled and measured data points is 0.69. A more consistent Faro Pit outflow dataset and total inflows to the WTP would be necessary to refine the current Faro Creek seepage coefficient.

6.1.4 X14 to R4

Originally, the flows entering the system between X14 and R4 were estimated as 849 L/s of natural flows (105 km^2 and 255 mm of HEP) with a monthly flow pattern based on Rose Creek flows. Measured water quality data from X14 and R4 indicate that there was an average 51 percent reduction in SO_4 concentration from January through April, and an average 22 percent reduction from May through December. Model results that used the Rose Creek monthly flow pattern for the undisturbed flows between X14 and R4 indicated an average SO_4 concentration reduction of only 20 percent from January through April and 25 percent from May through December. An adjustment in the shape of the monthly flow pattern resulted in a better comparison of concentration reduction from X14 to R4. The modified monthly flow pattern had the May peak attenuated and more baseflow during the winter, as is expected from an undisturbed catchment (pattern Rose Creek R4 on Table 7B-4). The adjusted final model presents a SO_4 concentration reduction between X14 and R4 of 56 percent from January through April and 25 percent from May through December).

6.1.5 Other Flows compared in the Faro Mine Area

Other Faro Mine Area locations that had measured flows include the monitoring stations at X2, X10 and X14. The comparison between model results and measured flows are presented in Figures 7B-37d, 7B-37e, and 7B-37f. The flows at X2, X10 and X14 are 1 to 2 orders of magnitude higher than the collected seepage, aquifer seepage, inflows to the ponds, and overall system pumping. This order of magnitude difference, plus the scattered nature of the flow data collected, make the model calibration challenging. The comparison presented on the figures show that model results are generally at the same order of magnitude and with the same monthly flow pattern (peak

flows in May). The comparison of model results versus measured data at those locations does not justify a calibration of system inflows or different routing of flows.

6.1.6 Grum

The Grum Pit is assumed to be a closed system and no water is pumped out of the pit during the calibration time window; pumping water from Grum Pit to Vangorda Pit began in 2013. Flows to the Grum Pit include local runoff and seepage for the catchment draining to the pit, and for some fraction of what is not diverted at the Grum interceptor ditch and a fraction of the flows from the overburden. The current fractions of the seepage that bypasses the Grum Interceptor Ditch and the Grum Overburden Dump were used as calibration coefficients. In addition, the seepage that reached the Grum Pit was not originally included, and it is estimated to be close to 60 USgpm (Bryan, 2012). The Vangorda Waste Dump seep monthly distribution is applied to an annual seepage volume, which is also scaled up and down as a function of the precipitation. The annual seepage value is a calibration parameter.

Figure 7B-36d shows that although the overall elevation of the pit follows the measured elevation, the monthly flow pattern has some differences; the model inflows are greater during the freshet period, then lower during the winter when compared with the measured elevation data.

6.1.7 Vangorda

The Vangorda Pit had enough outflow measured data that could be used in the model. By fixing the volume of water pumped out of the pit to historical values and comparing measured versus model elevation, the inflow assumptions were determined to be close to observed inflows. Figure 7B-36e shows that model versus measured elevations compare well except for the second half of 2012. The increase in the water surface elevation after the second half of 2012 is due to the lack of historical pumping flows, the model assumes zero when in reality there was some pumping on the 2012 treatment season. The calibration parameter used for the Vangorda Pit was the seepage fraction from the Vangorda Diversion. The coefficient was set to be 3.5 percent; previous water balance calculations estimate the seepage to be around 4 percent of the Vangorda Creek flows (Bryan, 2012). The Vangorda Waste Dump runoff collection efficiency was set to 70 percent and the Vangorda Waste Dump seepage collection efficiency was set to 50 percent.

6.1.8 Little Creek Dam

The Little Creek Dam water quality does not impact the outcome of this study. It is assumed that LCD is pumped to Vangorda Pit then to the WTP before being discharged into V25BSP and eventually into the Vangorda Creek. The LCD will impact only the inflows to the Vangorda Pit and inflows to the Vangorda WTP. Some outflow data from LCD are available, however more reliable data are found from the water elevation of the pit. The LCD outflows were fixed so that the inflows could be calibrated. LCD receives seepage and runoff from the Vangorda Waste Dump mainly through the collection trench on the toe of the Vangorda dumps. The calibration adjusted the efficiency of the trench to collect runoff and seepage, and also the monthly flow pattern. Figure 7B-36f shows that the first 2 years of the simulation have a good correlation with the measured elevation. After 2008, elevation data are more scattered and outflow data might not be accurately being converted from daily to monthly flows, which might explain the significant difference between model and measured elevation values after the 2 first years of the simulation.

6.1.9 Other Flows compared in the Vangorda/Grum Area

Figure 7B-38 shows the model versus measured flow comparison at six locations in the Vangorda/Grum Area. Although Figure 7B-38 shows that the measured flow data are limited, the magnitude and monthly flow pattern modelled generally match the measured records. Flows from V15+GC include all the flows upstream of V15 and the flows captured by the lined pond at the base of the Grum Sulphide Cell. Measured data (Figure 7B-38a) show flow peaks not seen in the model results, this could be daily peak readings that are averaged in the model results. Figure 7B-38b shows the outflows from the V25 BSP pond. Flows could be calibrated at that location by adjusting the flows from the Grum Overburden Dump and Grum Interceptor Ditch, but a more complete flow dataset would be needed. The flows from V4 (Shrimp creek) seems to be at the right order of magnitude and monthly pattern (Figure 7B-38c); at this point the available dataset does not support further calibration.

Flows at V1, V27, and V8 were not directly calibrated and are a function of the parameters adjusted upstream of those locations.

6.2 Water Quality

Within the Faro Mine Area, groundwater sources are used as input water quality terms (NFRC GW, S-Wells bypass, and RCAA discharge). As described in Section 3.3.1, the groundwater monitoring wells used to generate the input time-series specifically target areas receiving deteriorated water from the waste dump. This results in the groundwater quality input to the model having higher concentrations than what would actually be expected over the broad area being represented in the model. Further, attenuation of trace metals (Cd, Co, Mn, and Zn) is known to occur within the subsurface alluvial aquifer material at the FMC, reducing the load received in NFRC (*Geochemical Characterization Report, Faro Mine Remediation Project* [CH2M HILL, 2014]). Metal attenuation can be a result of adsorption to natural organic matter or to secondary oxyhydroxides, or coprecipitation of secondary mineral phases. This attenuation may act to slow the migration of trace metals away from the waste dumps within the shallow groundwater system, especially in the early stages of seep development when pH is near neutral but Zn and SO4 are elevated. Therefore, a calibration factor is applied to Cd, Co, Mn, and Zn concentrations at the source terms (S-Wells bypass and NFRC GW) to produce input water quality more representative of site conditions. The calibration factor applied to Cd, Co, Mn, and Zn at the source terms was adjusted until model predictions provided an acceptable match to observed concentrations at X2 (Figure 7B-39). A calibration factor of 0.1 (0.1 x median monthly source term concentration) was selected to be applied in the model for those 4 parameters.

The black line on the plots from Figure 7B-39 presents average monthly concentrations from available data between 2009 and 2012. The two bar graphs on Figure 7B-39, below the calibration line plots present the observed concentrations (i.e., not the average monthly concentration) for the parameters of interest between 2009 and 2012, which show that there is variability in the observed concentrations, but no obvious trend, and therefore it is reasonable to attempt to match to the average monthly concentrations.

Figure 7B-39 includes the base-case-X2-predicted concentrations when no calibration factor is applied (orange line).

The calibration factor improves the initial condition as compared to the base case (no calibration factor) while maintaining conservative inputs. Figure 7B-40 presents a comparison between the measured data and the predicted values. The predicted concentrations provide a reasonable match to the monthly pattern and magnitude, reducing or removing the initial step function increase seen when the base case source terms are used (beginning of orange line). For Zn and Cd, where a smaller step function increase still persists, the median predicted results are within the historical range.

After applying the calibration factor, the predicted concentrations show an improved match to the observed concentrations, although there are some remaining differences in the monthly pattern (Figure 7B-39). One of the reasons the model monthly pattern does not match the observed X2 monthly pattern is because of the limited data available from winter months for the fixed water quality source terms (S-Wells bypass and NFRC GW).

Using the input water quality source terms described in Section 3.3, and after applying the calibration factor described above, a comparison was performed for the key water quality parameters between the predicted concentrations and the observed concentrations at X14 and V8 (Figure 7B-41). Figure 7B-41 presents the comparison of model results to measured 2013 concentrations as model water quality inputs rely on source concentrations up to 2012. This check against a dataset not used in model input demonstrates that the modelled water quality inputs provide a reasonable approach to predict near-term water quality. Model results (median, minimum, and maximum) relying on the four source areas on the Faro side and seven source areas on the Vangorda/Grum side were considered to provide a good match to the magnitude of measured concentrations and a reasonable representation of monthly patterns for the key water quality parameters (Figure 7B-41).

It is important to note that the model calculates an average concentration on a monthly time step. Measured concentrations reflect an instantaneous snapshot of the concentrations at the moment sampled. Samples at X14 and V8 are collected between a weekly and monthly frequency.

SECTION 7

Results

The calibration results described in Section 6 show that the model, at its current state and limitations, is a valuable tool to understand the seasonal concentration changes, flow magnitudes, origin of loads, dilution of concentrations between given locations, and impact of operational changes in the system.

Water quality was predicted for the duration of the IW (2014 through 2023) at key locations in the aquatic receiving environment within and downstream of the FMC. Locations within the model where water quality was predicted include: NF1, X2, X3A, X14, R4, R5, A1, P4 and V8. Specifically, water quality was predicted for the following eight constituents of concern (COCs): Ca, Cd, Co, Mg, Mn, Pb, SO_4, and Zn (Minnow, 2014b). Hardness was also predicted, calculated from the predicted Ca and Mg concentrations.

The predicted water quality results for the COCs were provided to Minnow Environmental Inc. to support the assessment of potential effects of the IW on the aquatic receiving environment, which can be found in Minnow (2014a). Although a detailed assessment of the predicted water quality is outside the scope of this study, a preliminary summary of the model results is presented in the following sections.

7.1 Load Contribution

The proportion of load contribution by season at X14 and V8 from the source terms for the key water quality parameters is presented on Figures 7B-42 and 7B-43. Figure 7B-42 provides the proportion of load contribution at X14 considering the load contribution from RCAA, S-Wells bypass, NFRC, CVD Pond discharge, and background. Figure 7B-43 provides the proportion of load contribution at V8 considering the load contribution from V1, V25BSP, Grum Runoff, Grum Seepage, V15 bypass, V4, V5, and residual flows in the V8 catchment. Load contribution is determined and presented on an average seasonal basis. The three seasons used to group the data are consistent with the three hydrology seasons identified for the FMC (i.e., freshet – May and June, open water – July to October, and winter – November to April).

7.1.1 Faro Mine Area

The proportion of contribution for all key water quality parameters are shown on Figure 7B-42. The largest contributor of all constituents during the open water season is the CVD Pond. During freshest, discharge from the CVD Pond also provides the largest source of the key water quality parameters, except for Mg, Cd, and Pb, which have the greatest contribution from background stream flows, followed by CVD Pond discharge. A large contribution (greater than 10 percent) of load for Ca, Mg, and SO_4 during freshet and open water is provided by RCAA. S-Wells provide a large contribution of Cd and Zn during freshet and open water.

During lower flow winter conditions, the largest load is contributed from RCAA for Ca, Mg, SO_4, and Mn. The largest contributor of Cd is the S-Wells, followed closely by background stream flows. The NFRC, specifically source loadings to NFRC, provides the largest source of Zn during winter flow conditions, with Pb primarily sourced from background stream flows.

7.1.2 Vangorda/Grum Area

The proportion of contribution for all key water quality parameters are shown on Figure 7B-43. The largest contributor of all constituents during the open water season (except for Co, Mg, and Pb) is discharge from V25 BSP. For Co and Mg V5 provides the greatest contribution and V25BSP provides the second-largest contribution. For Pb, V4 provides the greatest contribution and V5 the second-largest contribution. During freshet, discharge from V25BSP also provides the largest source of SO_4, Mn, and Zn, and is the second largest source of Cd. V5 provides the greatest contribution of Ca, Mg, Cd, Co, and Pb during freshet; the Mn and Zn load from V5 is the second largest during freshet. V4 provides the second largest contribution of the Pb during freshet.

During lower flow winter conditions, the largest or second largest load is contributed from V5 for all parameters except Pb. Grum Waste Dump seepage provides a large contribution (greater than 10 percent) of load for Mg,

SO_4, Cd, and Co. The contribution of Ca, Cd, Co, Mn, Pb, and Zn from V1 is greater than 10 percent during winter low flows. A large contribution of load for Cd is provided by V15 bypass.

7.2 Predicted Water Quality

The complete set of water quality estimates are presented in tables and figures in Appendix 7C (Minnow 2014a). The tables present a summary for all stochastic realizations done for the 2014-2023 period. The figures show the seasonality, range of stochastic results, and trends of water quality at different stations for Ca, Cd, Co, Mg, Mn, Pb, SO_4, Zn, and hardness (calculated from the predicted Ca and Mg concentrations).

The tables summarize (by location) the water quality results for the above noted parameters. The specific information provided includes monthly exceedance probabilities, monthly concentrations (5th, 50th, and 95th percentiles), and seasonal concentrations (5th, 50th, and 95th percentiles).

The monthly exceedance probability represents the percentage of months that exceeded guidelines out of the total 24,000 months considered in the simulation. For example, a 3 percent monthly exeedance value for Cd indicates that the variable exceeded guidelines in 720 months out of the 24,000 months considered in the stochastic simulation. The 24,000 months are from the monthly model results of a 10-year stochastic simulation with 200 realizations (12 months times 10 years times 200 stochastic realizations).

The monthly concentrations are values that were not exceeded x percent of the months, where “x” represents the 5th, 50th, and 95th percentiles of all simulation results. For example, the 95th percentile represents 95 percent of the months having concentrations below the value on the table. In other words, 1,900 out of the 2,000 individual months simulated (10 years times 200 stochastic simulations) had concentrations below that value.

The seasonal concentrations table shows the average percentile threshold concentration for the months that represent each season.

Two figures are presented for each variable except for hardness. The first figure shows the range of the stochastic simulations represented by 5th, 50th, and 95th percentiles of all 200 stochastic realizations; for example, the top line indicates that 95 percent of the simulation results were below the indicate concentration. The second figure summarizes all months in the 10 year window and 200 stochastic simulations, and shows the percentage of all months that exceeded the guideline threshold.

Results show that although none of the water quality parameters are likely to be above guideline thresholds at the most downstream location (P4), there is a probability that some of the parameters at some locations upstream P4 will exceed the determined guidelines.

Future median surface water concentrations of SO_4, Cd, and Pb are expected to be below water quality guidelines for protection of aquatic life during winter baseflow, spring freshet, and summer/fall periods at all stations. However, the predicted range of values for Cd and Pb suggest that peak concentrations may occasionally exceed guidelines at some locations. Median as well as peak concentrations of Co, Mn, and Zn are predicted to be above guidelines at some stations and/or during some seasons.

Median concentrations of Cd are predicted to be less than the hardness-adjusted water quality guidelines in all local and regional study areas, but the guidelines may sometimes be exceeded in localized stream reaches within the local study area (e.g., NFRC and in Rose Creek immediately downstream from the Faro Mine Area); however, the predicted concentrations are not expected to be toxic to fish and effects on other aquatic biota are expected to be minimal. Co concentrations are predicted to exceed the water quality guideline in Rose Creek at X14 and R4 in approximately 45 percent and 35 percent of the months respectively, particularly during the open water seasons; however, predicted concentrations are not expected to be toxic to fish and effects on other aquatic biota are expected to be minimal. Mn concentrations are not predicted to change substantially from baseline conditions, except that concentrations may decrease slightly in winter months and increase slightly in other months at Rose Creek stations at and downstream from X14. Overall, Mn concentrations are predicted to be above the hardness-adjusted guidelines in approximately 65 percent of months at X14 (65 percent) and in an increasingly lower percentage of months at stations farther downstream. The available data indicate that aquatic

effects, if any, of Mn in surface waters around the FMC would be limited to the vicinity of X14 (i.e., within the local study area) and would likely be minor in magnitude.

During the 10-year IW, concentrations of Zn under normal operating, winter, and summer/fall conditions, are predicted to be above guidelines throughout the Rose Creek system downstream of NF1 to the mouth at Anvil Creek (R4). At these stations, probabilities of monthly guideline exceedance range from 60 percent to 80 percent, but decline from 80 percent at X14 to 70 percent at the mouth of Rose Creek (R4), to 30 percent after the confluence of Rose Creek, and to 20 percent at the mouth of Anvil Creek (R5). The water quality guideline for Zn is also expected to be exceeded in approximately 30 percent of months at V8, near the mouth of Vangorda Creek, but will not be exceeded at P4 in the Pelly River downstream of Vangorda Creek and Anvil Creek. Despite these conditions of elevated Zn, the available data indicate that aquatic effects, if any, in surface waters around the FMC would be comparable to those currently observed at X14. This means that concentrations would rarely exceed fish toxicity thresholds, effects to other aquatic biota would be minor (i.e., affecting only a few sensitive species), and the effects would be limited to the local study area.

A more comprehensive assessment of the aquatic effects is provided in Minnow (2014a).

SECTION 8

Limitations

The model results are limited to monthly average estimates of flow and water quality at specific locations. The water quality is predicted for Ca, Cd, Co, Mg, Mn, Pb, SO_4, Zn, and hardness (calculated from the predicted Ca and Mg concentrations), and the locations of prediction are NFRC at NF1, X2, X3A, X14, R4, R5, A1, P4, and V8. Water quality predictions assume no reactive mixing of waters, and that water quality trends into the future for more than 10 years and. Spikes in concentrations at specific locations resulting from new source areas, like the one recently observed at NF1 (TEES, 2013), are nor addressed by this model. They will be addressed by the Adaptive Management Plan.

The model hydrology is based on annual values of precipitation and HEP with applied fixed monthly flow patterns. The model results do not account for climate change. It is possible that within the next 10 years, changes in precipitation volume and shifts in precipitation patterns might impact the water quality at the site. This assumption also limits the use of the model and its results to the next 10 years.

The model assumes that peak events happening in a period shorter than a month are averaged through the month. Therefore, it is not suitable for evaluating peak daily hydrology and daily water quality scenarios.

The modelled system conserves mass and flows, thus this model is not suitable to evaluate changes in concentrations between flow locations caused by any reactive processes. Concentrations between flow locations change only as a function of flows and loads added to the system.

Intermediate model flow locations mentioned in Section 5 that were (1) not calibrated, (2) not in the list of water quality prediction locations, or (3) not presented on Figures 7B-37 and 7B-38, should not be used for further analysis or reference. Those flows are subjected to calibration parameters and the values may change in the future, when additional data is available.

SECTION 9

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Tables

TABLE 7B-1

Fraction of Each WRD in Each Catchment on the Faro Mine Area

Description of Water Modelling & Results —Faro Mine Remediation Project

	Catchments							
WRD	**X23**	**MP**	**X2**	**RCV**	**GHU**	**Z2**	**NFRC**	**GHL**
Crusher Stockpile (CHSP)	0.66	0	0	0	0	0	0	0.34
Fuel Tank Dump E (FTE)	0.97	0.03	0	0	0	0	0	0
Fuel Tank Dump W (FTW)	1	0	0	0	0	0	0	0
Faro Valley North (FVN)	0	1	0	0	0	0	0	0
Faro Valley South (FVS)	0	1	0	0	0	0	0	0
Intermediate Dump (ID)	0	0	0.83	0	0	0.17	0	0
Intermediate Dump Sulphide Cell (IDSC)	0	0	1	0	0	0	0	0
Low Grade Stockpile A (LGSPA)	1	0	0	0	0	0	0	0
Low Grade Stockpile C (LGSPC)	0.95	0.05	0	0	0	0	0	0
Lower Parking Lot Dump (LPL)	0	0	0	0	0	0	0	1
Main Dump East MDE (MDE)	0	0	0.22	0	0	0	0	0
Main Dump West (MDW)	1	0	0	0	0	0	0	0
Main East Sulphide Cell (MESC)	1	0	0	0	0	0	0	0
Medium Grade Stockpile (MGSP)	1	0	0	0	0	0	0	0
Mt. Mungly East (MME)	1	0	0	0	0	0	0	0
Mt. Mungly West (MMW)	1	0	0	0	0	0	0	0
Lower Northeast Dump (NEL)	0	0.03	0	0	0	0.32	0.65	0
Lower Northeast Sulphide Cell (NELS)	0	0	0	0	0	0.98	0.02	0
Outer Northeast Dump (NEO)	0	0	0	0	0	1	0	0
Upper Northeast Dump (NEU)	0	0.22	0	0	0	0.23	0.55	0
Lower Northwest Dump (NWL)	0.33	0	0	0	0.02	0	0	0.65
Middle Northwest Dump (NWM)*	0.7/0.72	0	0	0	0.1/0.07	0	0	0.2/0.21
Upper Northwest Dump (NWU)*	0.5/0.75	0	0	0	0.4/0	0	0	0.1/0.25
Outer Haul Road East (OHRE)	0	0	0.91	0	0	0.09	0	0
Outer Haul Road West (OHRW)	0	0	0.64	0	0	0	0	0
Oxide Fines Stockpile (OXSP)	1	0	0	0	0	0	0	0
Ranch Dump RD (RD)	0.9	0.08	0.01	0	0	0.01	0	0
Ramp Zone Dump (RZD)	0	0.26	0.03	0	0	0.71	0	0
Stock Piles Base1 (SPB)	0.9	0	0	0	0	0	0	0.1
Southwest Pit Wall Dump (SWPWD)	0.19	0.81	0	0	0	0	0	0
Upper Parking Lot Dump (UPL)	0	0	0	0	0	0	0	1
Zone II East (Z2E)	0	0	0	0	0	0.95	0.05	0
Zone II West (Z2W)	0	0	0	0	0	1	0	0

*Notes: The Northwest Dumps change the fractions on year 3 of the simulation

TABLE 7B-2

Fraction of each WRD in each Catchment of the Vangorda/Grum Mine Area (Version 2.0 minus Version 1.0)

Description of Water Modelling & Results—Faro Mine Remediation Project

	Catchments		
WRD	**V27**	**V8**	**Vpit**
G1_S	1.00	0.00	0.00
G1_B	0.92	0.08	0.00
G2	0.00	1.00	0.00
G3_O	1.00	0.00	0.00
V1_S	1.00	0.00	0.00
V1_B	0.83	0.17	0.00
V2	1.00	0.00	0.00
V3_O	0.72	0.04	0.24
OTP	0.00	1.00	0.00
VPL1	0.00	0.00	1.00
VPL2	0.00	0.00	1.00
VPL3	0.00	0.00	1.00

TABLE 7B-3

Model Boundary Conditions

Description of Water Modelling & Results—Faro Mine Remediation Project

Boundary Condition Description	Model Abbreviation	Average HEP (mm)	Area (km^2)	Average Annual Flow Volume (m^3)
Faro Mine Area				
Faro Pit Lake Surface Inflows	FP_HEP	247	0.7	172,900
Faro Pit Catchment WRD inflows	FP_HEP	247	1.29	319,391
UFC inflows	UFC_HEP	352	15.3	5,385,600
NFRC inflows	NFRC_HEP	325	103.9	33,767,500
Upper SFRC inflows	Upper_SFRC_HEP	342	74.3	25,393,500
Alluvial Inflow	IN_Alluvial_Inflow	N/A	N/A	1,893,415
FCD Seepage	FC_Div_Leakage	N/A	N/A	% of UFC_HEP inflows
SFRC inflows	SFRC_HEP	292	102.1	29,813,200
Rose Creek X14 mouth inflows	Rose_X14_Mouth_HEP	255	105	26,775,000
Upper Anvil inflows	Upper_Anvil_HEP	325	322	104,650,000
Anvil Mouth (minus Upper Anvil) inflows	Anvil_Mouth_HEP	267	321	85,707,000
RCAA inflows	DVTI_HEP	161	4.1	660,100
WRDs above X2, including NFRC, Z2, and X2 catchments	WR_aboveX2_HEP	202	1.75	354,349
WRDs between X2 and X14, including RCV, X23, GHL, and GHU catchments	WR_btwn_X2_X14_HEP	214	3.31	707,624
Vangorda Mine Area				
Grum Pits	GP_HEP	263	2.26	594,380
V1 Area or undisturbed Catchment V1 upstream of V27	V1_HEP	374	20.2	7,554,800
Area between V1 and v27 Flows, locations V1 to V27	V1_V27_HEP	193	3	579,000
V27 to V8 Area; includes the drainage area between V8 and v27, including Shrimp Creek	V27_V8_HEP	193	59.6	11,502,800
Pelly River				
Pelly River Upstream V8 confluence with Pelly	Pelly_US_V8	N/A	N/A	6,125,170,000

Note:
km^2 = square kilometre(s)

TABLE 7B-4

Monthly Patterns Used to Convert Volumes from Annual to Monthly Values

Description of Water Modelling & Results—Faro Mine Remediation Project

Month	Faro Surface	Faro WR Seep	Faro DVT	Rose Creek	Rose Creek R4	Faro Creek Diversion Seepage
JAN	0.031	0.068	0.089	0.014	0.065	0.044
FEB	0.023	0.047	0.083	0.01	0.065	0.04
MAR	0.023	0.065	0.073	0.009	0.06	0.044
APR	0.028	0.062	0.074	0.013	0.05	0.047
MAY	0.24	0.128	0.102	0.286	0.2	0.082
JUN	0.205	0.125	0.096	0.214	0.15	0.161
JUL	0.12	0.086	0.098	0.132	0.09	0.142
AUG	0.096	0.096	0.083	0.103	0.07	0.118
SEP	0.093	0.108	0.072	0.102	0.07	0.106
OCT	0.067	0.087	0.071	0.065	0.06	0.101
NOV	0.038	0.062	0.074	0.031	0.065	0.071
DEC	0.036	0.066	0.085	0.021	0.055	0.044

TABLE 7B-5

Locations and the Period of Record Used to Fix Water Quality

Description of Water Modelling & Results—Faro Mine Remediation Project

Model Catchment/ Location	Location	Description	Period
Faro Mine Area			
RCAA – GW discharge to SW	RCAA	Selection of wells downgradient of CVD to represent current WQ conditions for GW discharge to SW *(P01-01A/B, P01-2A/B, P01-11, P03-09-01 through -09, P05-01-02 through -06, P05-02, P05-03, X13, X16A/B, X17A/B, X18A/B)*	2008 to 2012
S-Wells bypass	S-Wells	Selection of perimeter wells to represent WQ of S-Well collection system bypass *(S1A, S2A, S3, SRK05-SP1A, SRK05-SP1B, SRK05-SP2, SRK05-SP3A, SRK05-SP3B, SRK08-SBR3, SRK08-SP7A, SRK05-SP7B)*	2009 to 2012
NFRC (Zone II and NE WRD)	NFRC	Selection of wells/seeps to represent WQ entering NFRC upstream of Haul Road *(BH1, BH2, BH4, BH5, BH6, BH7B, BH10A, BH10B, P05-04, SRK08-P12A, SRK08-P12B, BH12A, BH12B, BH13A, BH13B, BH14A, BH14B; NE1, SRK-FD05, SRK-FD06)*	2006 to 2013
WTP - select parameters	CVD	X5 - Ca, Mg, SO_4 and Mn only (operational change in 2011)	2011 to 2012
Vangorda/Grum Mine Area			
Shrimp Creek	V4	Shrimp Creek	2007 to 2012
Sheep Pad Pond	V25BSP	Receives flows form the Grum Interceptor, upstream catchment and a portion of the Overburden Catchment	2008 to 2012
Grum WRD - V15 Collected	V15	V15 is either pumped to Vangorda or drains to Moose Pond (represented by V2a)	2006 to 2012
Grum WRD - Runoff	V2	Uncollected Runoff from Grum WRD that discharges to V27 (represented by Sheep Creek and V2)	2009 to 2012
Grum WRD - Seepage	Moose Seep	Seepage flowing from Moose Pond to V27 (represented by MOOSEw2 and MOOSE SEEP)	2009 to 2012
Vangorda WRD - Runoff/Seepage	LCD	Vangorda WRD is designed to intercept runoff/seepage and direct to LCD Pond. LCD is pumped to Vangorda Pit and subsequently treated. Limited GW data downgradient of Vangorda WRD.	2004 to 2012
West Fork Vangorda Creek	V5	West side of the V8 catchment	2008 to 2012

TABLE 7B-6

Water Quality Discharge Data

Description of Water Modelling & Results—Faro Mine Remediation Project

	Faro WTP Discharge (mg/L)		X5 Discharge (mg/L)		Vangorda/Grum WTP Discharge (mg/L)		V25 BSP Discharge (mg/L)	
Analyte	**Median**	**Max**	**Median**	**Max**	**Median**	**Max**	**Median**	**Max**
Sulfate	548	663	950	1243	393	787	933	1914
Calcium	122	150	487	663	89	185	195	528
Magnesium	59	78	48	57	50	71	46	126
Antimony	0.0004	0.0009	0.0002	0.0005	0.0025	0.0027	0.0001	0.0023
Arsenic	0.04	0.05	0.02	0.04	0.0003	0.0003	0.0003	0.0007
Cadmium	0.005	0.005	0.0004	0.0004	0.003	0.003	0.0003	0.0031
Cobalt	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Copper	0.05	0.05	0.03	0.04	0.001	0.001	0.004	0.007
Lead	0.03	0.05	0.02	0.03	0.0002	0.0002	0.01	0.01
Manganese	2.8	7.7	17.7	26.8	5.1	5.1	0.1	4.7
Molybdenum	0.0004	0.0008	0.0003	0.0005	0.0013	0.0014	0.0011	0.0023
Nickel	0.09	0.15	0.06	0.09	0.001	0.001	0.002	0.004
Selenium	0.005	0.013	0.003	0.007	0.001	0.001	0.001	0.001
Silver	0.00004	0.00004	0.00001	0.00001	0.00001	0.00001	0.00001	0.00005
Zinc	0.5	0.5	0.3	0.4	0.5	0.5	0.2	0.6

Notes:

mg/L = milligrams per liter

WTP = water treatment plant

TABLE 7B-7

Background Water Quality[1]

Description of Water Modelling & Results—Faro Mine Remediation Project

Analyte	Units	n	Mean[2]	Standard deviation[2]
Sulfate	mg/L	234	8.0	6.0
Cadmium, Total	mg/L	212	0.0000256	0.0000396
Calcium, Total	mg/L	230	19.0	13.8
Cobalt, Total	mg/L	207	0.0000756	0.000168
Lead, Total	mg/L	228	0.000600	0.00152
Magnesium, Total	mg/L	228	3.86	3.37
Manganese, Total	mg/L	229	0.0126	0.0230
Zinc, Total	mg/L	230	0.0039	0.0057

Notes

[1]Water quality summary statistics for pooled reference stations (V1, VR, USFR, R7, FC, R6, W10), Faro Mine, Yukon.

[2] values reported as less than the detection limit (DL) were used at 1/2 the DL for calculation

mg/L = milligrams per liter

TABLE 7B-8
Source Term Trends
Description of Water Modelling & Results—Faro Mine Remediation Project

	Faro Mine Area									Vangorda/Grum Mine Area														
	RCAA			S-Wells		NFRC		X5		V4		V25BSP		V15		Grum Runoff		Grum Seepage		LCD		V5		
Analyte	A	S-K	X13-S-K	A	S-K	A	S-K	A	S-K	A	S-K	A	S-K	A	S-K	A	S-K	A	S-K	A	S-K	A	S-K	
Calcium	↑	↑'''	↑'	→	↓	↑	↑'	↑	i	↑	←	→	←	↑	↑'''	→	←	→	↓	↑	←	↑	←	
Cadmium	↑	←	↑'	↑	←	→	↓			→	↓	→	←	↑	↑''	↑	←	→	←	↑	↑'	→	↑'	
Cobalt	↑	←	↑'	→	↓	↑	←	↑	i	→	↓	→	←	→	↑''	↑	←	↑	↑'''	↑	←	→	←	
Magnesium	↑	←	↑'	→	↓	↑	↑'	→	i	↑	←	↑	←	↑	↑''	↑	←	→	↓'''	↑	↑''	↑	←	
Manganese	→	←	↑'	→	↓	↑	↑'	↑	i	↑	←	↑	←	→	←	↑	←	↑	↑'''	↑	↑''	→	←	
Lead	→	←	→	→	←	→	←			↑	←	↑	←	→	←	→	←	↑	↑'	↑	↑'	→	←	
Sulfate	↑	↑'''	↑'	→	←	↑	↑'	↑	i	↑	↑''	↑	←	↑	↑'''	↑	←	→	↓	↑	←	↑	←	
Zinc	↑	←	↑''	→	↓	↑	↑'			↑	←	↑	←	↑	↑'''	→	←	↑	↑'	↑	↑'	→	←	

Notes
A - trend from linear regression on average annual data
S-K - Seasonal Kendal test
↑ - indicates a trend of increasing concentration
→ - indicates no trend or trend was negative
← - indicates no significant trend
↓ - indicates significant decreasing trend
↑'- indicates significant increasing trend at 0.05 significance
↑'' - indicates significant increasing trend at between 0.05 and 0.1 significance
↑''' - indicates significant increasing trend at between 0.1 and 0.2 significance
i - insufficient independent data points to determine significance

TABLE 7B-9

Precipitation at Faro Airport (mm)

Description of Water Modelling & Results—Faro Mine Remediation Project

Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	0.4	11.9	12.4	4.1	11.6	27	38.1	41.6	7.8	32.4	20.2	19	226.5
1979	8.9	18.3	20.2	6.7	10.5	68.2	55.4	13.8	13.4	11.6	12.4	34.4	273.8
1980	19.7	2.4	11.7	12.5	10.5	11.1	95.4	33.2	46.7	24.7	21.3	13.3	302.5
1981	6.5	23.1	4	4.5	7.8	42.8	41.3	22.5	41.9	21.5	17	5.4	238.3
1982	10.2	18	9.5	4.1	18.2	14.3	58.3	47.3	47.2	42.3	11.8	13.6	294.8
1983	35.7	6.6	9.8	2.2	20.6	55.6	49.1	65.8	21.2	16.3	11.4	3.9	298.2
1984	27.6	24.1	5.9	2.4	38.8	49	16.6	64.9	5.5	10.8	10.7	22.5	278.8
1985	22.5	24.8	2.2	13.8	17.2	28.1	62.6	80.8	46.3	20	22.2	26.1	366.6
1986	8.4	4.7	34.6	12.9	35.1	12.8	81.8	77.4	44.4	22.7	15.9	5.6	356.3
1987	3.1	14	2.8	10	40.1	50.8	92.4	63.5	30.2	26.6	17.8	6.2	357.5
1988	7	10.4	17.2	8.2	38	37.3	97.2	25.5	43.8	29	17.9	16.5	348
1989	19.8	3.6	19.8	2	17.9	41	51.7	16.9	30.8	46.3	39.8	13.8	303.4
1990	14.4	25.8	5	7	23.4	45.4	30	64.4	66.2	22.7	25.4	24.8	354.5
1991	17.2	22.6	16.6	2.8	22.4	30.2	115.4	33	48.2	49.6	43.4	40	441.4
1992	22.8	24.6	7.6	15.8	14.4	11.4	66.1	34.4	47.8	13.8	18.8	13	290.5
1993	22.2	15	1.6	6	76.7	48.6	50.2	56	50.8	35.7	18.9	16.7	398.4
1994	20.2	8.4	11.4	5	39.8	24.2	19.6	25.2	45.6	41.6	24.4	8	273.4
1995	8.4	7.8	18.4	5.2	10.9	33.9	73.4	63.4	28.8	12.2	22.3	15.4	300.1
1996	10.2	9.1	27.1	7.2	13.4	20	64.4	70.8	52.7	34.8	3.5	5.9	319.1
1997	6.6	8.7	1.4	14	16.5	39.3	86.4	33.2	38.5	25.2	6.4	12.4	288.6
1998	7	2.8	4.8	4.2	14.4	29.6	19.2	24.2	23.4	24	4.6	8.2	166.4
1999	24.4	10	15.4	1.8	44.4	64.8	42	33.8	27	22.4	12.8	21.6	320.4
2000	12.2	2	12.4	6	9.6	39.6	48.1	116.2	102.2	8.6	19.4	5.8	382.1
2001	7.4	3	4	14.6	30.8	35	58.4	14.2	44.6	28.6	12.2	15.4	268.2
2002	9.2	5.8	9	7	19.6	19.4	34.9	64.1	38.4	18.2	9.6	9.4	244.6
2003	22.4	8	16	0.4	7.6	45.2	63.2	30.4	30.8	12.8	32.8	19.9	289.5
2004	31.1	11.4	45	4	15.6	34	13.5	38	48.5	33.6	9.8	45	329.5
2005	26.7	12.4	2.6	19.5	58.6	41	83.8	38.6	36.6	13	30	10.8	373.6
2006	11	7	18.5	21.6	16.2	38	33.4	33.3	35.6	21	33.1	8.3	277
2007	16.4	16.4	14.4	3.6	11.4	52	43.5	33.5	50.7	39.6	13.4	28	322.9
2008	15.3	11.9	12.4	7.8	22.8	68.6	74.8	99	27.2	24.7	18.9	16.7	400.1
2009	15.3	15.4	20.3	20.4	19.9	26.1	16.8	62.4	28.2	24.7	18.9	16.7	285.1
2010	20.3	5.6	9	3.4	15	45.6	37.4	29	30.8	16.4	29.2	12.8	254.5
2011	9.5	9.8	0	4.4	6.8	74.2	51.1	55.8	28.8	12.4	15.8	31.4	300

Note:

Original data from Environmental Services (DES) 2012. Shaded cells represent missing values that were replaced by the monthly average

TABLE 7B-10

Storage Elevation-Capacity Tables

Description of Water Modelling & Results—Faro Mine Remediation Project

Faro	
Elev(m)	Capacity(m^3)
1050	0
1052	6
1054	62035
1056	224156
1058	465514
1060	741013
1062	1040444
1064	1363121
1066	1708870
1068	2078372
1070	2467411
1072	2874512
1074	3299332
1076	3744758
1078	4216164
1080	4714481
1082	5236516
1084	5782134
1086	6351471
1088	6943982
1090	7557306
1092	8184950
1094	8825928
1096	9482966
1098	10158855
1100	10858432
1102	11576370
1104	12316617
1106	13081603
1108	13870647
1110	14682641
1112	15516706
1114	16368970
1116	17236912
1118	18121156
1120	19022285
1122	19941264
1124	20879380
1126	21834308
1128	22806093
1130	23795736
1132	24805874
1134	25837640
1136	26889716
1138	27962964
1140	29055510
1142	30168496
1144	31302902
1146	32455676
1148	33635528
1150	34847647
1152	36090702
1154	37366198

CVD Pond	
Elev(m)	Capacity(m^3)
1014	228
1015	1566
1016	5918
1017	18481
1018	47507
1019	96442
1020	166892
1021	258718
1022	370747
1023	500509
1024	649108
1025	811560
1026	985025
1027	1166827
1028	1356425
1029	1552708
1030	1753619
1031.2	1999475

ID Pond	
Elev(m)	Capacity(m^3)
1037.7	300
1038.7	6521
1039.7	33019
1040.7	80090
1041.7	149256
1042.7	243413
1043.7	368949
1044.7	534892
1045.7	735961
1046.7	958042
1047.7	1191570

Grum	
Elev(m)	Capacity(m^3)
1136	0
1137	1
1138	52
1139	375
1140	2844
1141	7675
1142	14366
1143	23130
1144	33931
1145	46557
1146	60783
1147	76376
1148	93238
1149	111271
1150	130365
1151	150613
1152	172238
1153	195249
1154	219794
1155	245920
1156	273452
1157	302613
1158	333370
1159	365346
1160	398589
1161	433156
1162	469077
1163	506522
1164	545347
1165	585438
1166	626736
1167	669121
1168	712579
1169	757084
1170	802650
1171	849408
1172	897610
1173	947497
1174	999273
1175	1052856
1176	1108416
1177	1166103
1178	1226135
1179	1288989
1180	1355953
1181	1426341
1182	1499205
1183	1574459
1184	1651950
1185	1731805
1186	1814143
1187	1898901
1188	1986146

Vangorda	
Elev(m)	Capacity(m^3)
1040	0
1045	23506
1050	66765
1055	133806
1060	231092
1065	368614
1070	541437
1075	746304
1080	990968
1085	1279394
1090	1609661
1095	1981171
1100	2391173
1105	2840924
1110	3338739
1115	3892701
1120	4517781
1125	5225803
1130	6049345

LCD Pond	
Elev(m)	Capacity(m^3)
1103	0
1105.4	10000
1107	20000
1108	30000
1108.8	40000
1110.1	60000
1112	100000
1113.8	150000
1115	200000
1115.2	210000

TABLE 7B-10

Storage Elevation-Capacity Tables

Description of Water Modelling & Results—Faro Mine Remediation Project

Faro	
Elev(m)	Capacity(m^3)
1156	38665510
1158	39986563
1160	41333831
1162	42710738
1164	44116262
1166	45553386
1168	47022377
1170	48522636
1172	50059416
1173.6	51320855
1177	57744358.17
1178	58511414.17
1179	59284385.17
1180	60062959.17
1181	60845434.17

CVD Pond	
Elev(m)	Capacity(m^3)

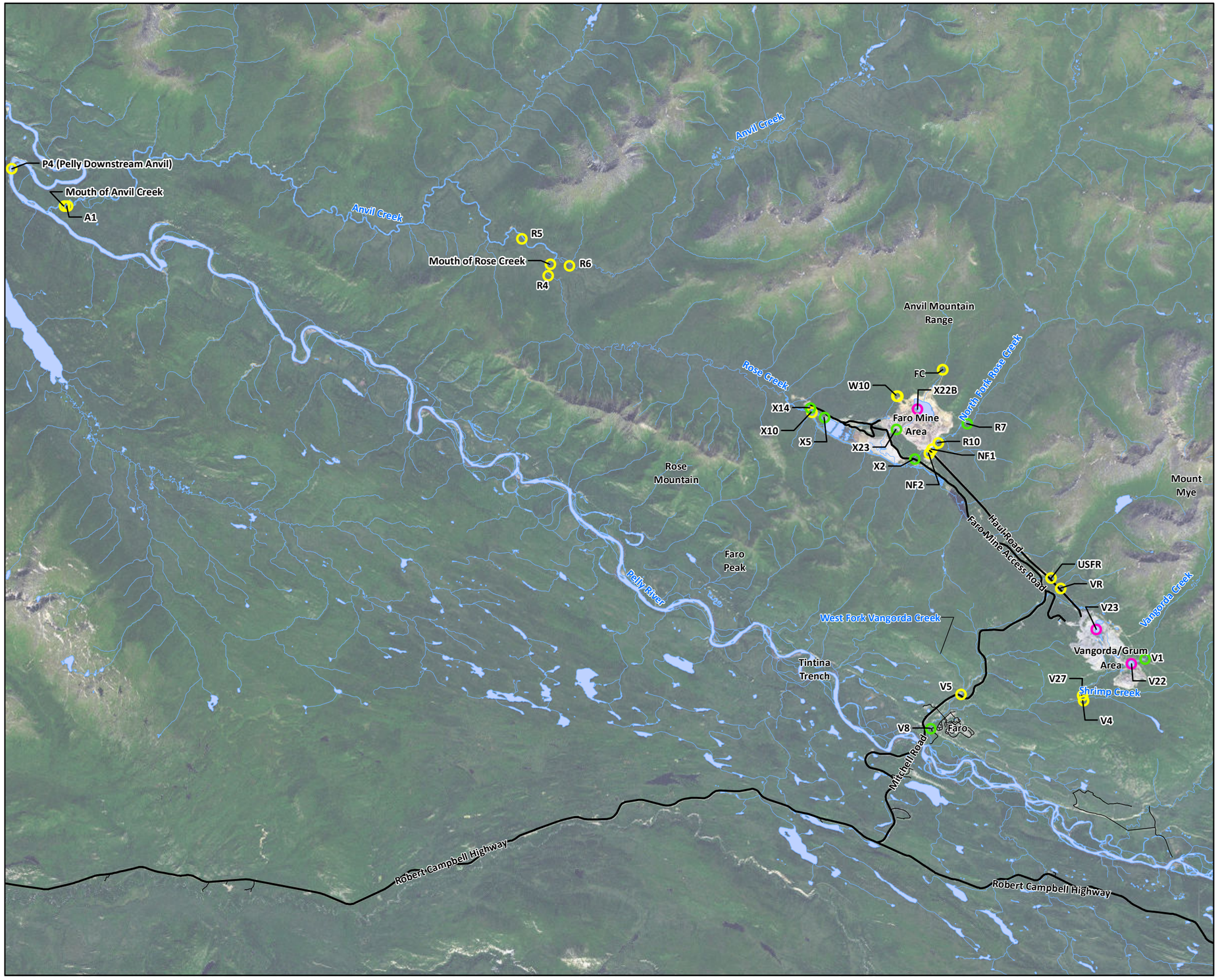
ID Pond	
Elev(m)	Capacity(m^3)

Grum	
Elev(m)	Capacity(m^3)
1189	2075793
1190	2167770
1191	2262085
1192	2358842
1193	2458339
1194	2560793
1195	2666248
1196	2775007
1197	2887177
1198	3002813
1199	3122181
1200	3245403
1201	3372385
1202	3503284
1203	3637567
1204	3774614
1205	3914077
1206	4055368
1207	4198446
1208	4343383
1209	4490283
1210	4639571
1211	4791805
1212	4946758
1213	5104520
1214	5265069
1215	5428396
1216	5594378
1217	5763669
1218	5936037
1219	6113539
1220	6294885
1221	6480545
1222	6669640
1223	6862418
1224	7058388
1225	7257595
1226	7459745
1227	7665387
1228	7874468
1229	8089505
1230	8314102

Vangorda	
Elev(m)	Capacity(m^3)

LCD Pond	
Elev(m)	Capacity(m^3)

Figures



VICINITY MAP



LEGEND

- Continuous Flow Monitoring Location
- Spot Flow Monitoring Location
- Water Quality and Water Level Monitoring Location

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

N

0 2,500 5,000 7,500 10,000

Metres

Created by: CRITIGEN

FIGURE 7B-1

Site-wide Stream Network and Main Monitoring Locations

Faro Mine Interim Works

CH2MHILL

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VICINITY MAP



LEGEND

- Continuous Flow Monitoring Location
- Spot Flow Monitoring Location
- Catchment Pour Point
- Catchment Area
- Waste Dump

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Rose Creek Tailings Area is also called Down Valley Tailings Area, and is where the Rose Creek Alluvial Aquifer is located.
4. Waste Dump Definitions:

CHSP - Crusher Stockpile
FTE - Fuel Tank East
FTW - Fuel Tank West
FVN - Faro Valley North
FVS - Faro Valley South
ID - Intermediate Dump
IDSC - Intermediate Dump Sulphide Cell
LGSPA - Low Grade Stockpile A
LGSPC - Low Grade Stockpile C
LPL - Lower Parking Lot
MDE - Main Dump East
MDW - Main Dump West
MESC - Main Dump Sulphide Cell
MGSP - Medium Grade Stockpile
MME - Mt. Mungly East
MMW - Mt. Mungly West
NEL - Northeast Lower
NELS - Northeast Lower Sulphide Cell
NEO - Northeast Outer
NEU - Northeast Upper
NWL - Northwest Lower
NWM - Northwest Middle
NWU - Northwest Upper
OHRE - Outer Haul Road East
OHRW - Outer Haul Road West
OXSP - Oxide Fines Stockpile
RD - Ranch Dump
RZD - Ramp Zone Dump
SPB - Stock Piles Base
SWPWD - Southwest Pit Wall Dump
UPL - Upper Parking Lot
Z2E - Zone II East
Z2W - Zone II West

N

0 250 500 750 1,000
Metres

Created by:
CRITIGEN

FIGURE 7B-2
Faro Mine Waste Dump Footprints and Catchment Boundaries
Faro Mine Interim Works

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CH2MHILL



VICINITY MAP



LEGEND

- GoldSim Model Node with Flow and Concentration Output
- Continuous Flow Monitoring Location
- Spot Flow Monitoring Location
- Catchment Area
- Waste Dump

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. Waste Dump Definitions:
   G1-B - Grum Main Dump
   G1-S - Grum Main Dump Sulphide Cell
   G2 - Grum Southwest Dump
   G3-0 - Grum Overburden Dump
   OTP - Ore Transfer Pad
   V1-B - Vangorda Main Dump
   V1-S - Vangorda Main Dump Sulphide Cell
   V2 - Vangorda Barite Dump
   V3-0 - Vangorda Overburden Dump
   VPL1 - Vangorda In-Pit Dump - Southwest of Ramp
   VPL2 - Vangorda In-Pit Dump - Inside Hairpin
   VPL3 - Vangorda In-Pit Dump - Oxide Fines

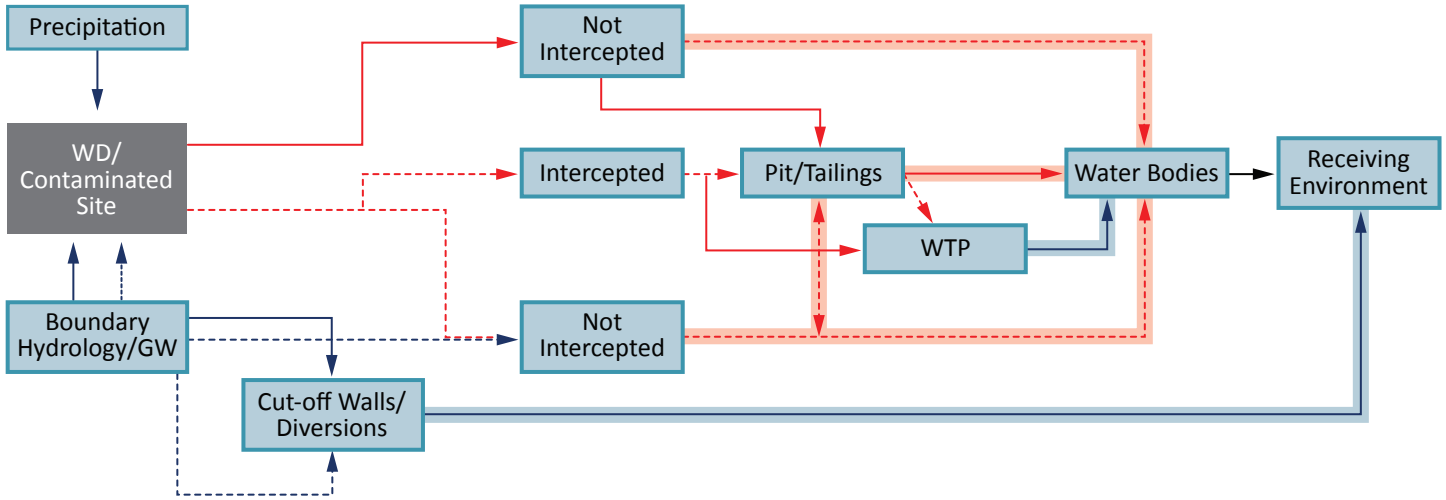
N

0 250 500 750 1,000
Metres

Created by: CRITIGEN

FIGURE 7B-3
Vangorda/Grum Area Waste Dump Footprints and Catchment Boundaries
Faro Mine Interim Works

CH2MHILL

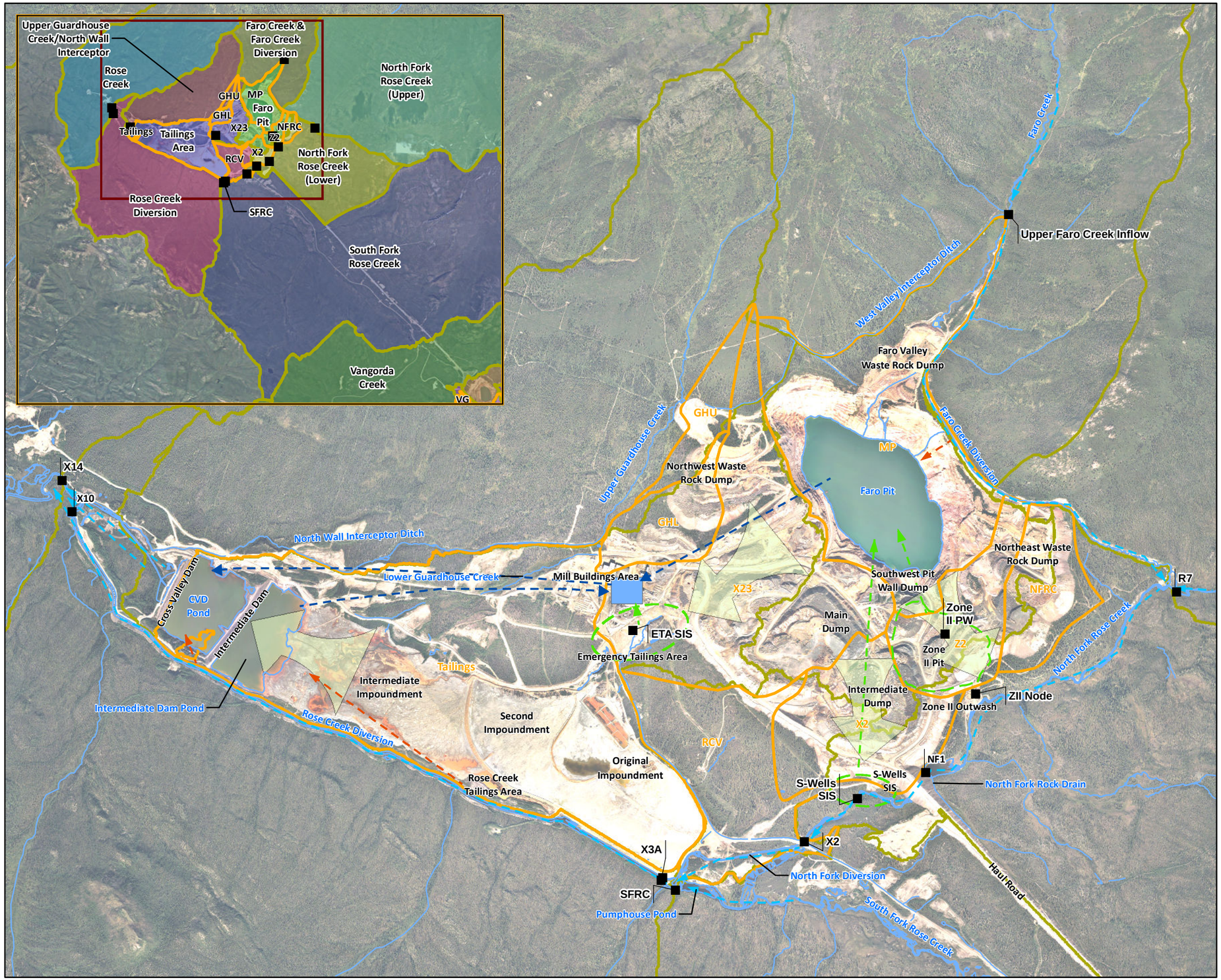


LEGEND

- Contaminated Run-off Flows
- Clean Flows
- Contaminated Seepage Flows
- Clean Seepage Flows
- Fixed Clean/Treated Water Quality
- Fixed Contaminated Water Quality

Notes:
1. Connections represent current and possible future connections.
2. The term "fixed" means that a pre-calculated time series of concentration was used in the model.

FIGURE 7B-4
General WD Flow Routing in the FMC
Faro Mine Interim Works



VICINITY MAP



LEGEND

- GoldSim Model Node with Flow and Concentration Output

Water Line Type

- Collected Water
- Runoff
- Seepage
- WTP Flow
- Installed Groundwater Seepage Collection System
- Water Treatment Plant
- Local Catchment
- Regional Catchment
- Groundwater Seepage and Underflow

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. ETA = Emergency Tailing Area
4. Downstream model output nodes "Mouth RC," "Confluence with Upper Anvil Creek," and "Mouth of Anvil Creek" not shown, out of view.
5. SIS = Subsurface Interception System
6. Regional catchment areas are approximate and do not exactly match the GoldSim model input areas. Regional catchments correspond to input parameters listed on Figure 7B-2.
7. Local catchment areas do match the water quality model. Local catchments correspond to catchments identified on Figure 7B-2.
8. SFRC inputs (posted on Figure 7B-2) include the following regional catchments shown in the inset: South Fork Rose Creek, Rose Creek Diversion, and Upper Guardhouse Creek/North Wall Interceptor.

N

0 250 500 750 1,000

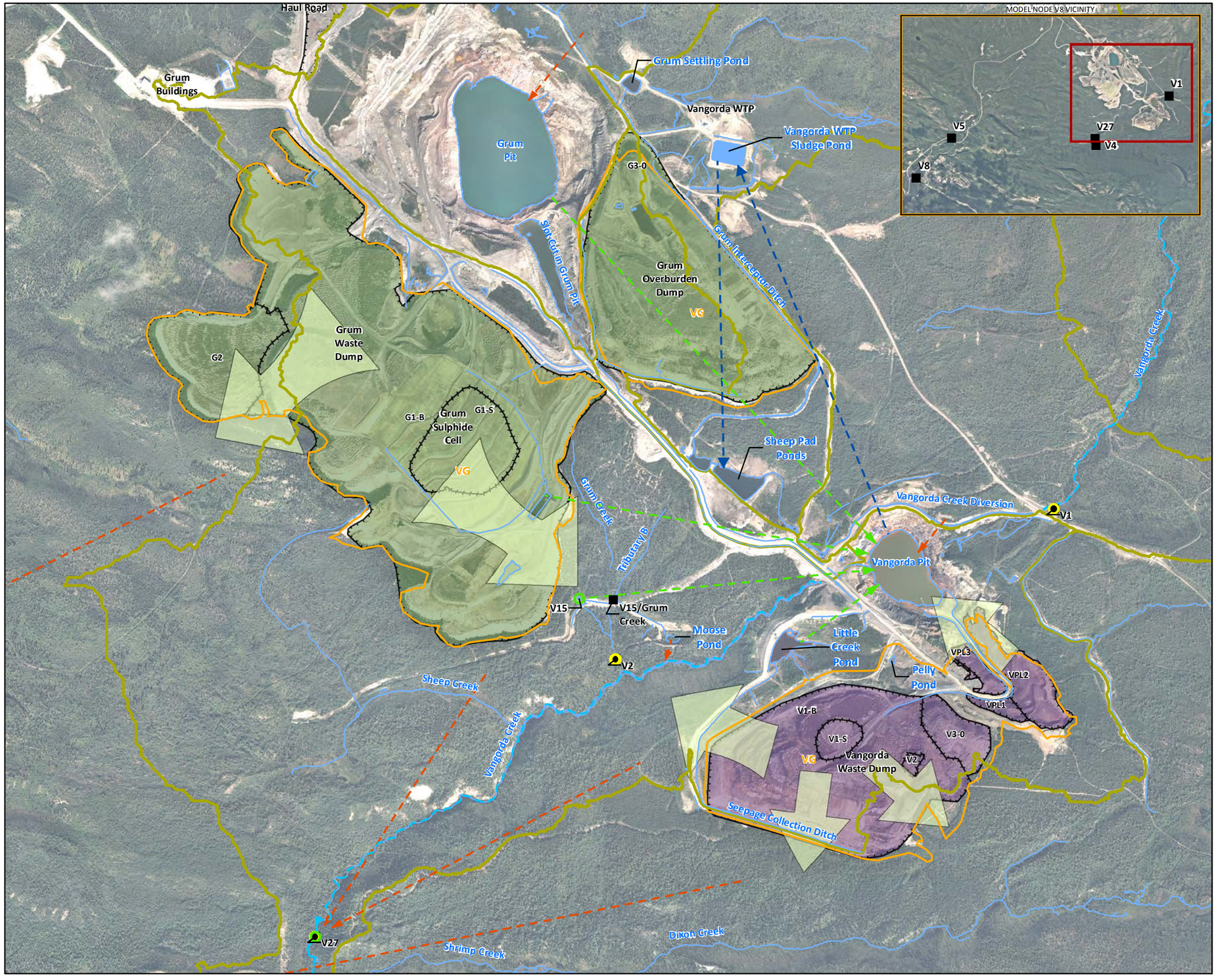
Metres

Created by: CRITIGEN

FIGURE 7B-5

Faro Mine Area - Major System Elements and General Geographic Connectivity

Faro Mine Interim Works



LEGEND

- GoldSim Model Node with Flow and Concentration Output
- Continuous Flow Monitoring Location
- Spot Flow Monitoring Location

Water Line Type

- Collection Water
- Runoff
- Seepage
- WTP Flow (to and from)
- Water Treatment Plant
- Regional Catchment
- Catchment Area
- Waste Dump
- Groundwater Seepage and Underflow

Notes:

1. Aerial photography acquired by Peregrine Aerial Surveyors Inc. and Eagle Mapping in August 2012.
2. Orthophotography prepared by Critigen Canada Corp.
3. SIS = Subsurface Interception System
4. Regional catchment areas are approximate and do not exactly match the GoldSim model input areas. Regional catchments correspond to input parameters shown on Figure 7B-3.
5. Grum and Vangorda Waste Rock Dump areas represent approximate areas of the GR and VG catchments identified on Figure 7B-3.
6. Water from Grum and Vangorda Pit may alternatively be routed to Faro WTP.
7. Locations of VPL1, VPL2, and VPL3 are approximate.
8. Waste Dump Definitions:
   - G1-B - Grum Main Dump
   - G1-S - Grum Main Dump Sulphide Cell
   - G2 - Grum Southwest Dump
   - G3-0 - Grum Overburden Dump
   - OTP - Ore Transfer Pad
   - V1-B - Vangorda Main Dump
   - V1-S - Vangorda Main Dump Sulphide Cell
   - V2 - Vangorda Barite Dump
   - V3-0 - Vangorda Overburden Dump
   - VPL1 - Vangorda In-Pit Dump - Southwest of Ramp
   - VPL2 - Vangorda In-Pit Dump - Inside Hairpin
   - VPL3 - Vangorda In-Pit Dump - Oxide Fines

N

0 250 500 750 1,000

Metres

Created by: CRITIGEN

FIGURE 7B-6

Vangorda/Grum Area - Major System Elements and General Geographic Connectivity

Faro Mine Interim Works

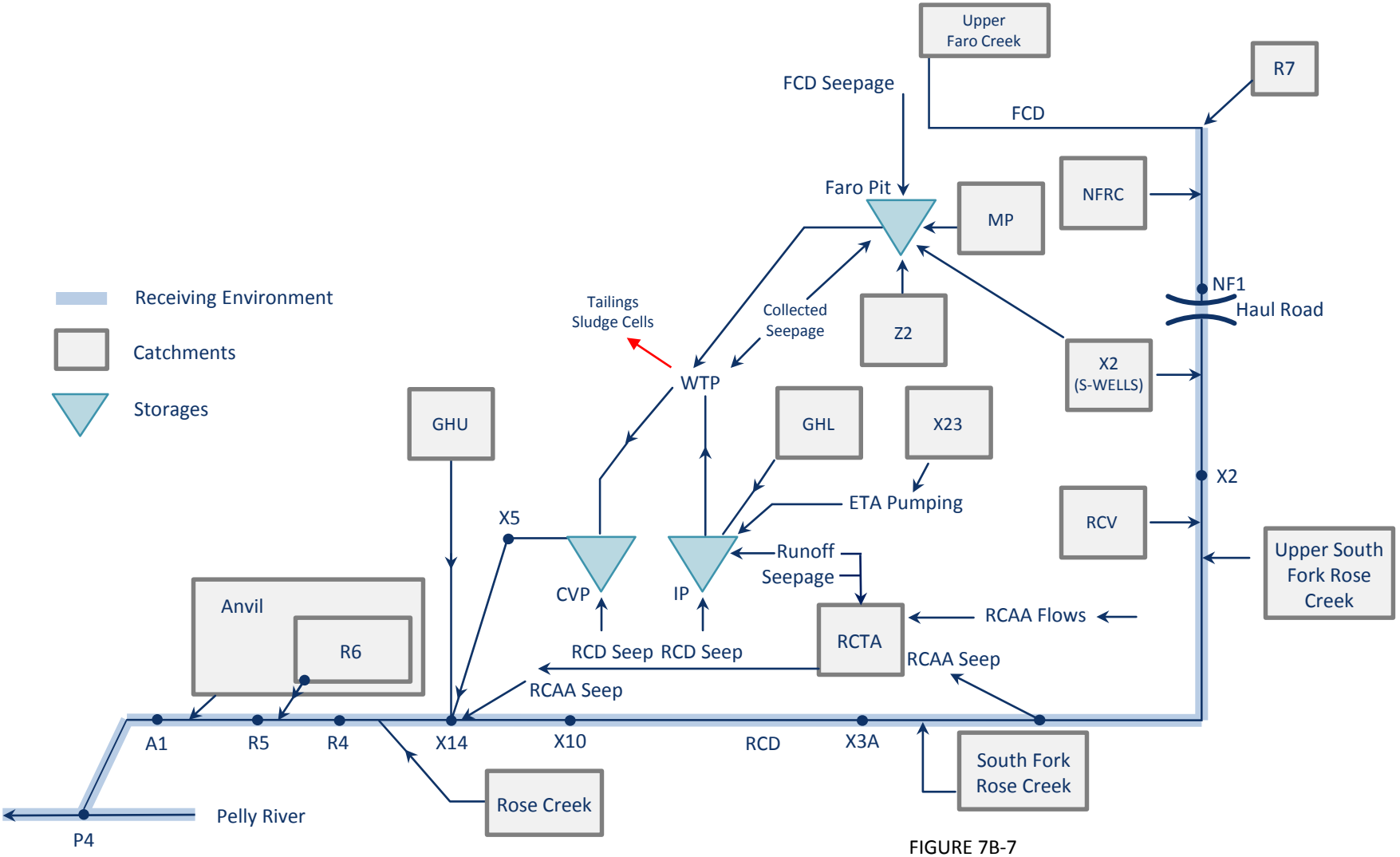


FIGURE 7B-7
Model Schematic for Faro Mine Area
Faro Mine Interim Works

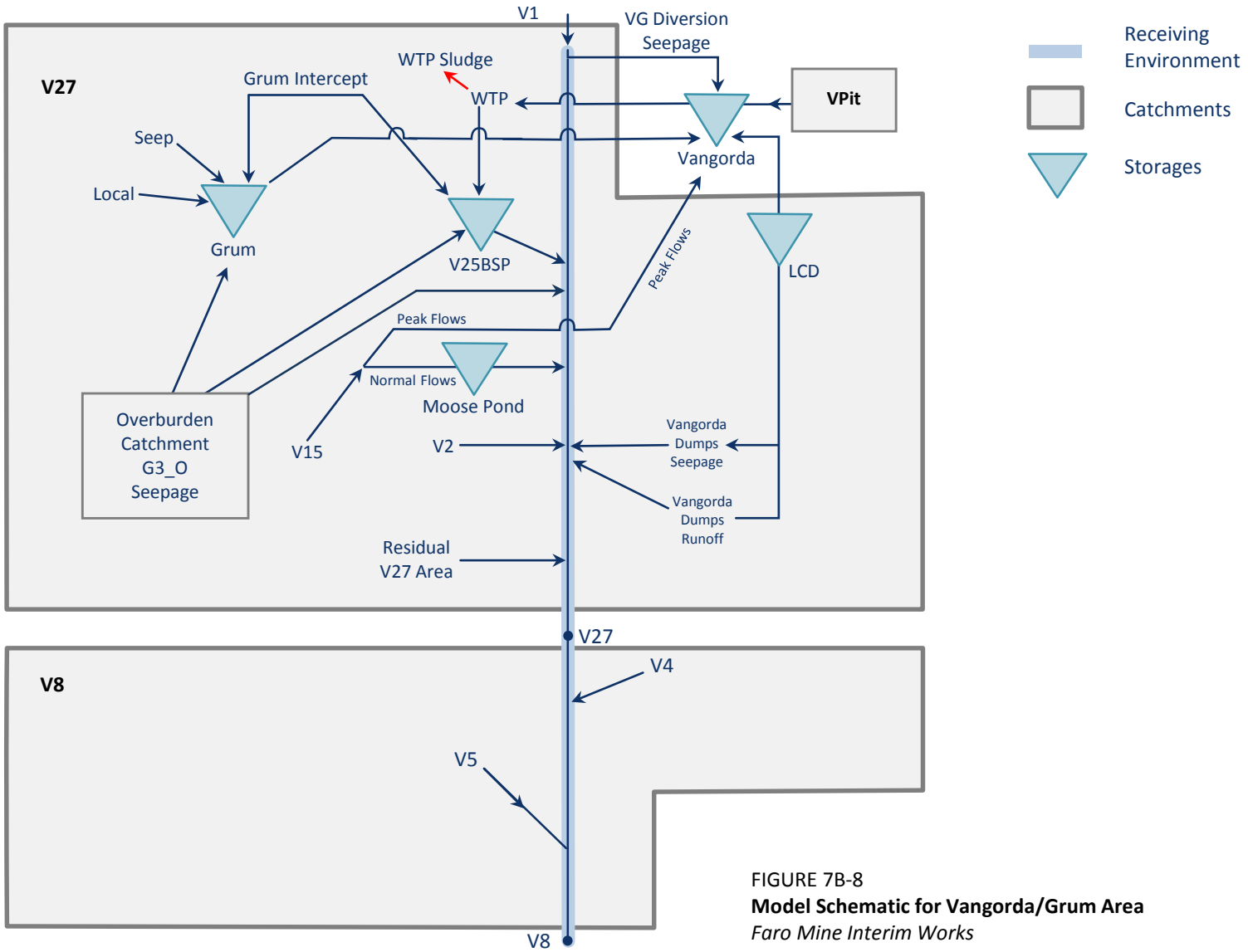


FIGURE 7B-8
Model Schematic for Vangorda/Grum Area
Faro Mine Interim Works

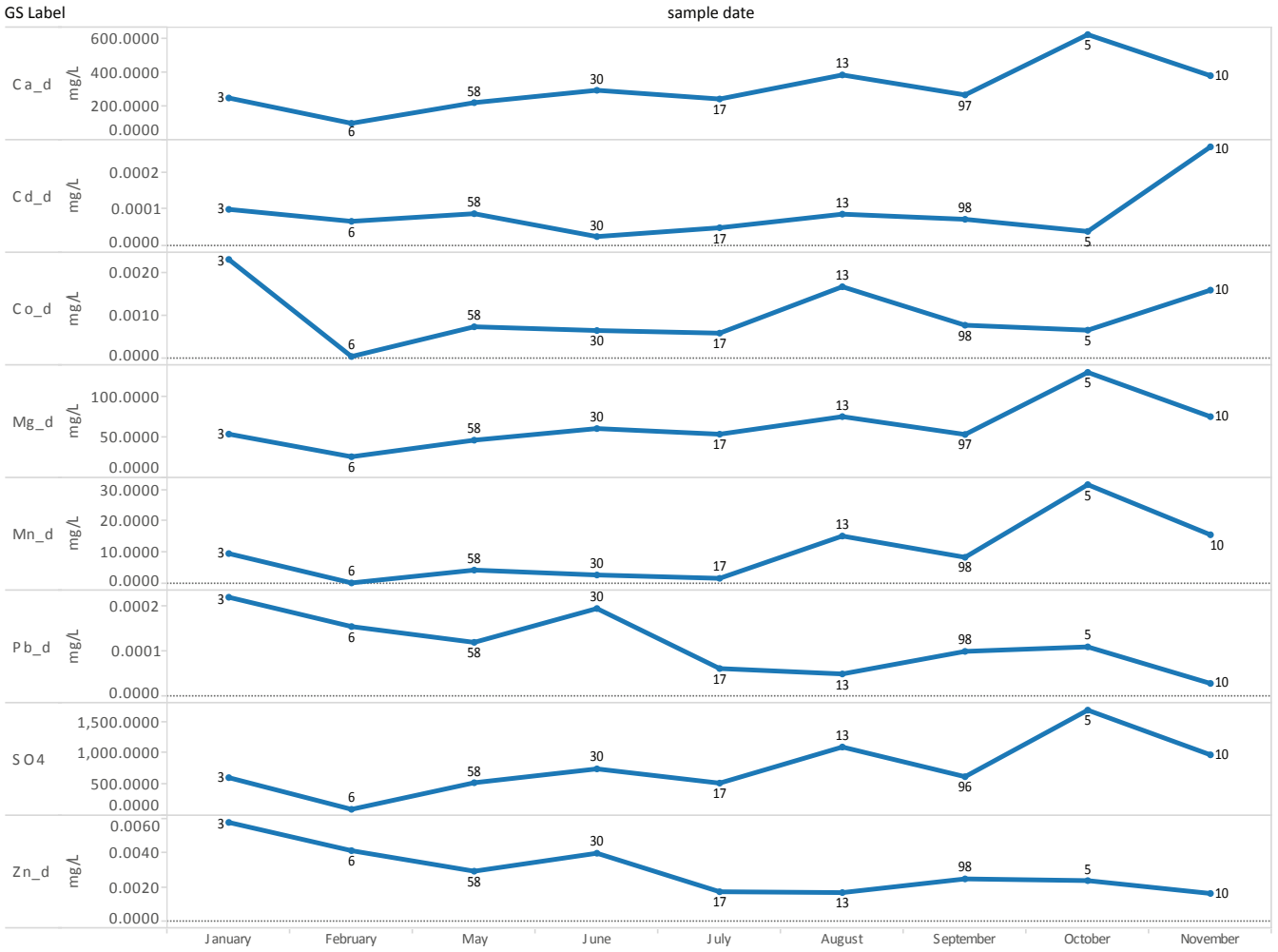


FIGURE 7B-9
RCAA Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.

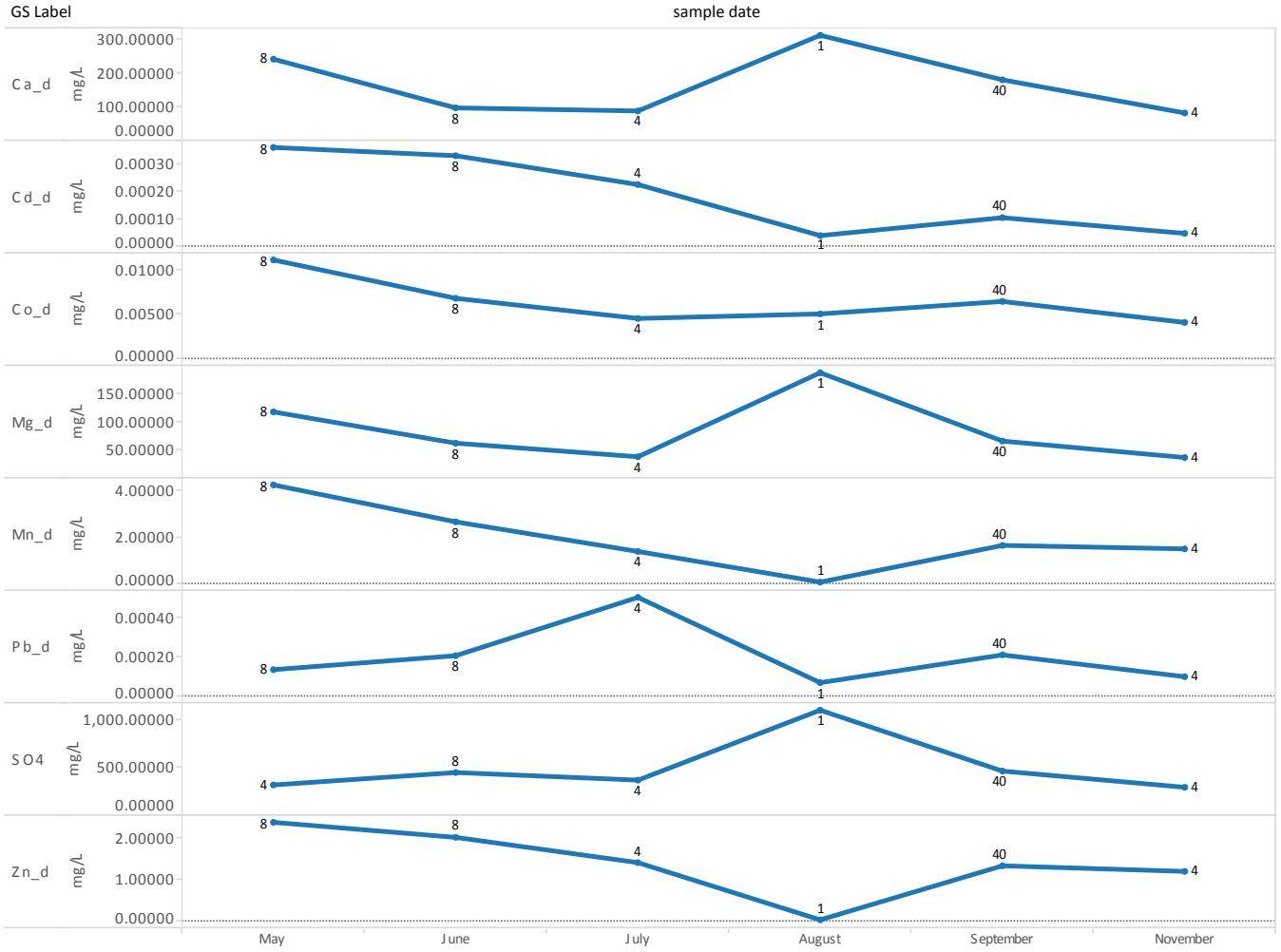


FIGURE 7B-10
SWells Perimeter Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.

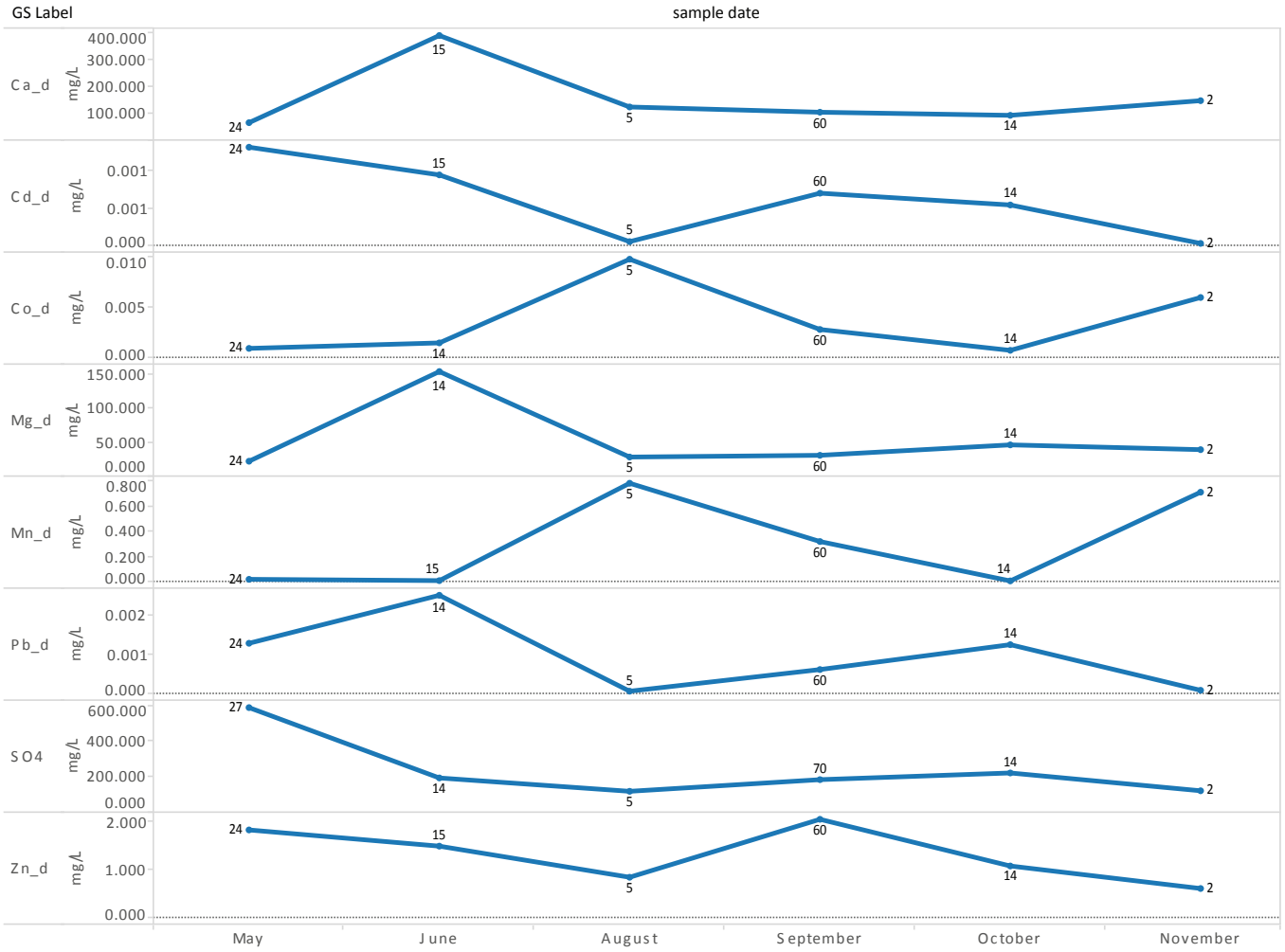
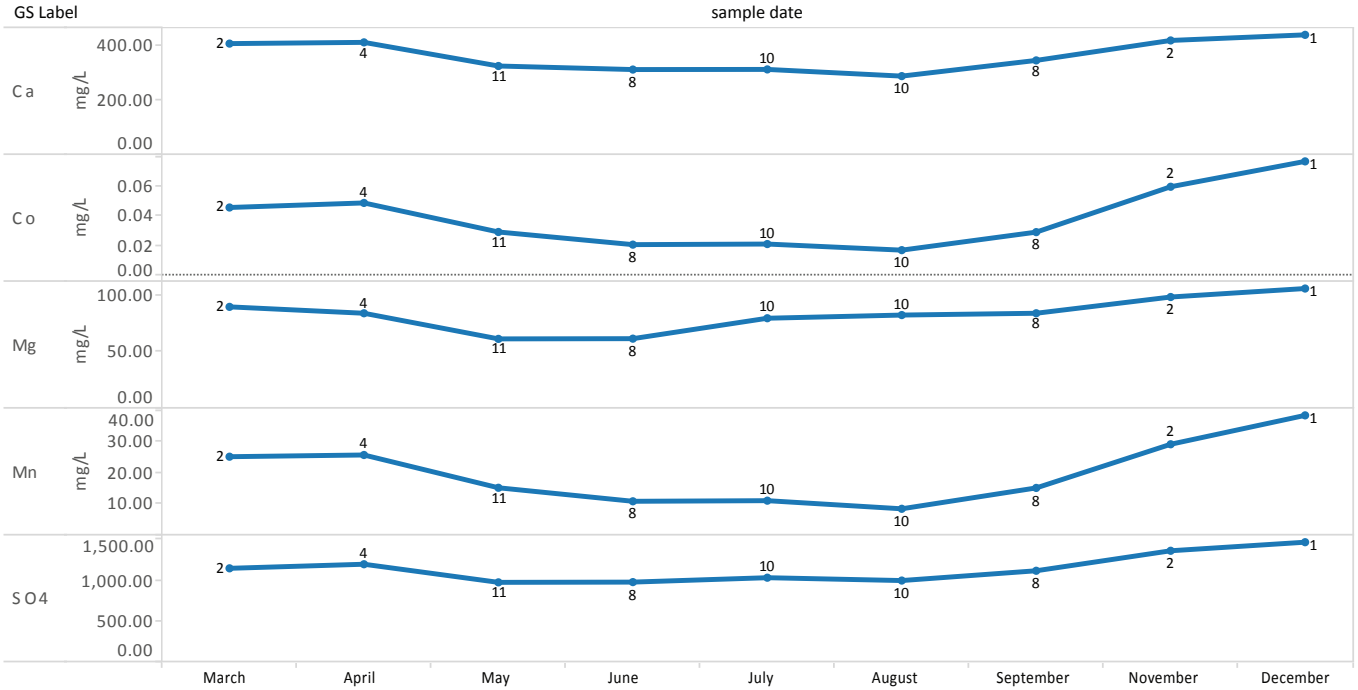


FIGURE 7B-11
NFRC Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.



Note:
Number next to point on plot indicates number of samples.

FIGURE 7B-12
X5 Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

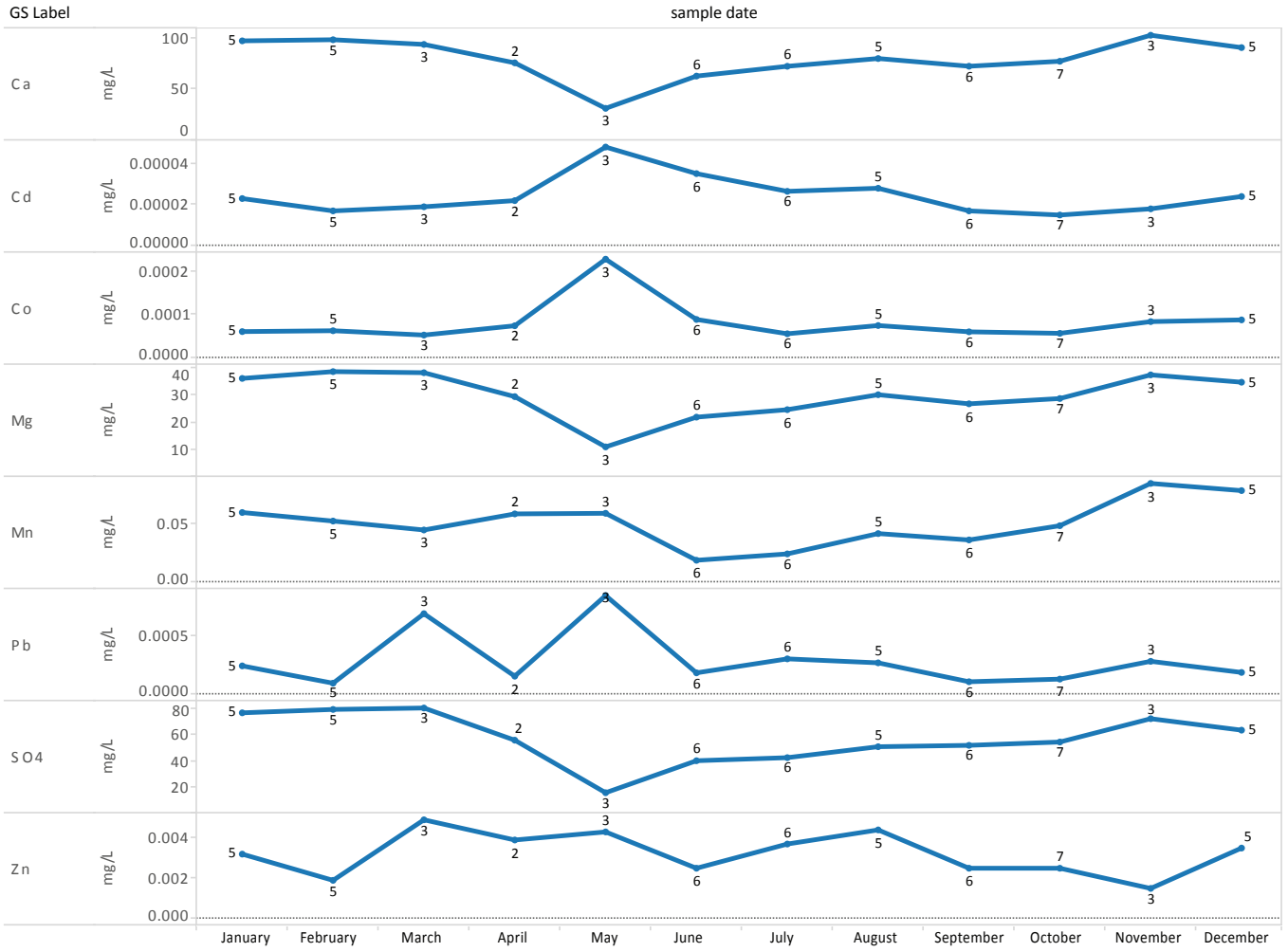


FIGURE 7B-13
V4 Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.

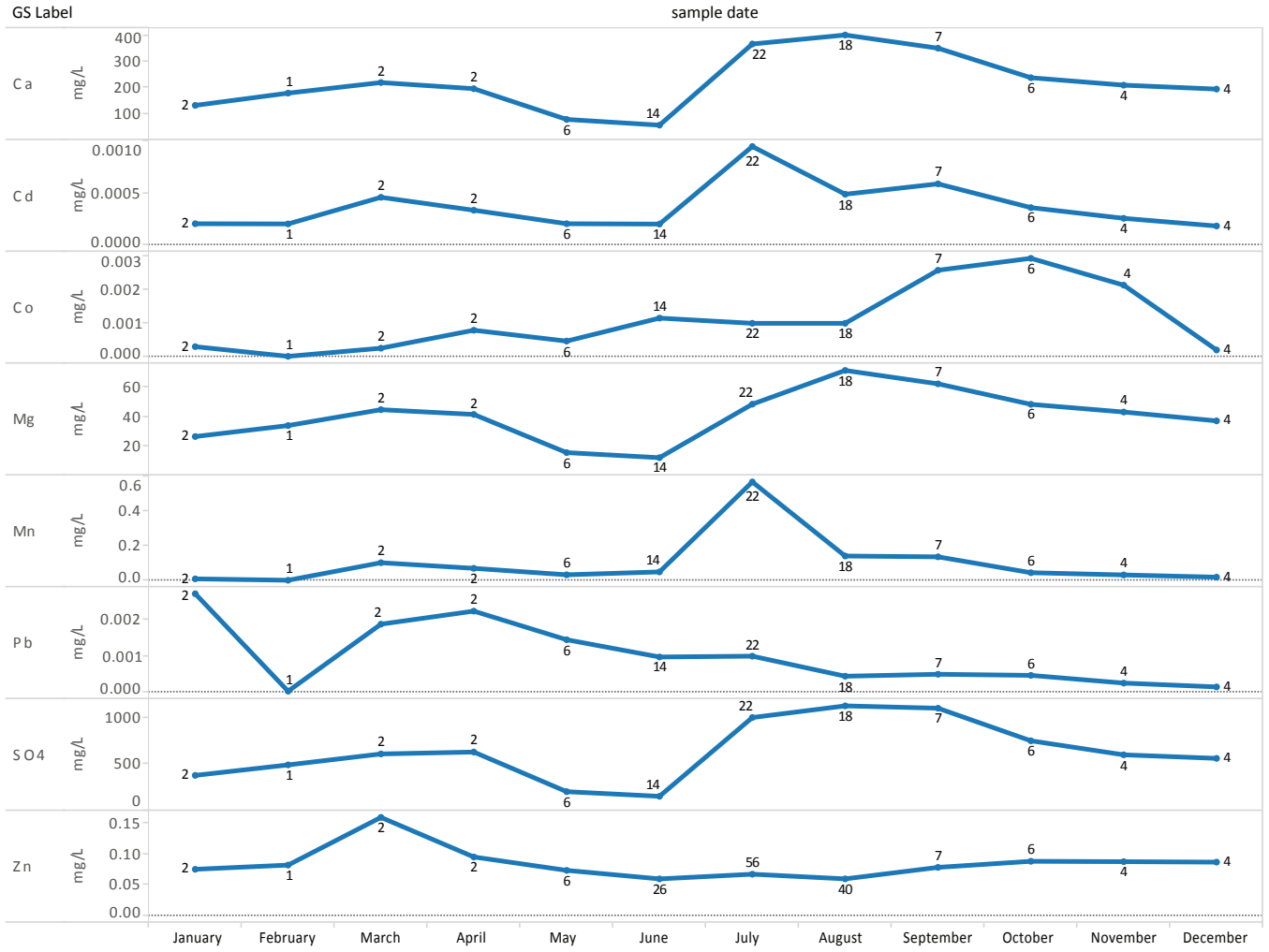


FIGURE 7B-14
V25BSP Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.

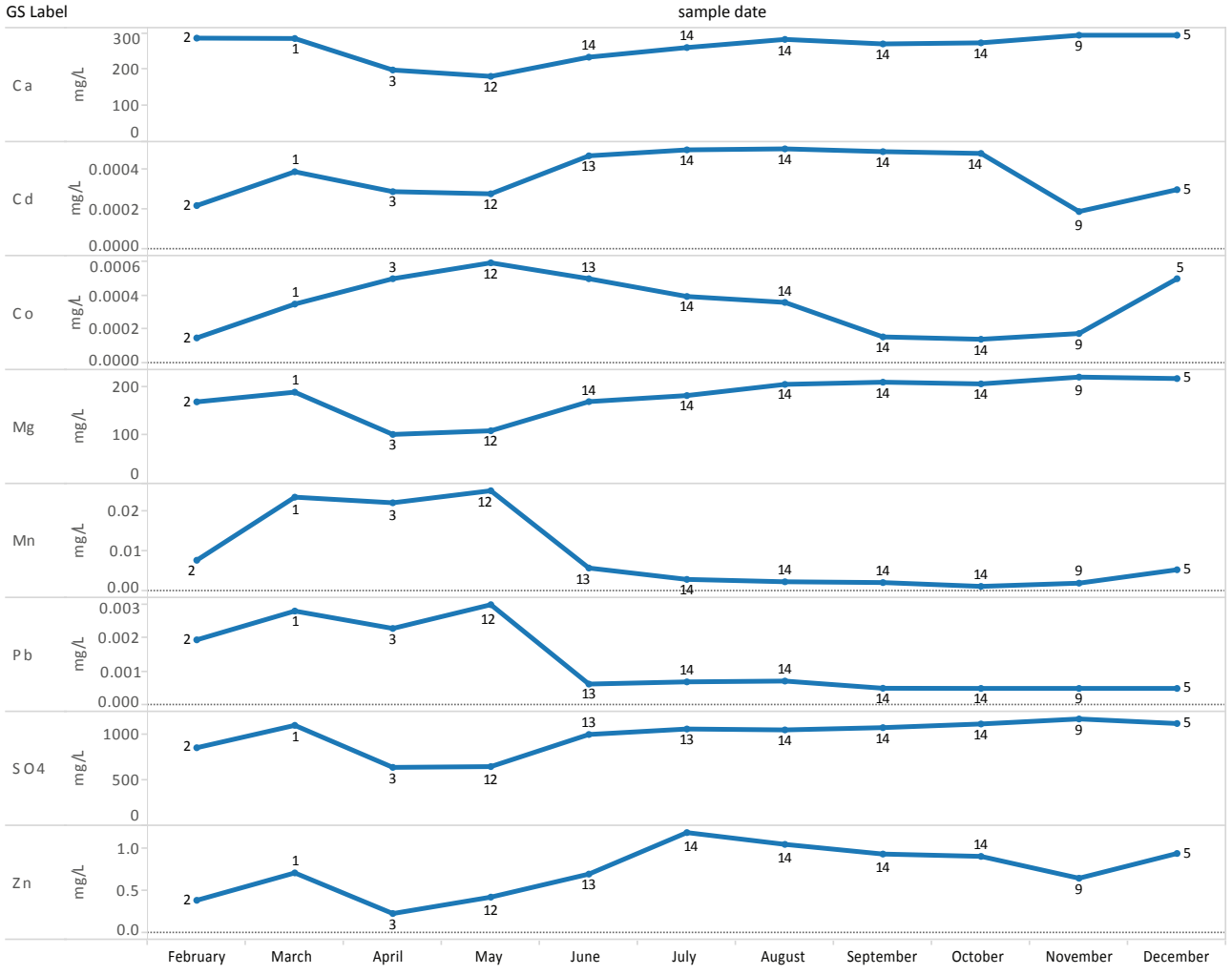


FIGURE 7B-15
V15 Collected Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.

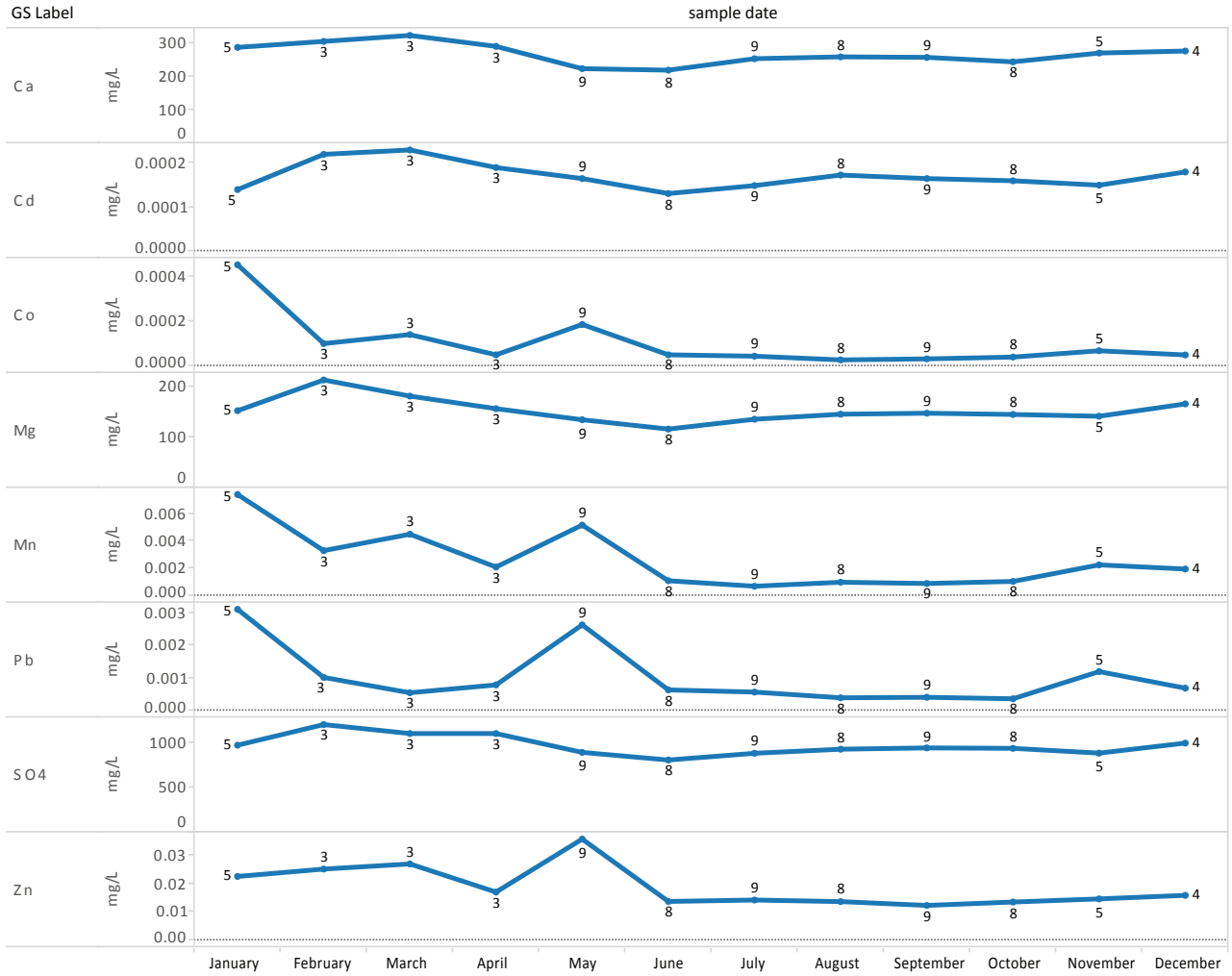
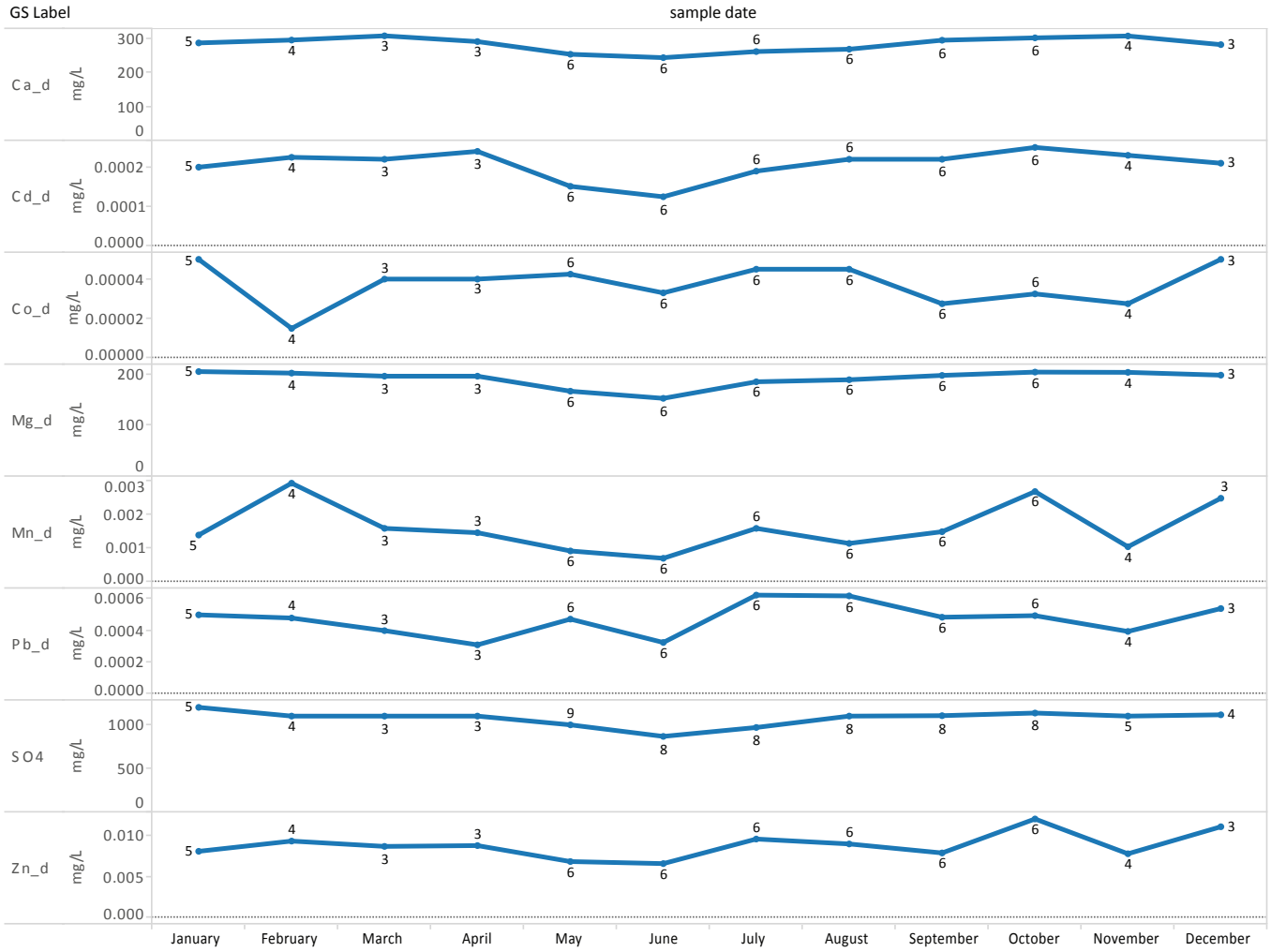


FIGURE 7B-16
Grum Run-off Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.



Note:
Number next to point on plot indicates number of samples.

FIGURE 7B-17
Grum Seepage Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

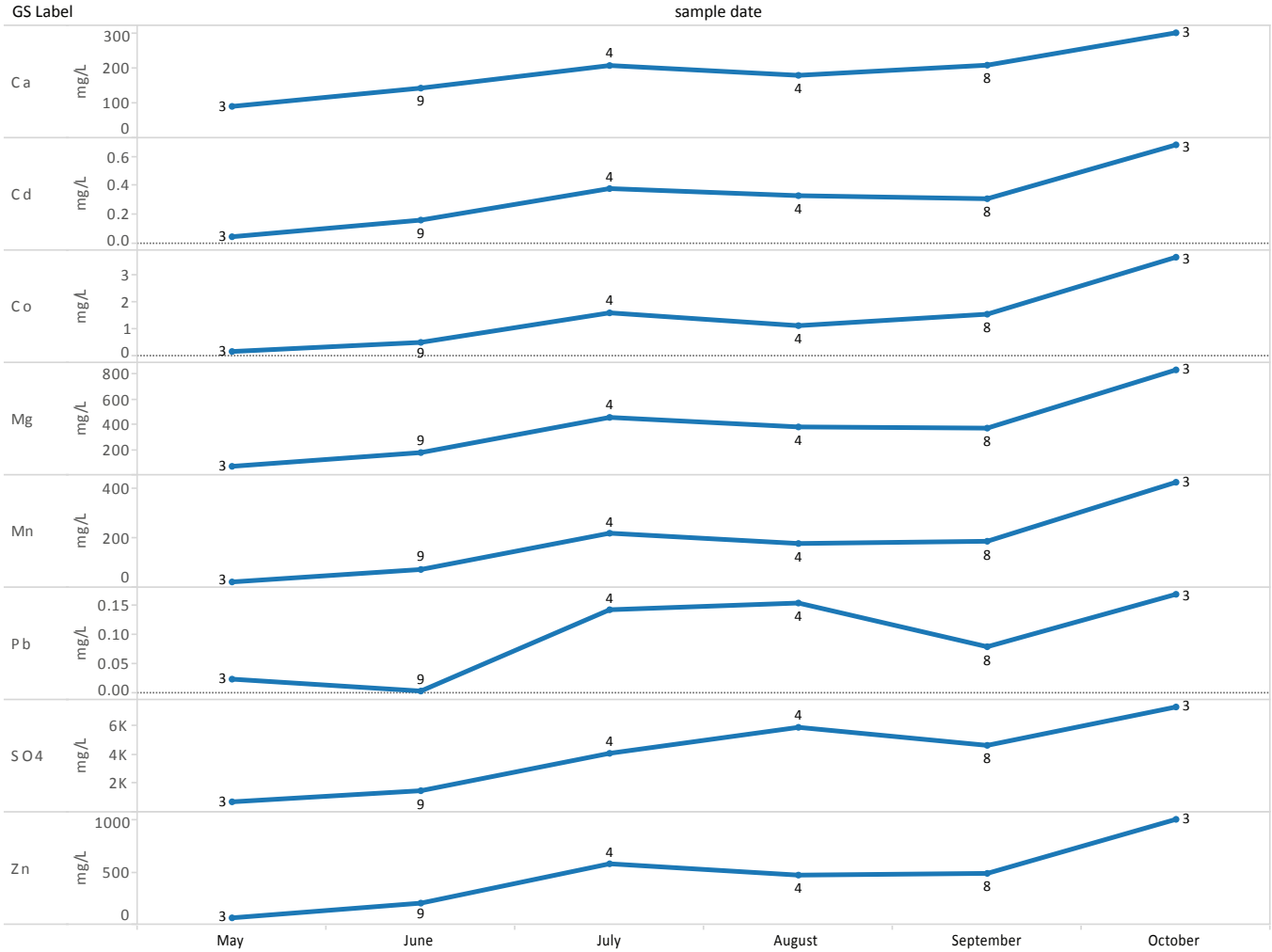


FIGURE 7B-18
VG WD Run-off Seepage Collected Monthly Median Concentration of Modeled Water Quality
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.

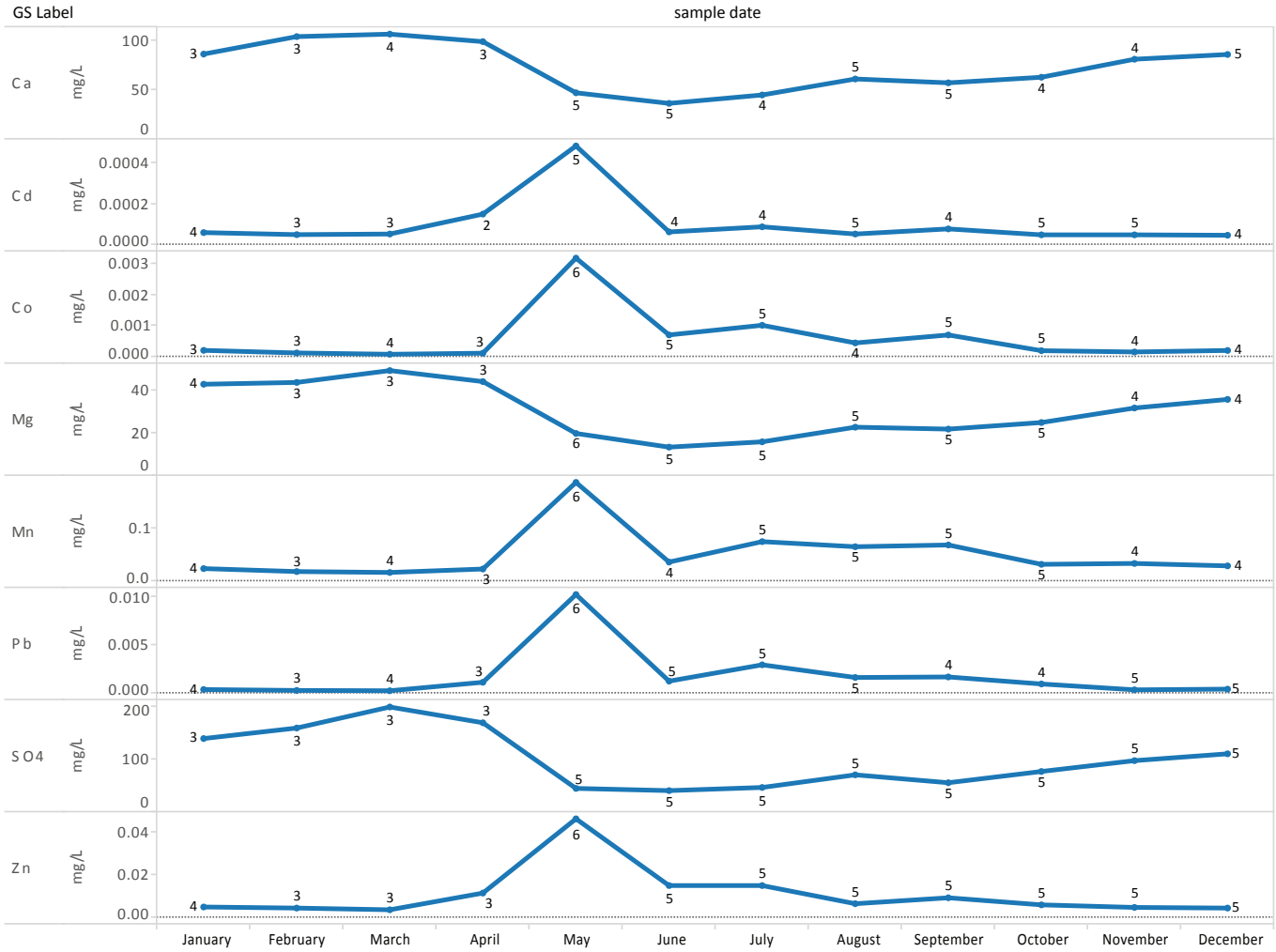


FIGURE 7B-19
V5 Monthly Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

Note:
Number next to point on plot indicates number of samples.

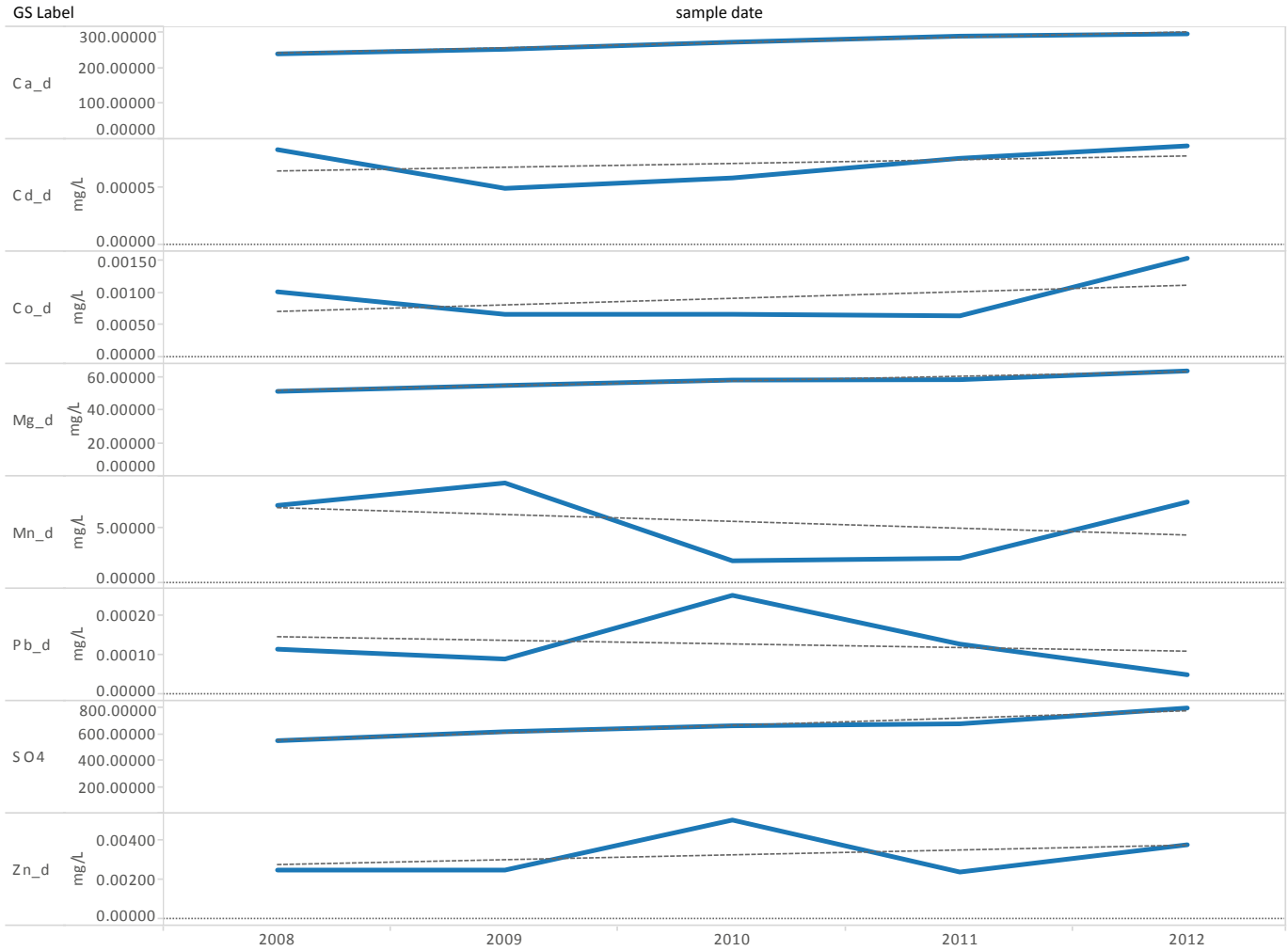


FIGURE 7B-20
RCAA Annual Median Concentration of Modeled Water Quality Parameters
Faro Mine Interim Works

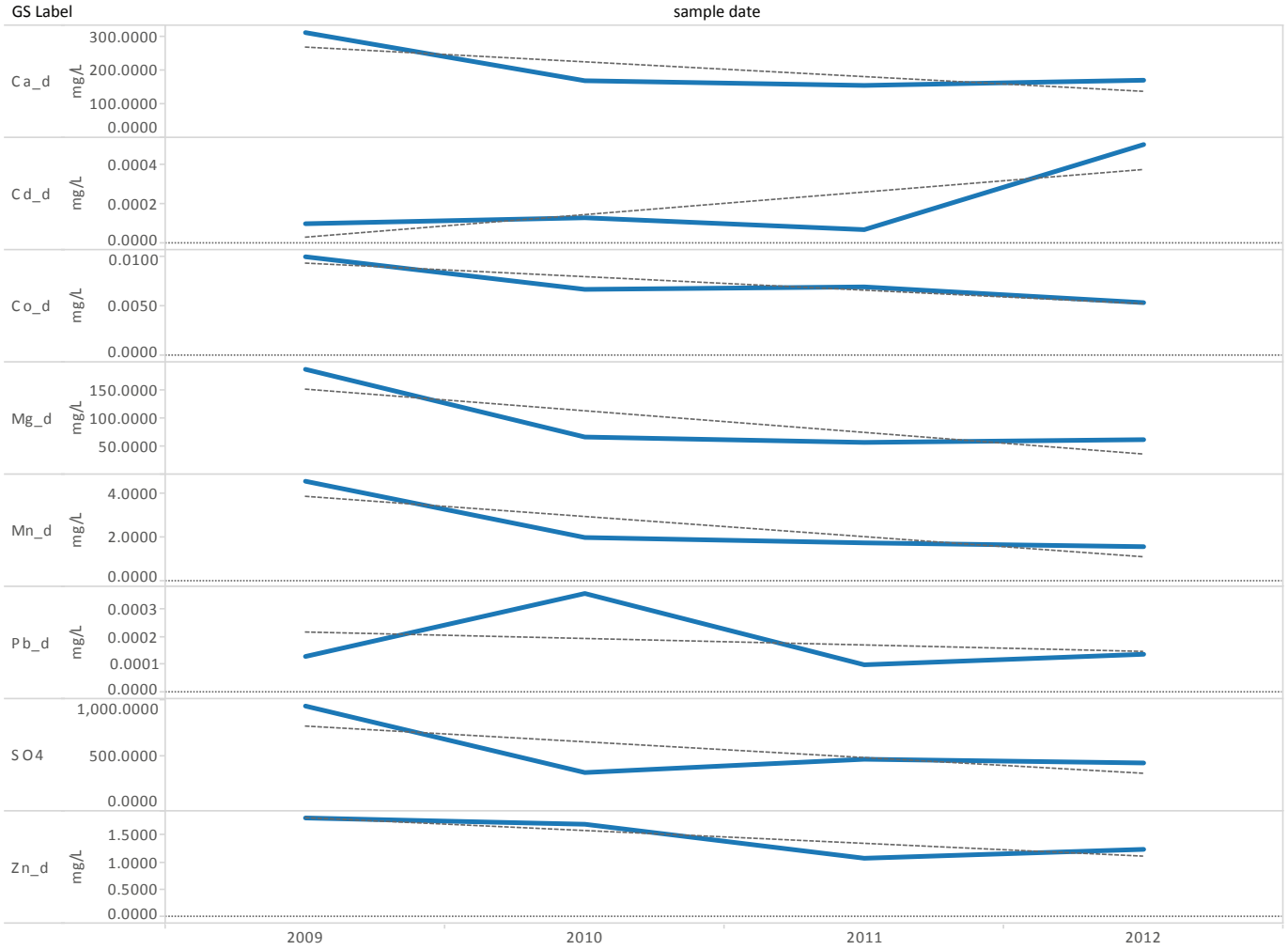


FIGURE 7B-21
SWells By-pass Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

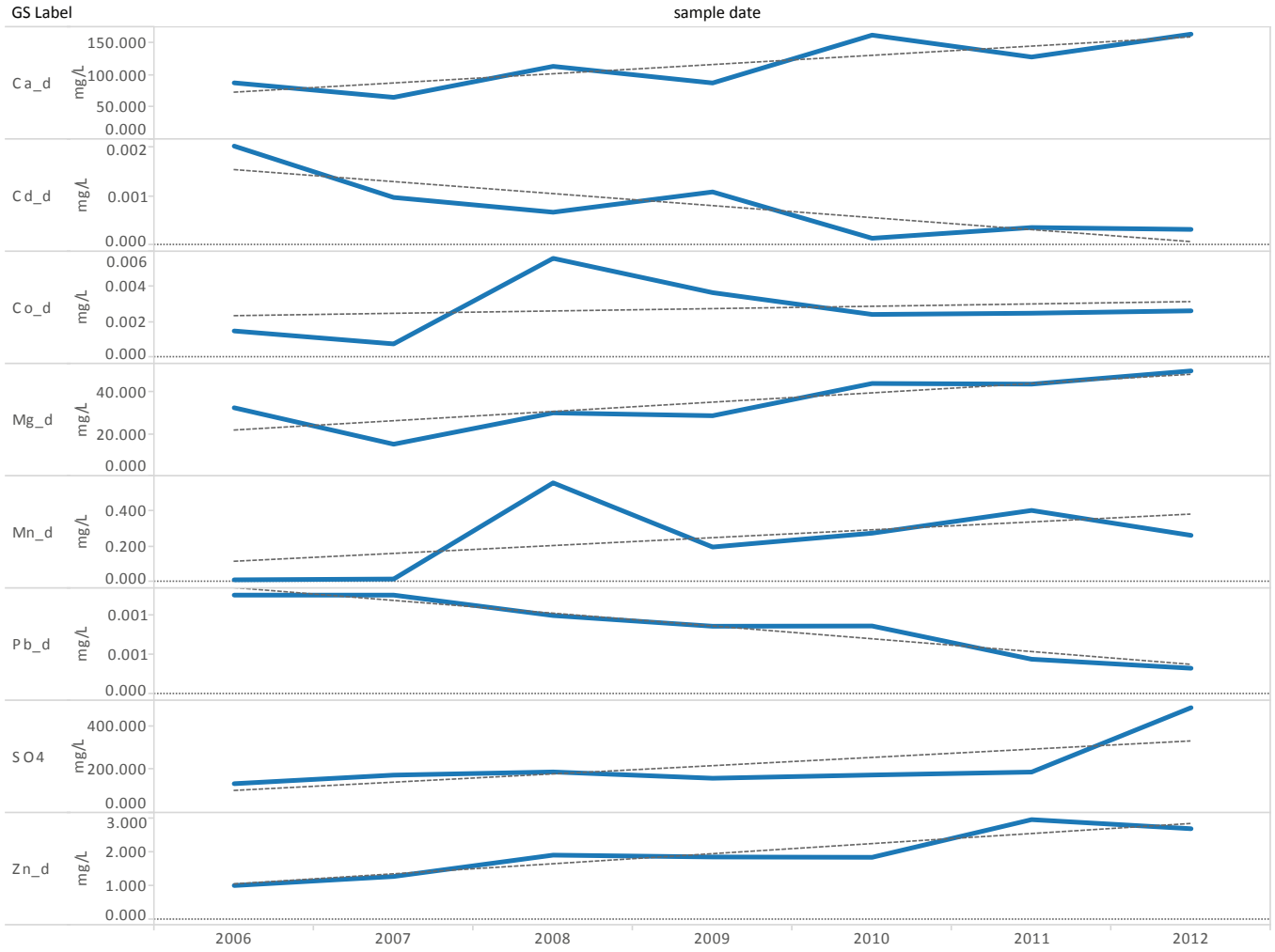


FIGURE 7B-22
NFRC Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

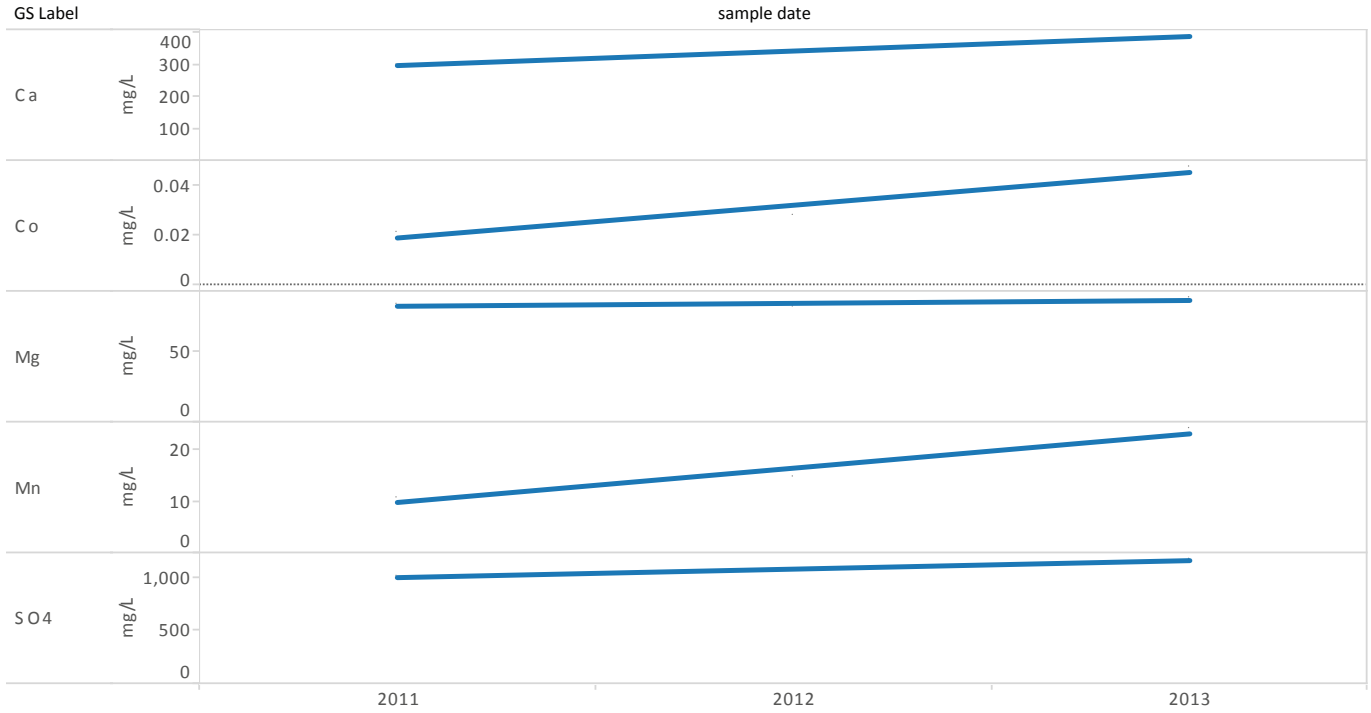


FIGURE 7B-23
X5 Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

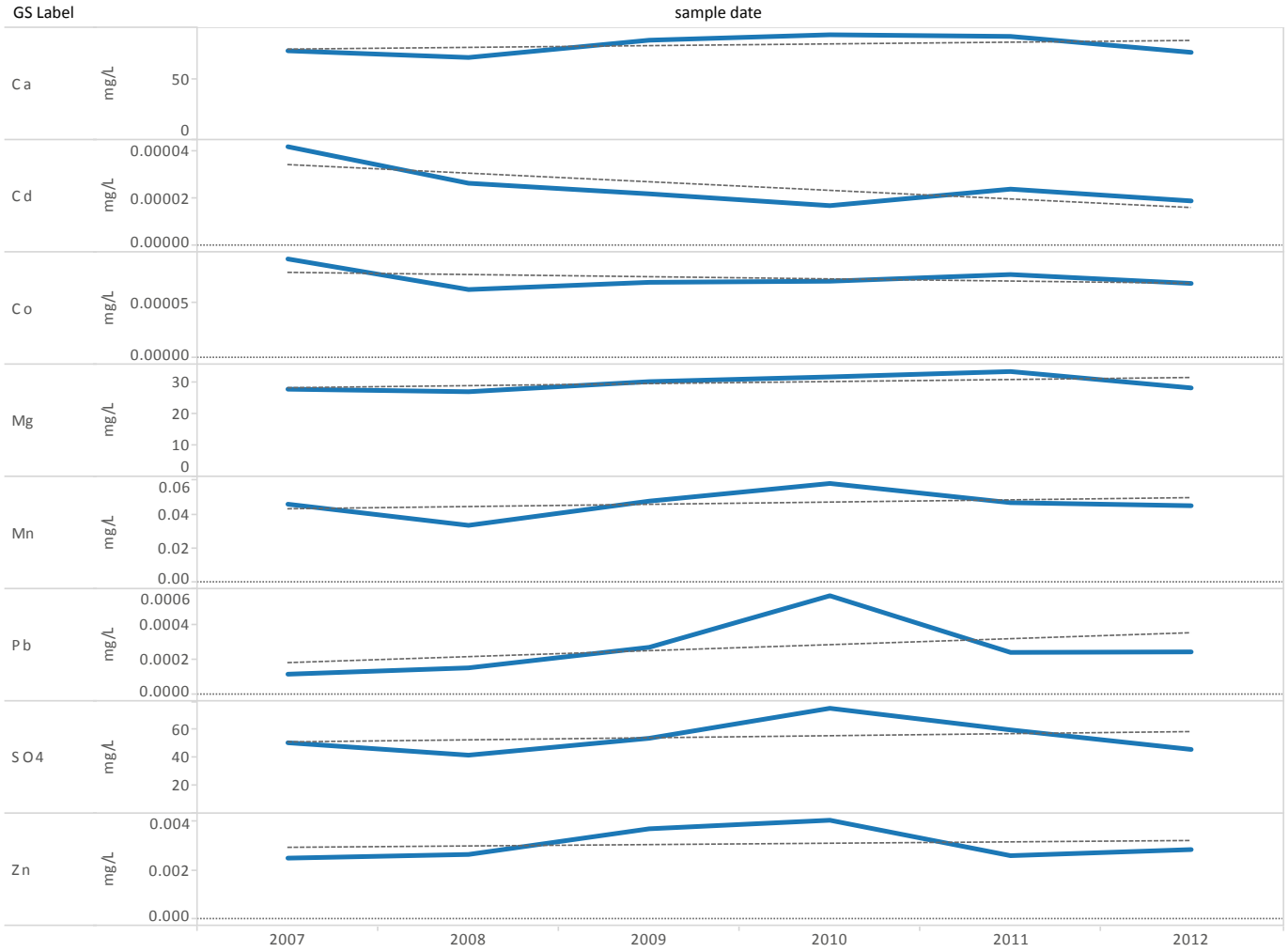


FIGURE 7B-24
V4 Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

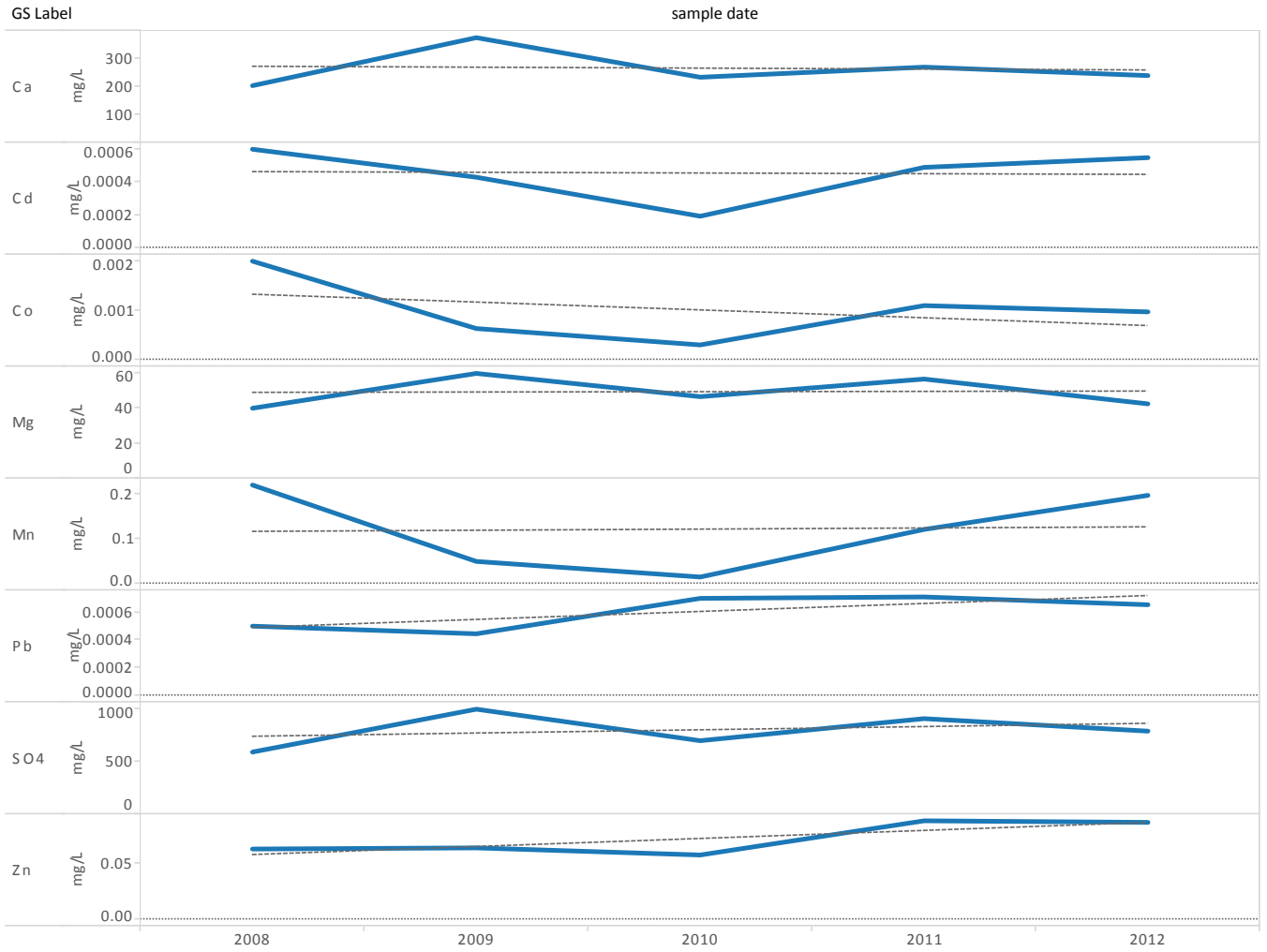


FIGURE 7B-25
V25BSP Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

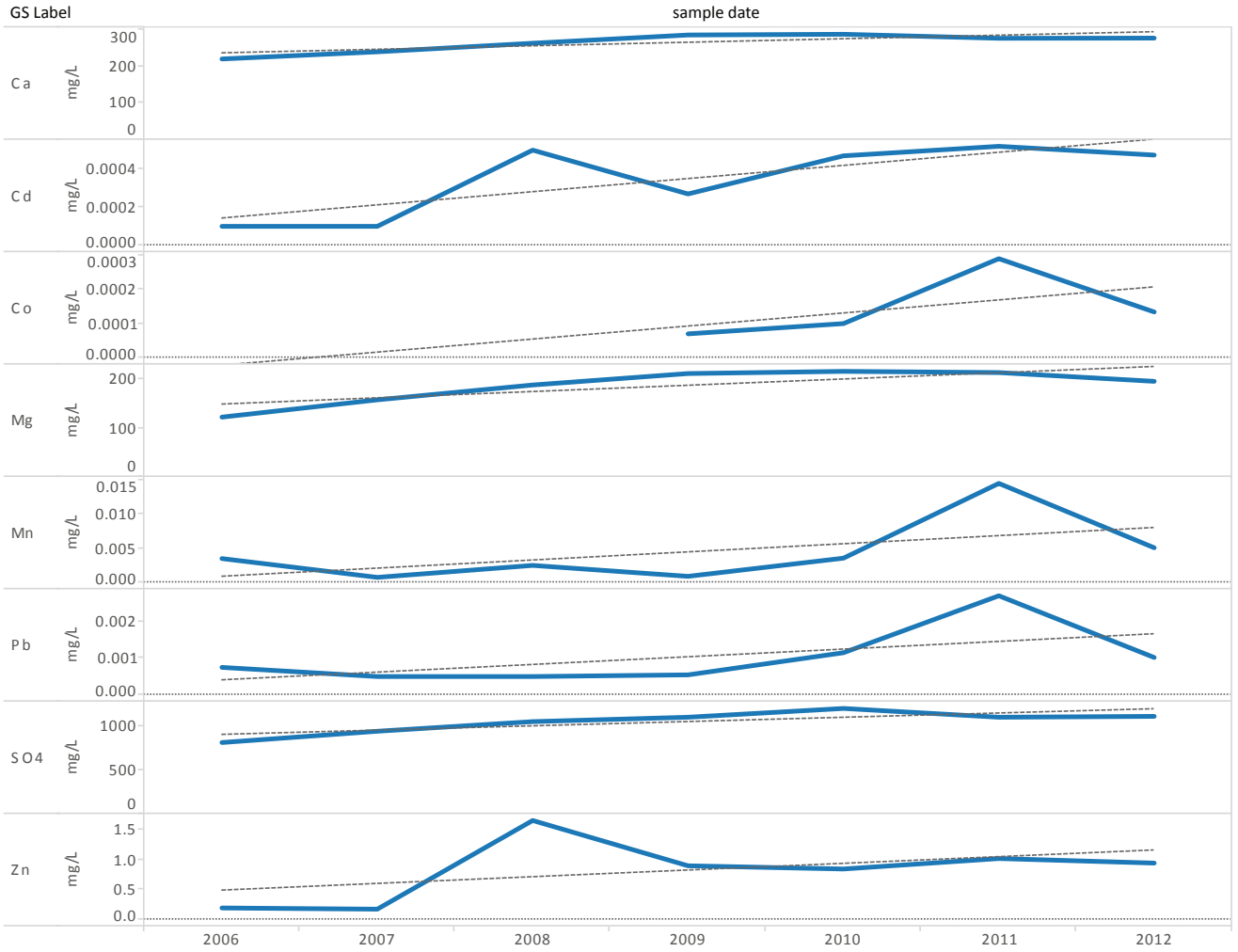


FIGURE 7B-26
V15 Collected Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

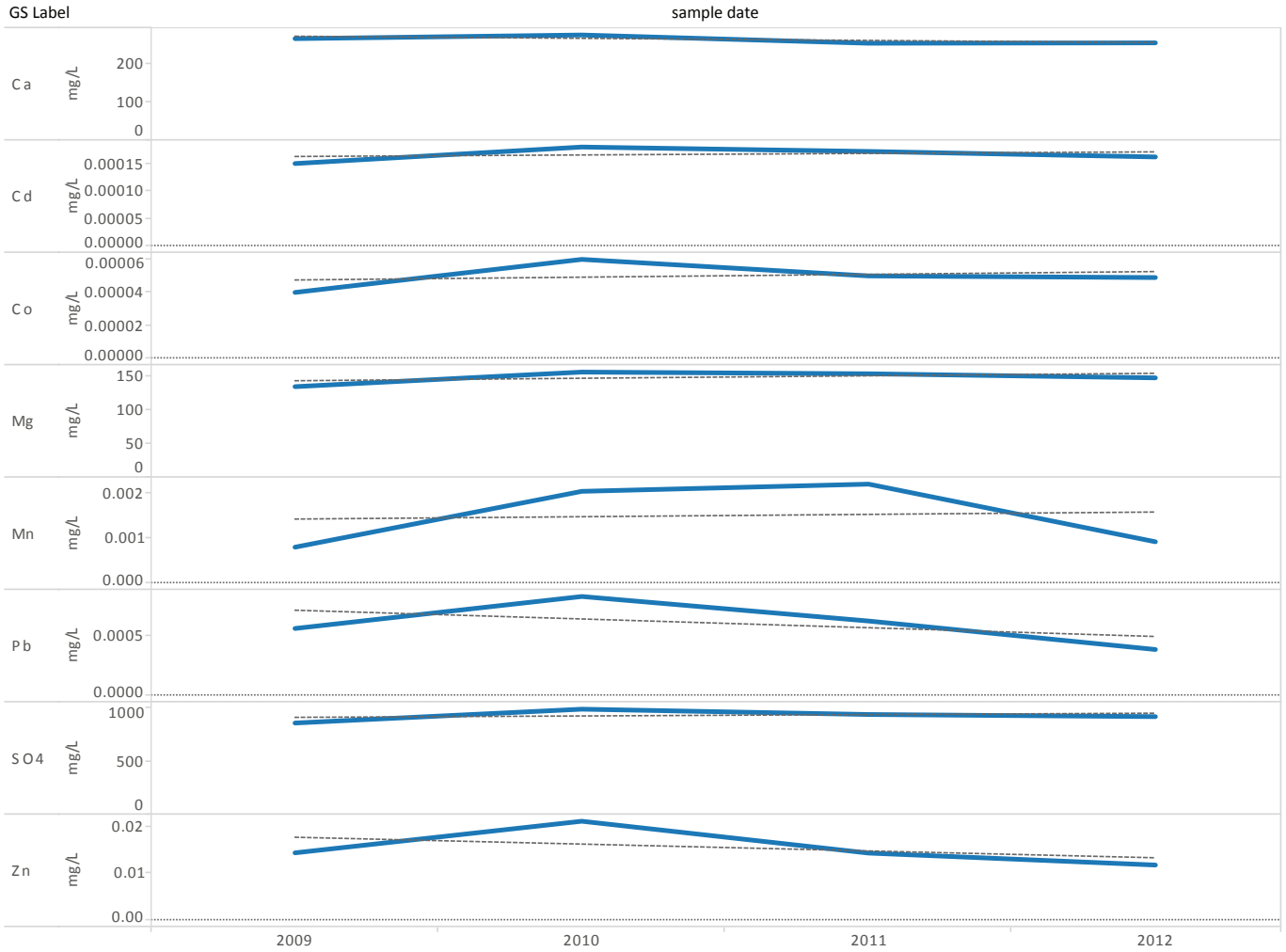


FIGURE 7B-27
Grum WD Run-off Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

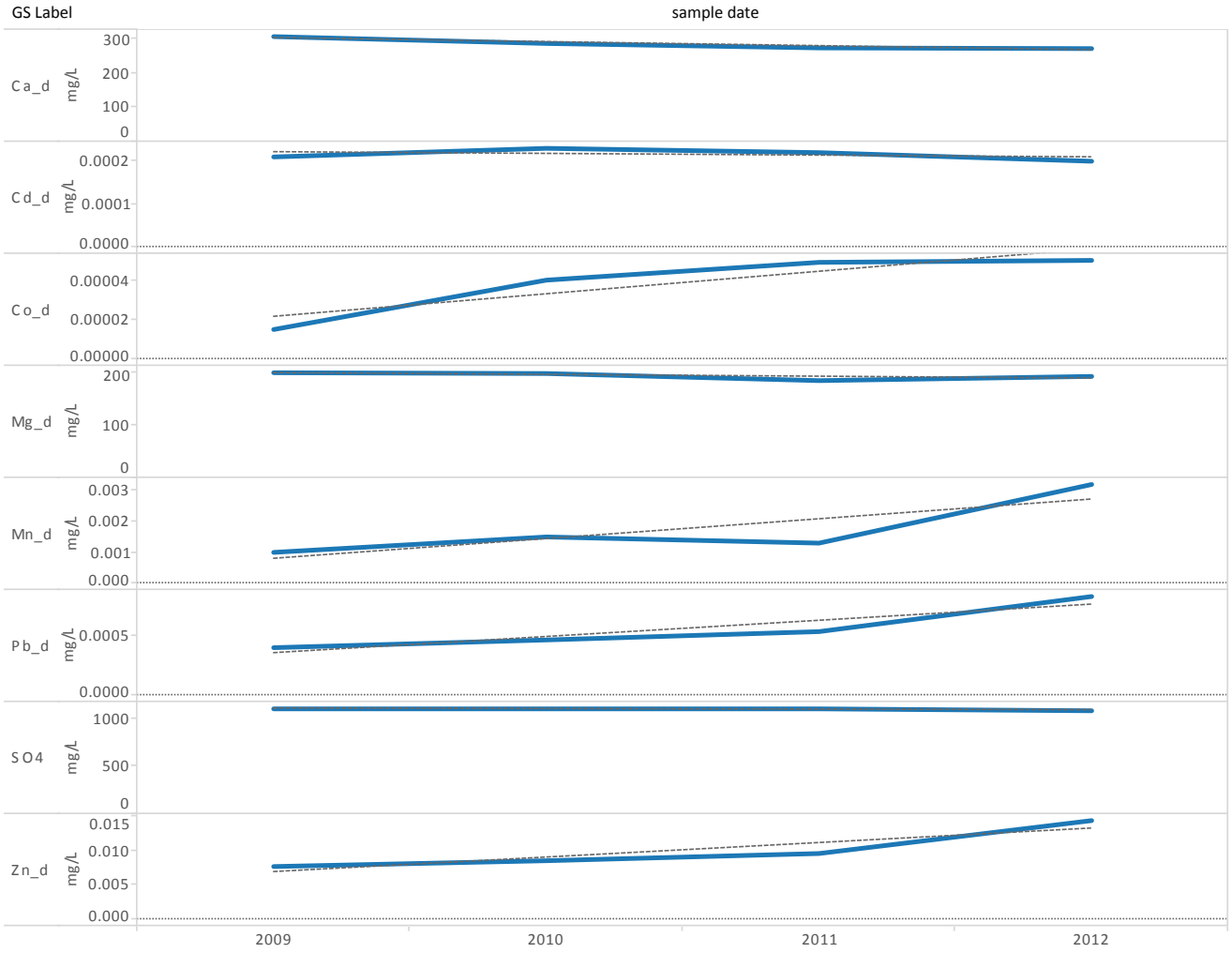


FIGURE 7B-28
Grum Seepage Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

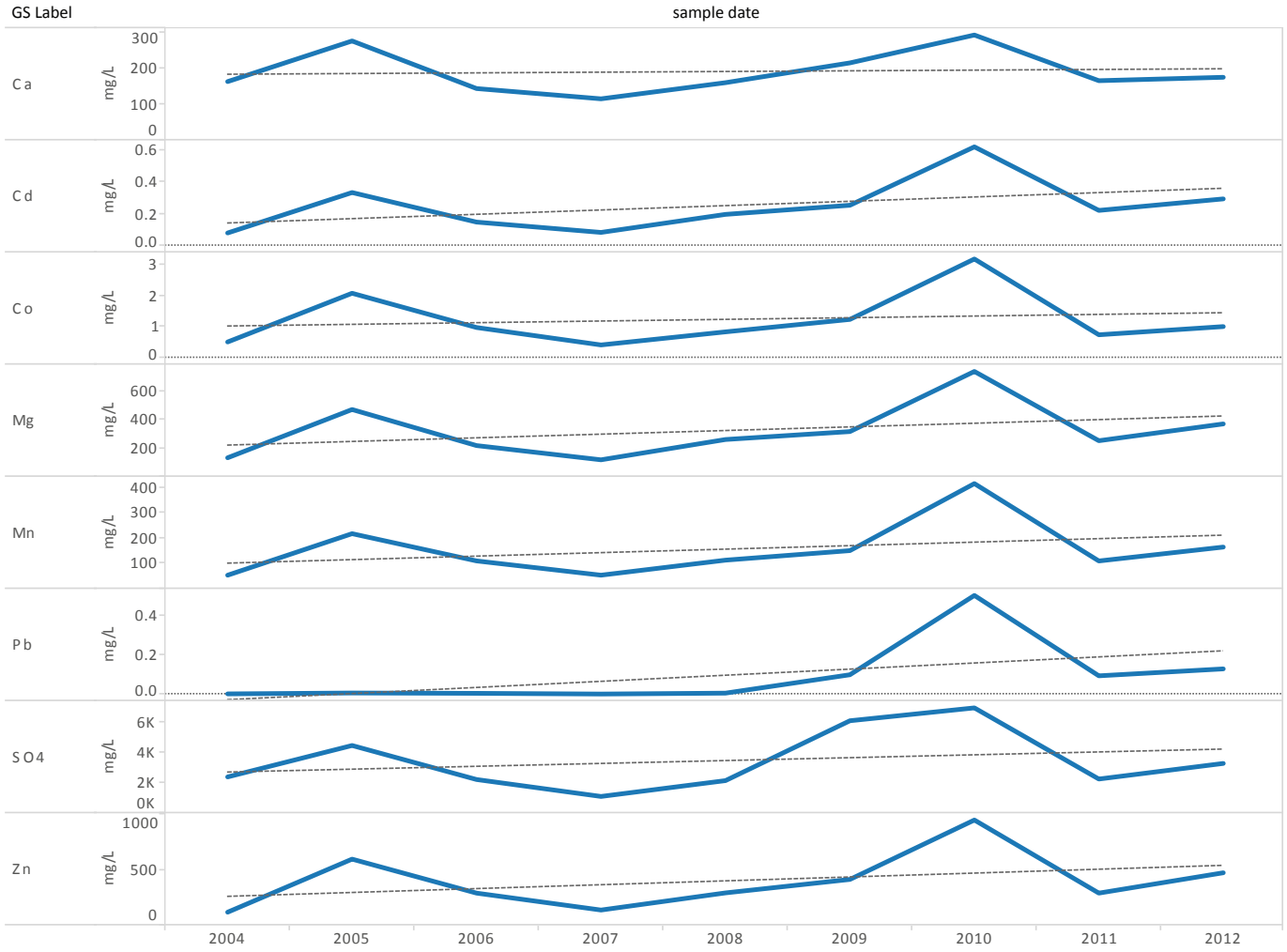


FIGURE 7B-29
VG WD Run-off Seepage Collected Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works

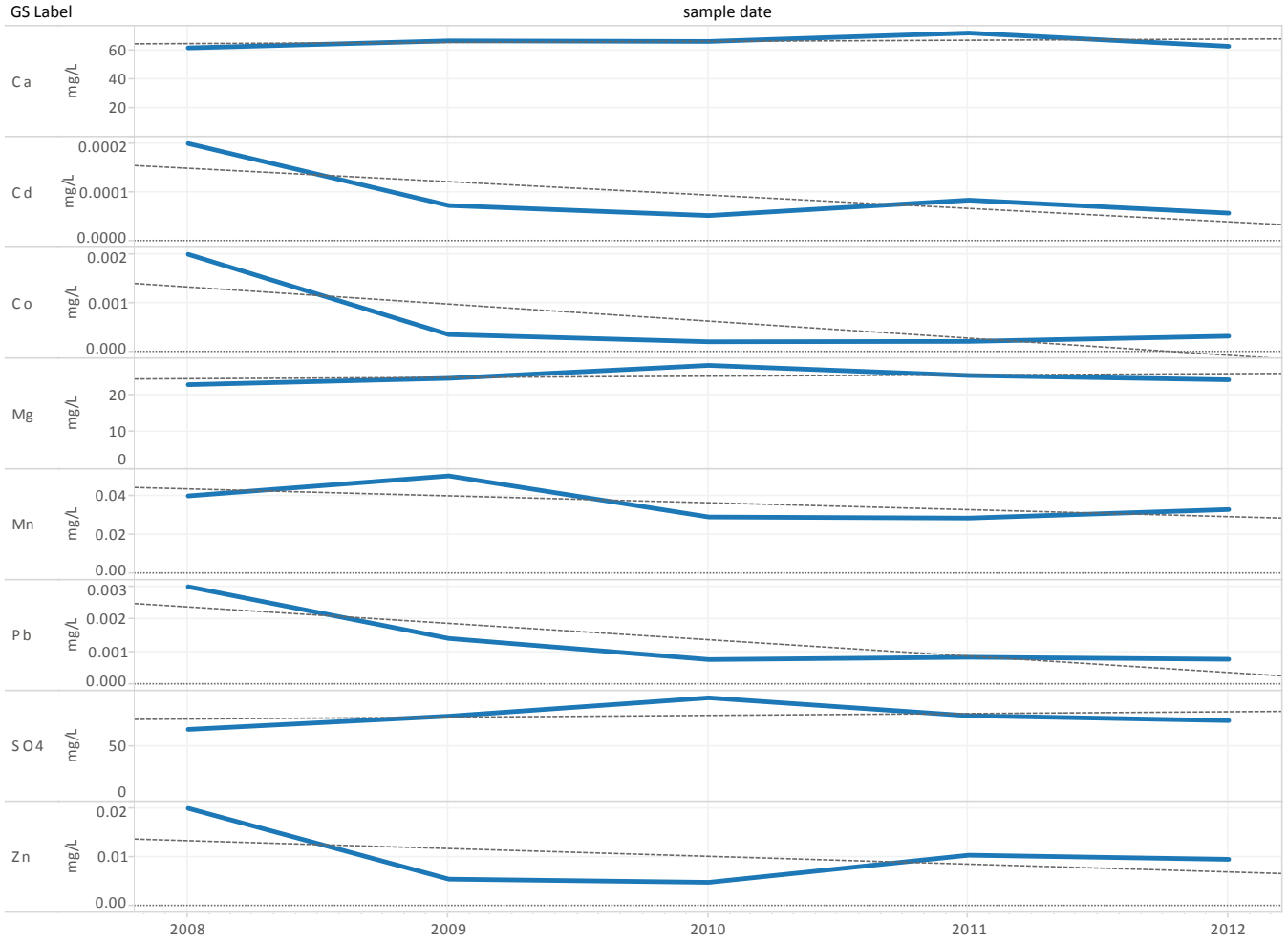
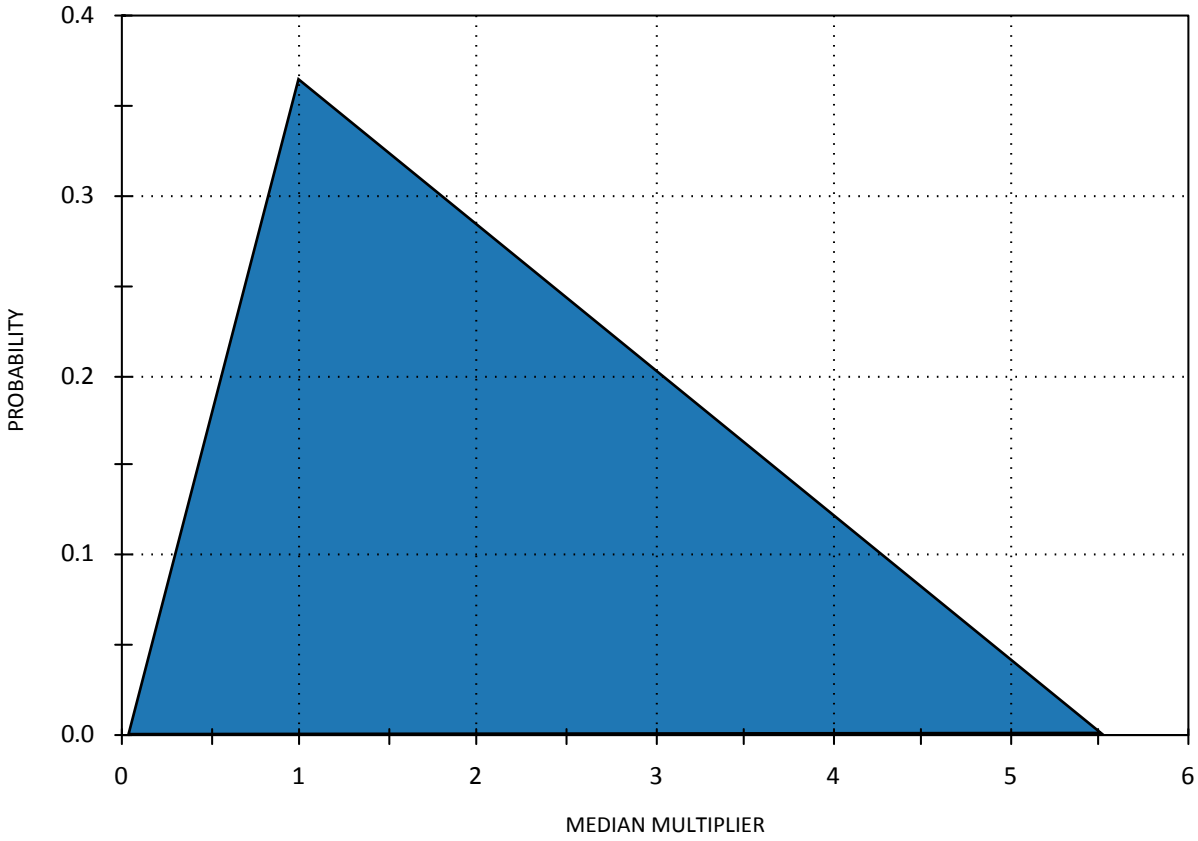


FIGURE 7B-30
V5 Annual Median Concentration of Modeled Water Quality Parameter
Faro Mine Interim Works



Notes:
Most Likely Value 1 = 0.36
Max Value = 5.52 probability = 0
Min = 0.038 probability = 0

FIGURE 7B-31
Example of How the Monthly Water Quality Variability was Considered in the Model
Faro Mine Interim Works

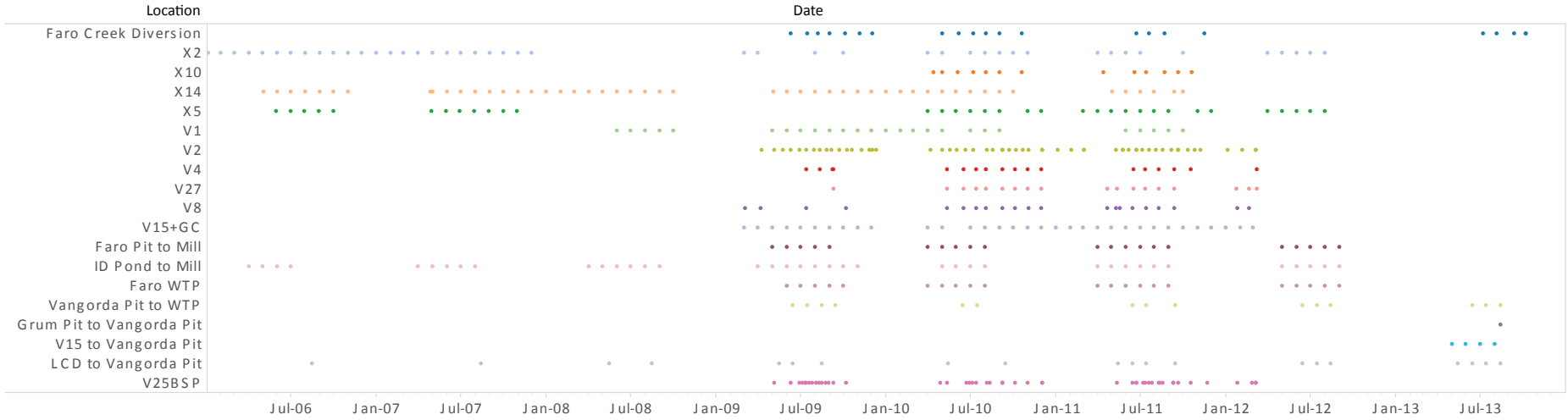


FIGURE 7B-32
Data Gaps – Flows
Faro Mine Interim Works

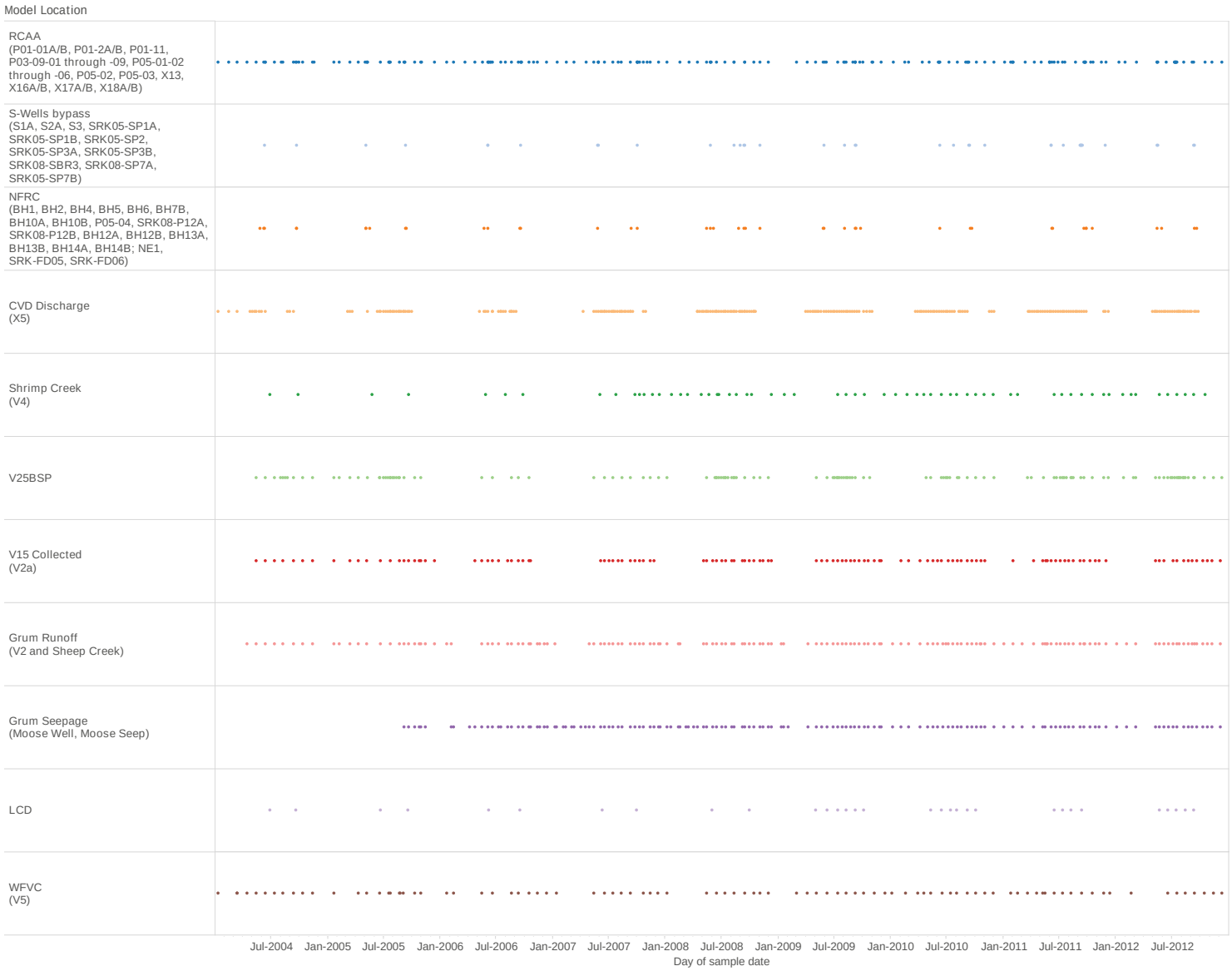


FIGURE 7C-33
Water Quality Data Gaps
Faro Mine Interim Works

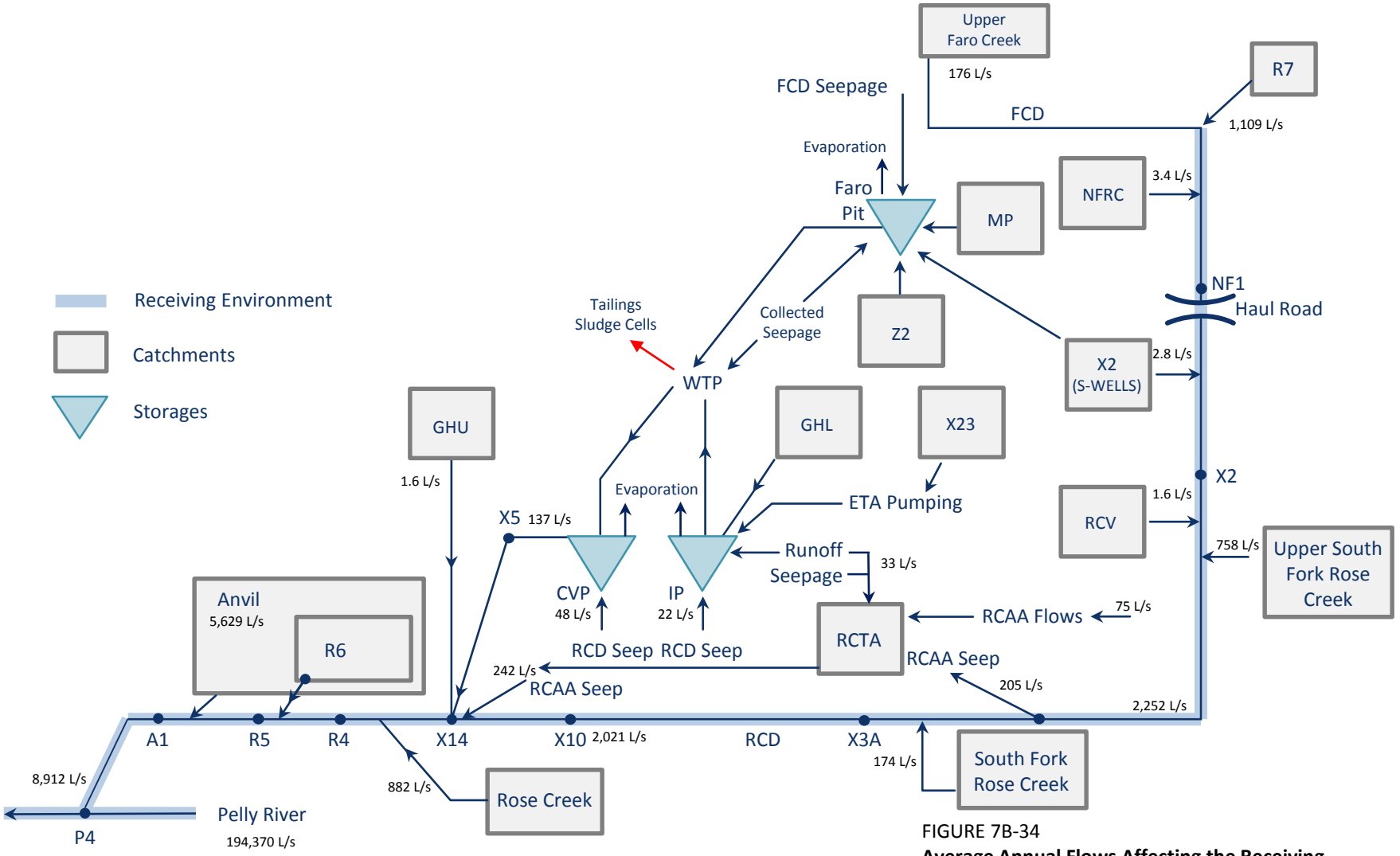


FIGURE 7B-34
Average Annual Flows Affecting the Receiving Environment for the Faro Mine Area
Faro Mine Interim Works

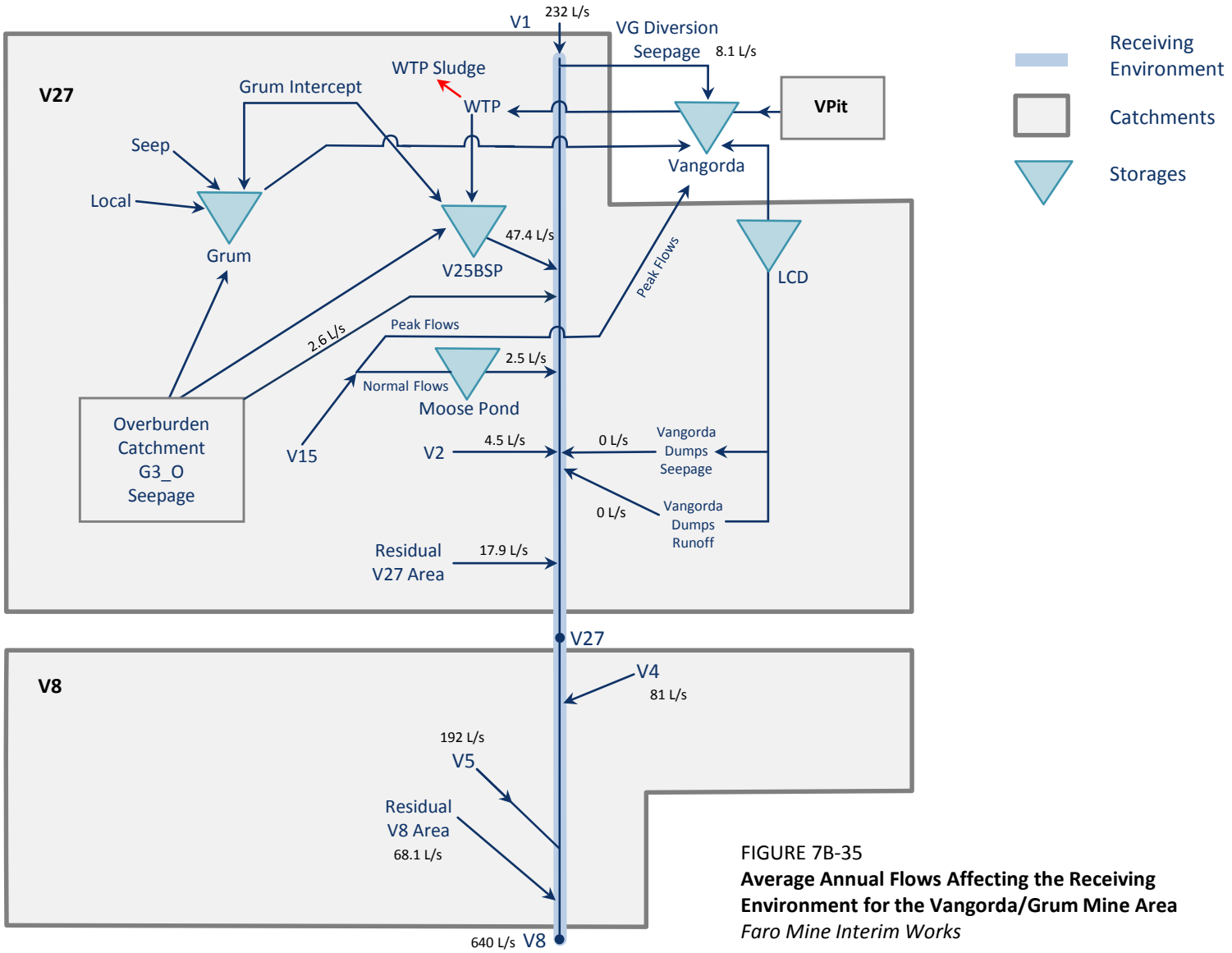
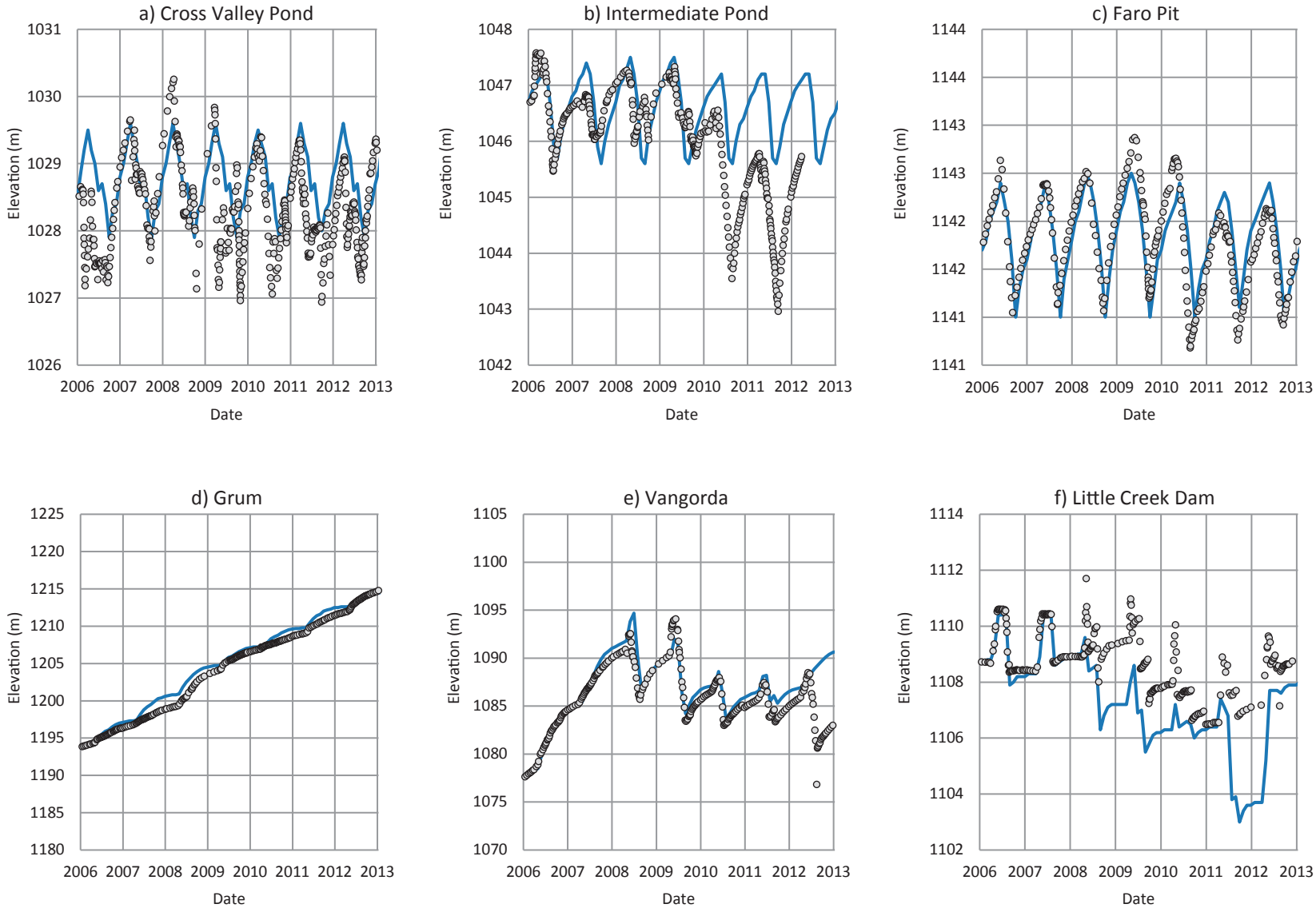


FIGURE 7B-35
Average Annual Flows Affecting the Receiving Environment for the Vangorda/Grum Mine Area
Faro Mine Interim Works

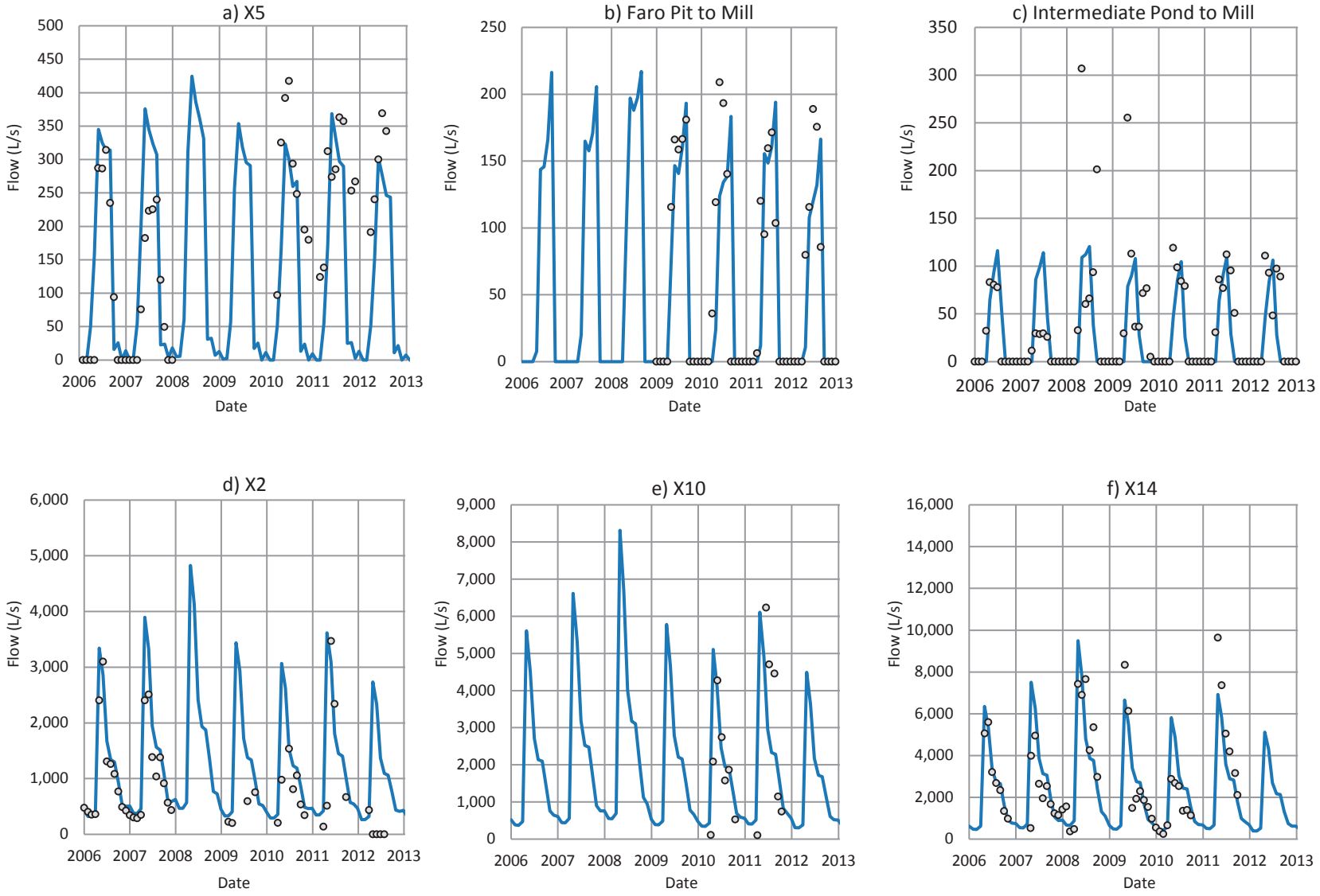


LEGEND

Historical Model Results

Measured Values

FIGURE 7B-36
Comparison of the Model Results versus Measured Elevation at all the Storages Modelled
Faro Mine Interim Works

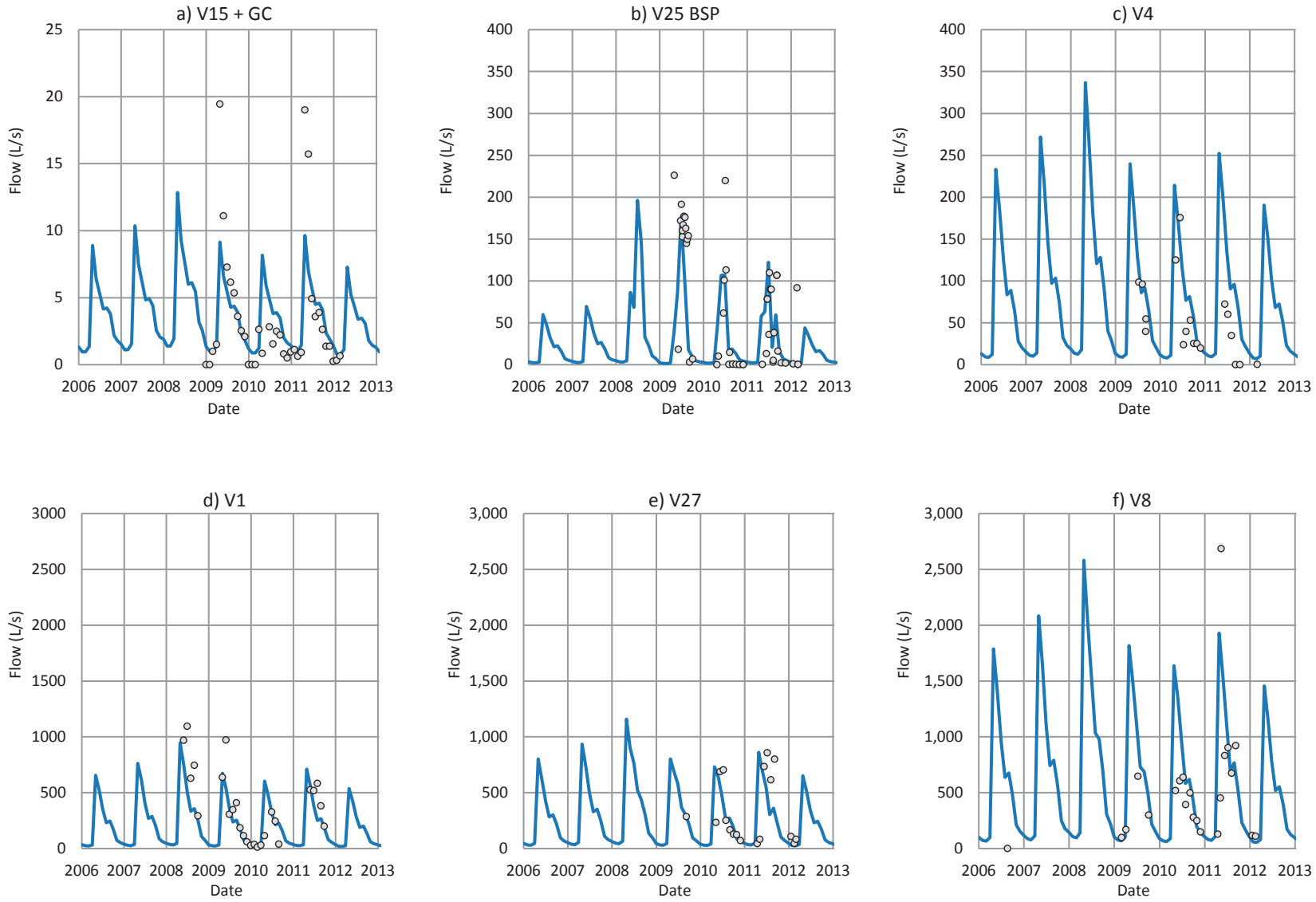


LEGEND

Historical Model Results

Measured Values

FIGURE 7B-37
Comparison of the Model Results versus Measured Flows at Key Locations at the Faro Mine Area
Faro Mine Interim Works

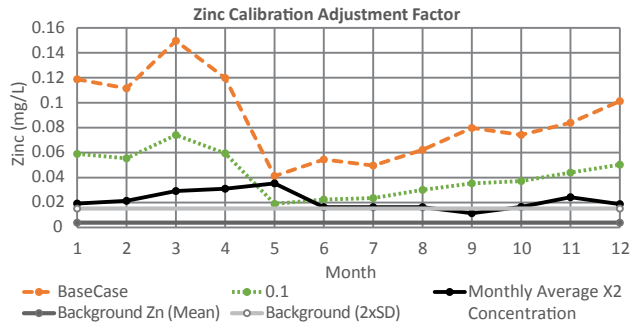


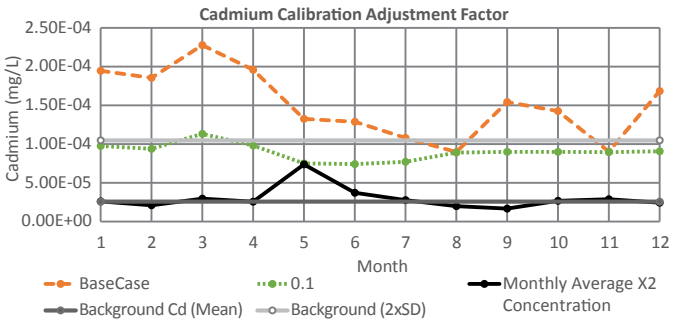
LEGEND

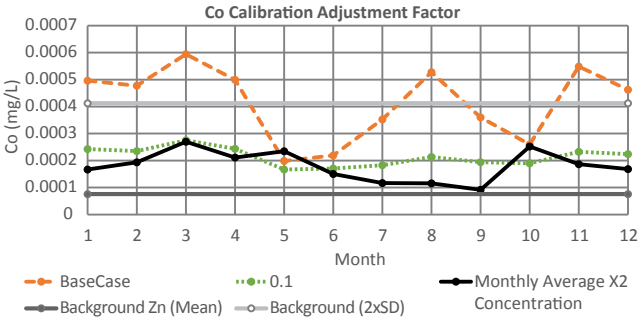
Historical Model Results

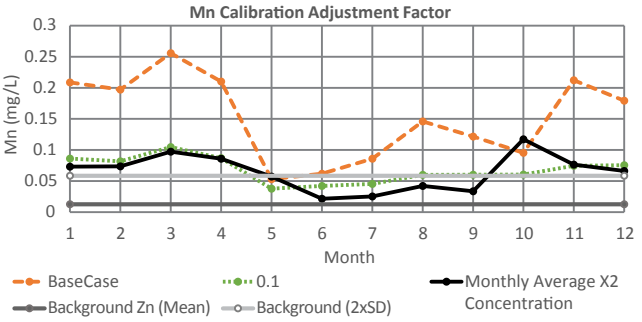
Measured Values

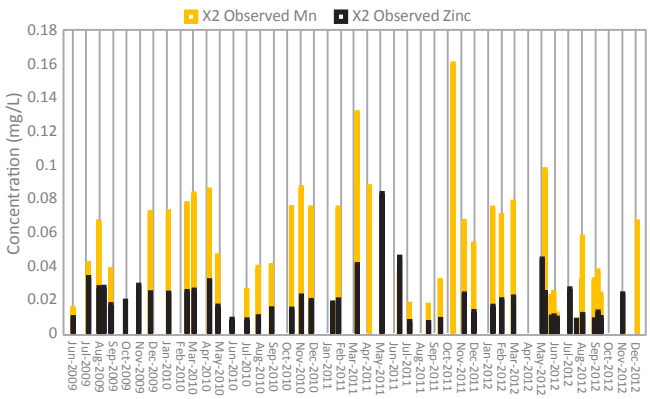
FIGURE 7B-38
Comparison of the Model Results versus Measured Flows at Key Locations at the Vangorda/Grum Mine Area
Faro Mine Interim Works











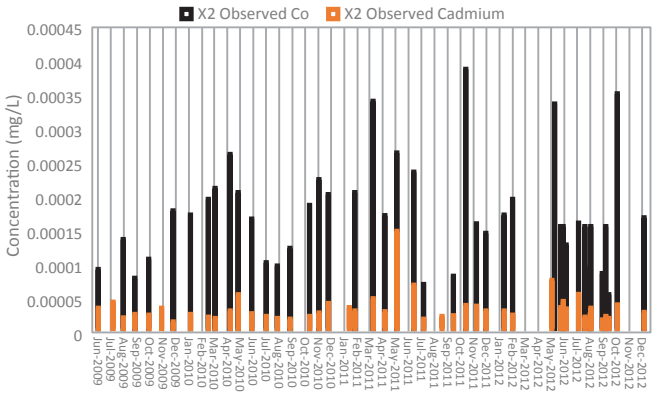
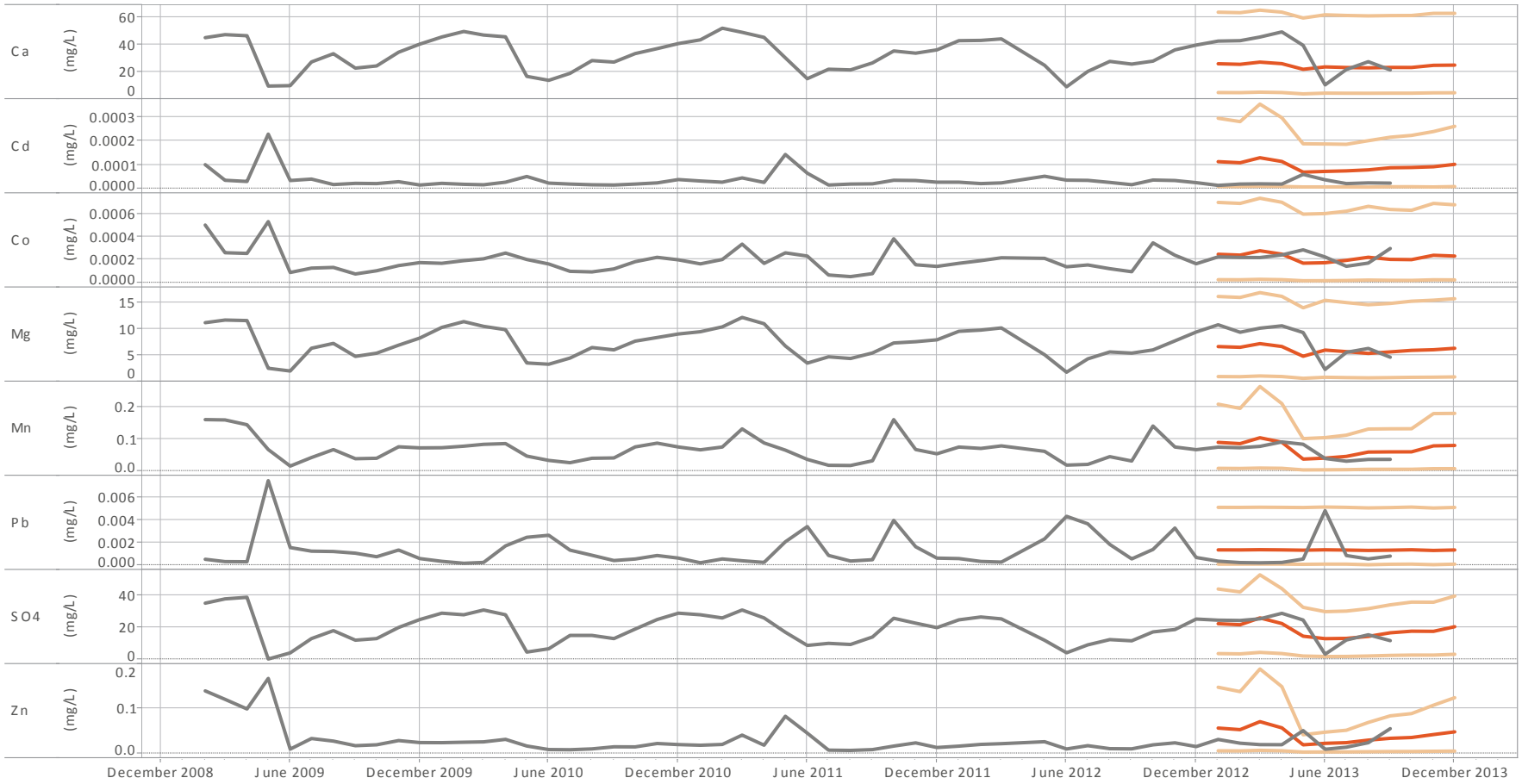


FIGURE 7B-39
Comparison of Model Results to Monthly Average Concentrations Based on Observed Data at X2 Between 2009 and 2012
Faro Mine Interim Works

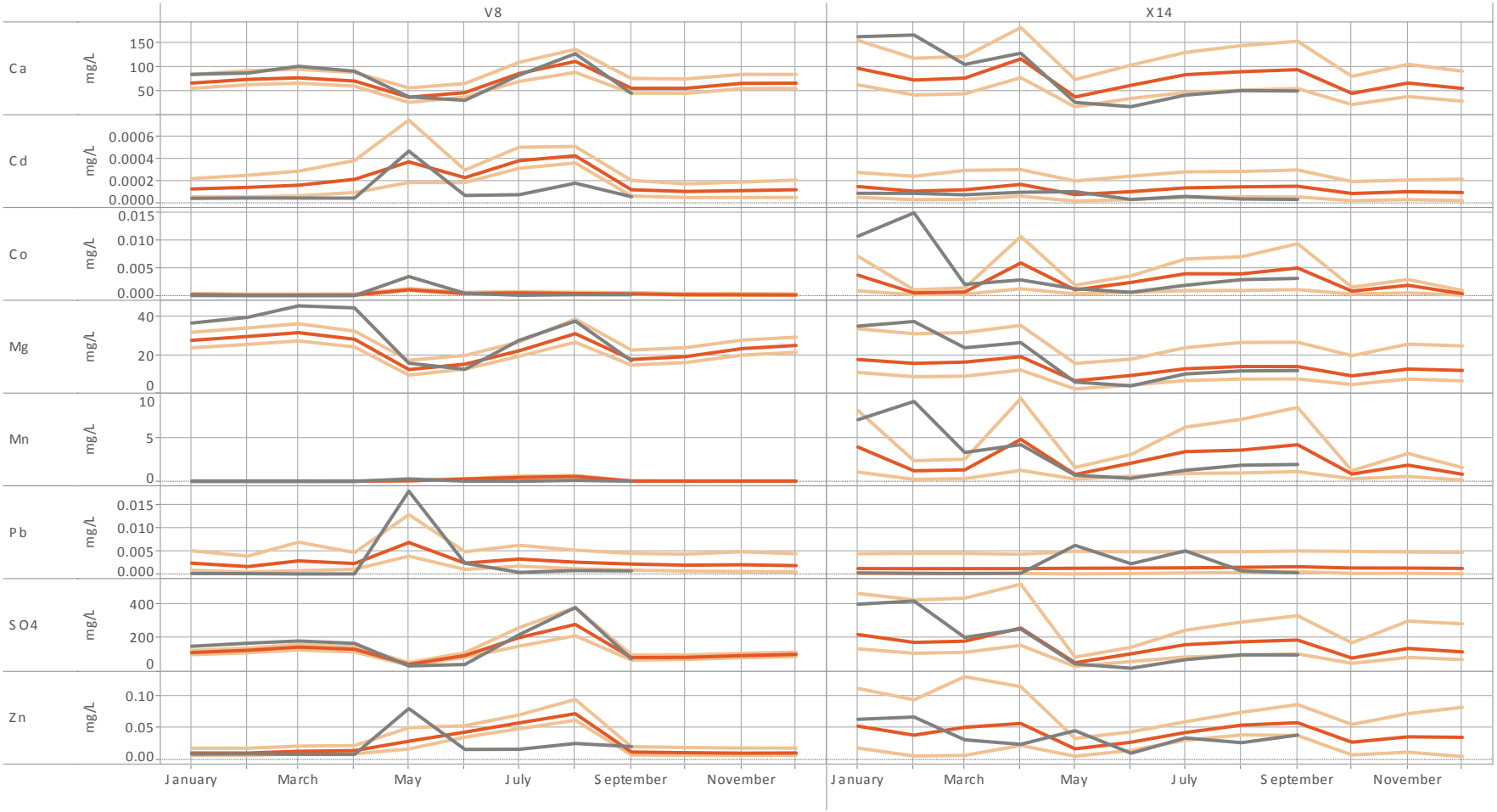


LEGEND

Data Type

- Measured
- Model
- Model Max
- Model Min

FIGURE 7B-40
Comparison of Model Results versus Measured Concentrations at X2 for 2013
Faro Mine Interim Works



LEGEND

Data Type

- Measured
- Model
- Model Max
- Model Min

FIGURE 7B-41
Comparison of Model Results versus Measured Concentrations at X14 and V8 for 2013
Faro Mine Interim Works

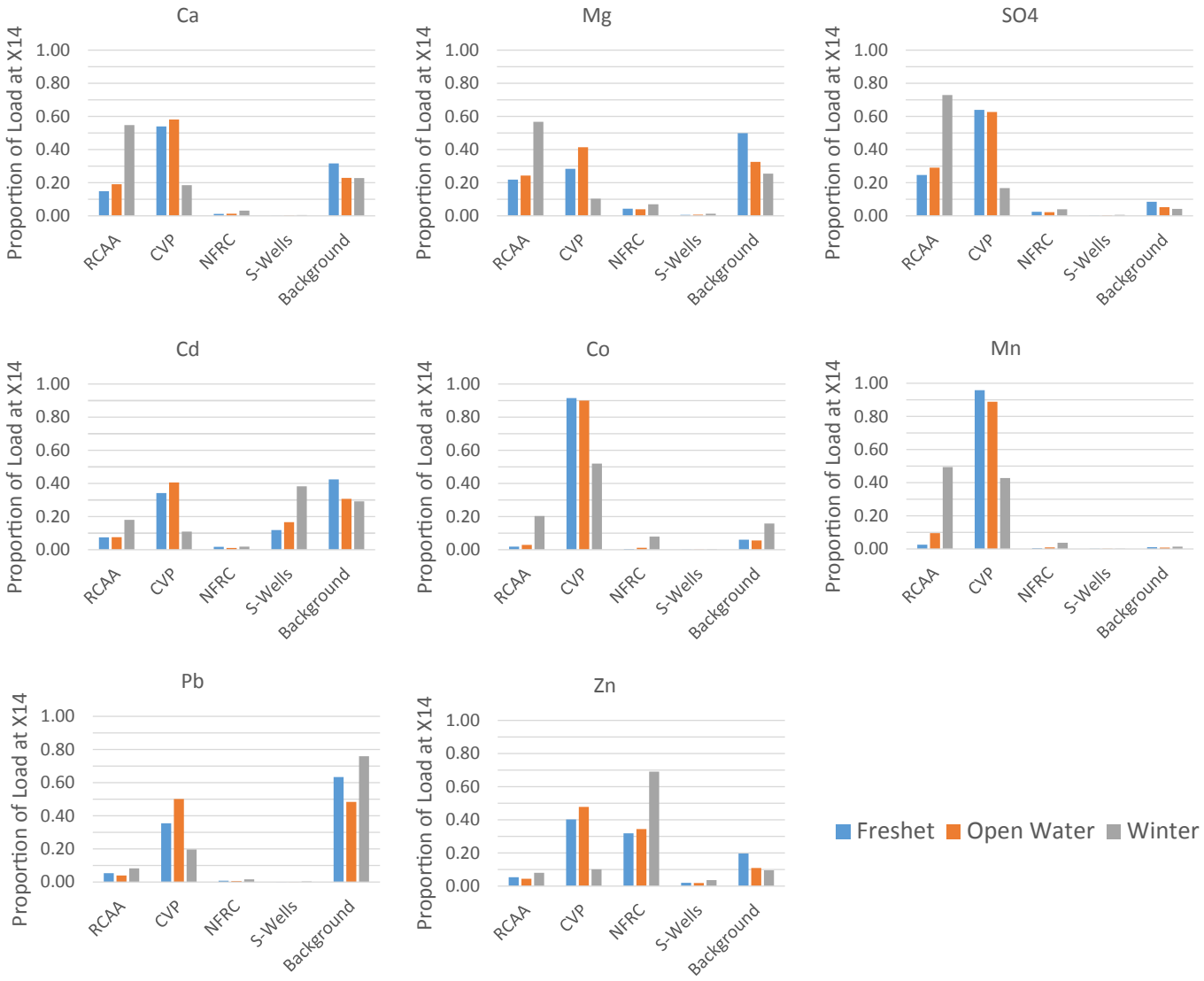


FIGURE 7B-42
Proportion of Load Contribution by Season at X14
Faro Mine Interim Works

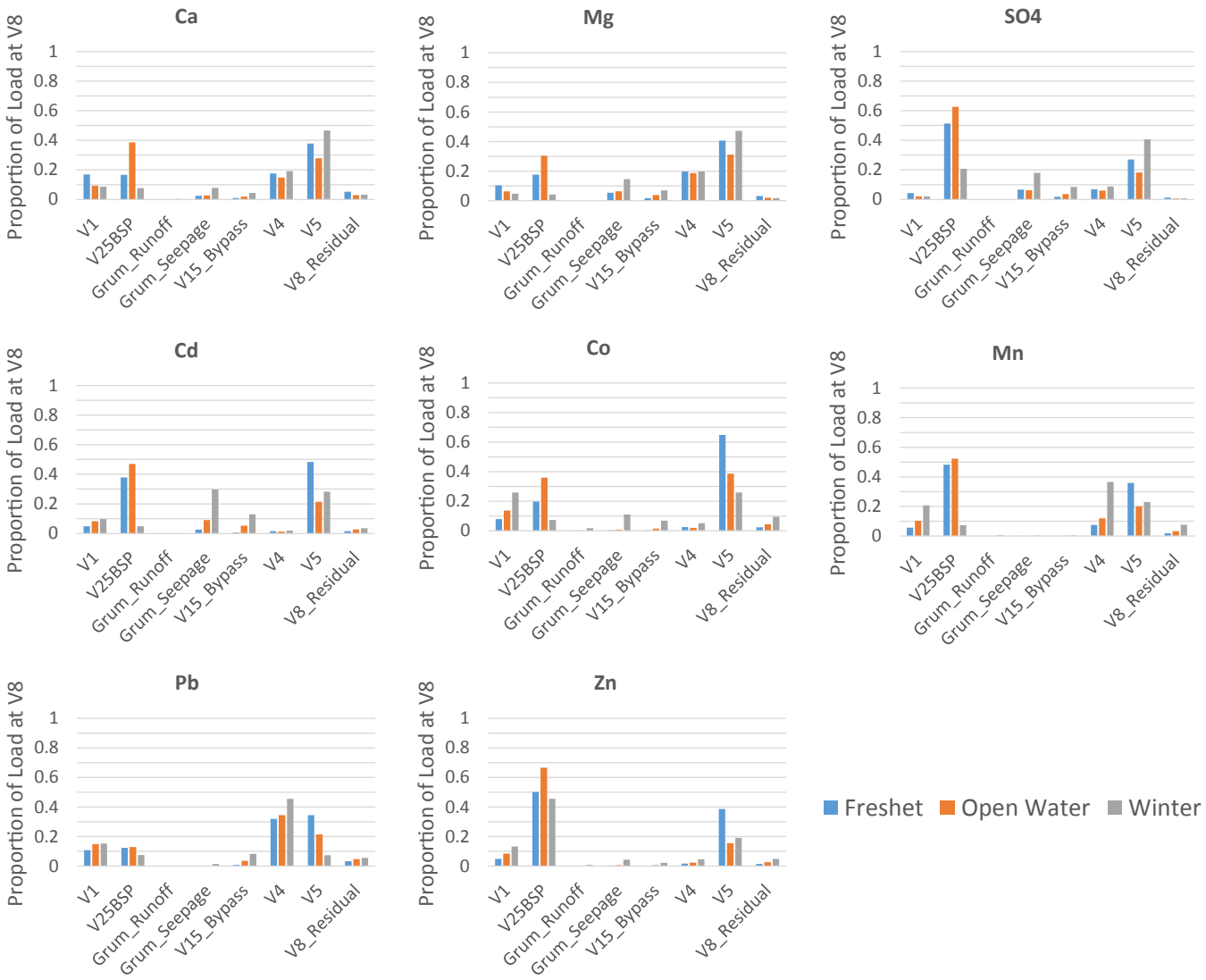


FIGURE 7B-43
Proportion of Load Contribution by Season at V8
Faro Mine Interim Works

Appendix 7C
Analysis of Aquatic Environmental Effects (Minnow)



Aquatic Effects Assessment for the Faro Mine Interim Works (DRAFT)

Prepared for:
CH2M HILL

Prepared by:
Minnow Environmental Inc.
Georgetown, ON

February 2014

Aquatic Effects Assessment for the Faro Mine Interim Works (DRAFT)

Prepared for:
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LIST OF ACRONYMS

µg/L – micrograms per litre
AANDC – Aboriginal Affairs and Northern Development Canada
AMP – Adaptive Management Plan
BMP – Best Management Practices
BCMOE – British Columbia Ministry of the Environment
CCME – Canadian Council for Ministers of the Environment
ChV –Chronic Value, typically derived as the geometric mean of the NOEC and LOEC determined in the same test
d – day
DOC – dissolved organic carbon
DOM – dissolved organic matter
EC10– the concentration that causes effective response to 10 percent of the test organisms
EC50 – the concentration that causes effective response to 50 percent of the test organisms
FAV – Final Acute Value
FMC - Faro Mine Complex
FMRP – Faro Mine Remediation Project
g - gram
GEI - GEI Consultants Inc.
h – hour
IC10– the concentration that causes inhibition to 10 percent of the test organisms
IC25– the concentration that causes inhibition to 25 percent of the test organisms
IC50 – the concentration that causes inhibition to 50 percent of the test organisms
IW – Interim Works
LC10– the concentration that will be lethal to 10 percent of the test organisms
LC50 – the concentration that will be lethal to 50 percent of the test organisms
Ln – natural logarithm
LOEC/L – Lowest Effect Concentration or Level
Log - logarithm
LSA – local study area
m - metre
MATC – Maximum Acceptable Toxicant Concentration, typically derived as the geometric mean of the NOEC and LOEC determined in the same test (same as ChV)
mg/kg – milligrams per kilogram
mg/L – milligrams per litre
mm - millimetre
NFRC – North Fork Rose Creek

NOEC/L – No Effect Concentration or Level
NR – not reported
RCTA – Rose Creek Tailings Area
RSA – regional study area
SFRC – South Fork Rose Creek
TLM – Threshold Limit median
TSS – Total Suspended Solids
USEPA – United States Environmental Protection Agency
VC – valued component
Wk - week
YG – Government of Yukon

1.0 INTRODUCTION

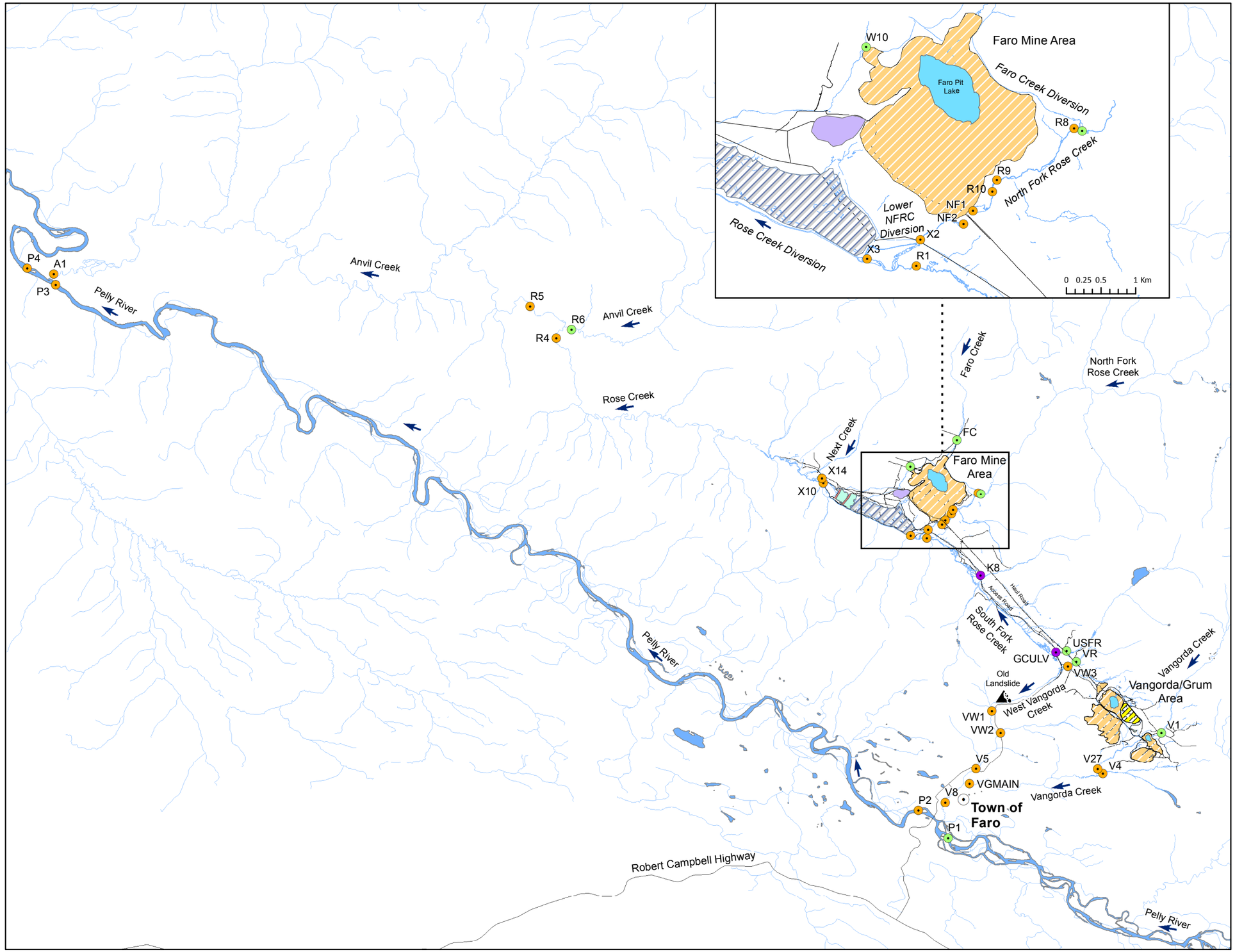
1.1 Background

The Faro Mine Complex (FMC) was formerly owned by the Anvil Range Mining Corporation, which produced lead and zinc concentrates that were extracted for lead, zinc, silver, and gold. Mine operations were terminated in April 1998 and the site went into receivership. Site Care and Maintenance responsibilities are being managed by contractors acting on behalf of the Government of Yukon (YG), while efforts continue towards development of the final scope and implementation of the overall Faro Mine Remediation Project (FMRP). In the meantime, YG seeks authorization for 10 years of interim site management, maintenance, and investigation activities, referred to as the Interim Works (IW).

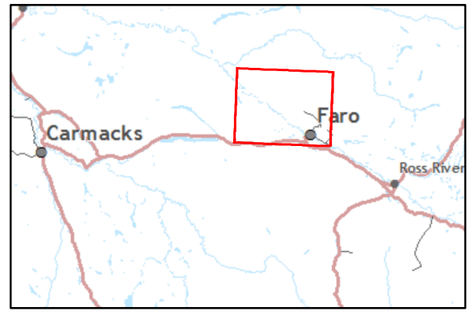
The FMC occupies portions of both the Rose Creek and Vangorda Creek watersheds. Both creeks are tributaries to the Pelly River, which is a major tributary to the Yukon River. Slimy sculpin (*Cottus cognatus*) and Arctic grayling (*Thymallus arcticus*) are the most abundant fish species in the Rose-Anvil Creek system. Both species appear to utilize surface waters around the Faro Mine Area year-round, although some Arctic grayling migrate to the Pelly River for overwintering. Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) have occasionally been observed in the Rose Creek system near the FMC, but adults have rarely been observed and the Rose-Anvil Creek system has been classified as having only low to moderate suitability for Chinook salmon spawning. Blind Creek, to the east of Vangorda Creek, is recognized as a local stream providing more important habitat for salmon. Downstream of the Vangorda/Grum Area, in lower Vangorda Creek, juvenile Chinook salmon are typically the most abundant fish because this area provides valuable rearing habitat.

Baseline water quality data for the FMC (2008-12) indicate that concentrations of a variety of non-metals and metals are presently elevated in surface waters relative to the typical range of background (reference station) concentrations (Minnow 2014)[1]. Alkalinity, conductivity, hardness, sulphate, total dissolved solids, calcium, cobalt, magnesium, nickel, sodium, strontium, and zinc occur at concentrations above background levels in approximately half or more of samples collected downstream of the Vangorda/Grum Area (station V8; Figure 7C-1) and the Faro Mine Area (station X14). Current concentrations of non-metal analytes, including pH and sulphate, would not be expected to adversely affect

[1] Appendix 6H of the IW Project Proposal.



VICINITY MAP



LEGEND

- Landslide
- Direction of Flow

Water Monitoring Station:

- Mine-Exposed
- Reference
- Historical First Nations Drinking Water Location

Mine Infrastructure:

- Open Pit
- Waste Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Building Area

FIGURE 7C-1
Locations of Reference and Mine-Exposed Water Monitoring Stations
Faro Mine Interim Works
Minnow Project No.: 2499 Date: January 2014

aquatic biota; however, concentrations of various metals, especially zinc, in surface waters around and downstream of the FMC, sometimes exceed water quality guidelines for protection of aquatic life. Recent studies of benthic invertebrate communities have concluded that mine-related effects on aquatic biota are minor in magnitude and confined to localized areas having highest concentrations of mine-related contaminants (e.g., portions of North Fork Rose Creek [NFRC] and in Rose Creek immediately downstream of the Rose Creek Tailings Area [RCTA]). Mine-related effects on water quality and biota do not presently extend into the Pelly River.

1.2 Report Objectives and Overview

Many of the site management and maintenance activities that have been in place, and are proposed to continue as part of the IW, are intended to minimize release of contaminants from the site, such as diversion of clean water around disturbed areas and collection and treatment of contaminated water. Regardless, contaminants will continue to be released from mine sources such as waste rock, tailings, and open pits, via direct or indirect surface and groundwater pathways (including treated effluents), into receiving environments around and downstream of the FMC during the IW period. The progression of acid-rock drainage conditions at the site means that contaminant mobilization from waste materials will likely increase through the IW period. These deteriorating conditions are one of the primary drivers for the eventual implementation of the FMRP that includes aggressive source control and contaminant collection measures. However, these measures require further planning, design and permitting before they can be implemented and the IW activities entail measures to mitigate effects prior to FMRP implementation. This report describes the expected interactions of the IW with surface water and aquatic biota and presents a detailed analysis of potential effects. However, predicted changes from baseline conditions are expected to develop as a result of existing conditions at the site rather than from proposed human activities associated with the project. This is an important context for interpretation of the results of the aquatic effects assessment.

2.0 INTERACTIONS, EFFECTS PATHWAYS, MITIGATION

As described in Section 7.2 of the main IW project proposal, the first step in conducting the effects assessment for the IW entailed a comprehensive identification of interactions between IW activities and Valued Components (VCs). This was done in two workshops, one for environmental VCs and one for socio-economic VCs, to promote consistency in decision-making among the different technical disciplines. Each interaction was classified to highlight those that warrant detailed consideration in the effects assessment. The classifications were defined as follows:

"0" = No Interaction: no measurable interaction that could cause an effect.

"1" = Minor Interaction: minimal interaction where measureable effects are possible, but the effects will be avoided or suitably mitigated through compliance with regulatory requirements and application of standard Best Management Practices (BMPs).

"2" = Major Interaction: potential interaction where measurable effects are likely even with application of best management practices, or where understanding the scale or magnitude of effects requires detailed analysis.

This systematic approach created a matrix of project activities and VCs, promoting thorough consideration and identification of all potential interactions, regardless of scale, magnitude, or direction. Only the interactions identified in this process that were associated with surface water quality and fish and fish habitat are assessed within this document.

Mine-related contaminants measured in surface waters around and downstream of the FMC originate mainly from waste rock piles, open pits, and the Rose Creek Tailings Area (RCTA). The contaminants are released to the environment via controlled surface discharges (e.g., treated effluent from the Faro and Vangorda Water Treatment Systems), uncontrolled surface discharges (e.g., untreated runoff and seepage), and groundwater. Table 7C-1 lists all of the specific project characteristics that have potential to influence surface water quality, along with a brief description of each interaction. Various BMPs will be implemented to control contaminant releases associated with each activity (Table 7C-1). These include continued treatment of surface water from the RCTA, as well as collection and storage of contaminated water in the Faro and Vangorda Pits, as well as the seasonal treatment of contaminated water at the Faro and Vangorda Water Treatment Systems. These systems are described in Section 5.0 of the main IW Project Proposal and it is expected that effluent limits will be applied to control concentrations and loads in

Table 7C-1: Project interactions with aquatic value components and associated mitigation and residual effects

Project Activities/Physical Works		Interaction Ranking[a]		Description of Interaction	Mitigation	Residual Effects
Category	Specific	Surface Water Quality	Fish and Fish Habitat			
Site Operations	Storage of tailings material in the RCTA	2	2	Contaminants will continue to be released into surface waters via treated effluent and groundwater, with potential to affect aquatic biota in downstream areas.	Effluent from the RCTA will continue to be treated and groundwater releases will be managed via the AMP.	The aggregate effects of project activities on surface water quality are incorporated in the site water quality model. Potential effects to fish may occur through effects on water quality. Therefore, potential effects on surface water quality and associated toxicity to aquatic biota are assessed through evaluation of water quality predictions relative to baseline conditions, water quality guidelines, and toxicity thresholds published in the literature. Low to medium effects are expected in some areas, after mitigation, based on concentrations being above water quality guidelines for some mine-related variables. See text for detailed assessment.
	Seasonal treatment and discharge of water at Interim Faro Water Treatment System	2	2	Contaminants will continue to be released into surface waters via treated effluent with potential to affect aquatic biota in downstream areas.	Effluent from the RCTA will continue to be treated and meet appropriate discharge requirements.	
	Storage of waste rock	2	2	Contaminants will continue to be released into surface waters via surface runoff, groundwater, and treated effluent with potential to affect aquatic biota in downstream areas.	Groundwater collections systems at the S-Wells area and ETA intercept and pump contaminants back to Faro Pit. Waste rock releases reporting to the RCTA will be treated continue to be treated before discharge and groundwater releases will be managed via the AMP. Water from collection systems at Vangorda and Grum Waste Rock Dumps (seepage and surface water) is directed to Vangora Pit and eventually treatment.	
	Storage of contaminated water in pit lakes and backfilled pits (Faro, Vangorda, Grum and Zone II)	2	0	Contaminants will continue to be released via treated effluent and potentially through groundwater.	Pit water will continue to be treated at Faro and Vangorda/Grum Areas before release to the environment. Groundwater releases will be managed via the AMP.	
	Storage of contaminated water in ponds (e.g., Little Creek Pond, Intermediate Pond, Cross-Valley Pond, Sheep Pad Pond, Moose Pond, Groucho Pond, Vangorda Water Treatment Pond)	2	2	Contaminants will continue to be released via treated effluent and potentially through groundwater. Also potential for TSS release from some ponds, which could affect fish habitat.	Contaminated pond water will be pumped for treatment prior to release. Groundwater releases will be managed via the AMP. Solids loads will be managed via the Sediment and Erosion Control Plan.	
	Interception, collection and transfer of contaminated water from S-Wells to Faro Pit	2	2	Contaminants will continue to be released as a result of incomplete interception. Pipeline break would result in discharge of pit water to the environment.	Groundwater releases will be managed via the AMP. Pipeline break is considered to be an extreme event (see Section 7.3.13)	
	Seasonal discharge of contaminated water into Moose Pond	2	2	Potential contaminant release via groundwater to Vangorda Creek	Groundwater releases will be managed via the AMP. AMP also addresses pumping back of pond water to Vangorda pit as needed.	
	Seasonal treatment and discharge of water at Vangorda Water Treatment System	2	2	Contaminants will continue to be released into surface waters via treated effluent and have potential to affect aquatic biota in downstream areas.	Effluent will continue to be treated at the Vangorda Water Treatment System.	
	Transfer of contaminated water from Zone II Pit to Faro Pit	1	0	Pipeline break could occur, resulting in discharge of pit water to the environment	Pipeline break is considered to be an extreme event (see Section 7.3.13)	Any such occurences are expected to be localized, short duration, and reversible and can be effectively mitigated through Best Management Practises and adherence to applicable regulations. No signficant residual effects predicted.
	Interception, collection and transfer of contaminated water from ETA to Faro Pit	1	0	Contaminants released through incomplete interception. Pipeline break would result in contaminants reporting to tailings or Rose Creek aquifer.	Effluent from the RCTA will continue to be treated and groundwater releases will be managed via the AMP. Pipeline break is considered to be an extreme event (see Section 7.3.13)	
	Seasonal transfer of contaminated water from Grum Pit, Grum Dump and Little Creek Pond to Vangorda Pit and V15	1	1	Pipeline break could occur, resulting in discharge of pit water to the environment	Pipeline break is considered to be an extreme event (see Section 7.3.13)	
	Disposal of sludge from water treatment systems. Original Impoundment at Faro, and Vangorda Pit	1	0	Potential remobilization of contaminants from disposed treatment sludges.	Manage using BMP.	
Site Investigations	Boreholes/test pits	1	1	Potential TSS release and/or contaminants from water use and release during drilling	Manage using BMP.	
	Monitoring equipment installation including wells, thermistors, flow measurement facility	0	1	Potential TSS release and/or contaminants from water use and release during drilling	Manage using BMP and adherence to regulatory requirements respecting protection of fish and fish habitat.	
	Aquifer and pump testing	1	1	Potential TSS release and/or contaminants from water use and release during drilling	Manage using BMP.	
	Access route development (may include stream crossings)	1	1	Potential channel disturbances	Manage using BMP for suspended solids control and adherence to regulatory requirements respecting protection of fish and fish habitat.	
Down-Valley Interim Hydraulic Upgrades	Excavation of Intermediate Dam Spillway	1	0	Potential TSS release	Manage using BMP.	
	Sourcing and transport of borrow material	1	0	Potential TSS release	Manage using BMP.	
	Construction of erosoion protection in spillway	1	0	Potential TSS release	Manage using BMP.	
	Geomembrane and dam raise (gabion) construction	1	0	Potential TSS release	Manage using BMP.	
	Removal of vegetation in RCD	1	1	Potential TSS release and/or stream channel disturbances	BMP for controlling suspended solids losses plus adherence to regulatory requirements respecting protection of fish and fish habitat.	
	Removal of bank sloughs in RCD	1	1	Potential TSS release and/or stream channel disturbances	BMP for controlling suspended solids losses plus adherence to regulatory requirements respecting protection of fish and fish habitat.	
	Repair of RCD dyke	1	1	Potential TSS release	Manage using BMP.	
Accessory Activities	Transport fuel and materials	1	1	Potential fuel spill	Manage using BMP and adherence to regulatory requirements related to fuel/chemical handling.	
	Transport of personnel and supplies	1	1	Potential spill of chemical supplies	Manage using BMP.	
	Hazardous materials storage and use (reagents, fuel and hydrocarbons)	1	1	Potential spills	Manage using BMP and adherence to regulatory requirements related to fuel/chemical handling.	
	Temporary Camp	1	0	Potential for sewage contamination	Manage using BMP.	
	Sourcing and transport of borrow material	1	1	Potential TSS release	Manage using BMP.	

[a] Ranking: 0 = No Interaction: no measurable interaction that could cause an effect.
1 = Minor Interaction: minimal interaction where measureable effects are possible, but the effects will be avoided or suitably mitigated through compliance with regulatory requirements and application of standard best management practices.
2 = Major Interaction: potential interaction where measurable effects are likely even with application of best management practices, or where understanding the scale or magnitude of effects requires detailed analysis.

downstream surface waters. Mine-related chemicals may also enter surface waters via surface runoff, shallow seepage, and groundwater pathways. Except where interception systems already exist, such as at the S-wells area south of the Faro waste rock dumps, timing and magnitude of loading from groundwater discharges are uncertain (see Appendix 7B Description of Water Modeling and Results). Operators will continue to use on-going monitoring of seeps, groundwater, and surface water around the FMC to identify new load sources as they emerge, and the Adaptive Management Plan (AMP) describes how mitigation plans will be developed and implemented, as appropriate. Even with mitigation and the AMP in place, the combined sources of the eight project activities listed at the top of Table 7C-1 are expected to sufficiently affect downstream surface water quality that they were scored a "2." The associated effects are assessed in more detail in the following sections of this report.

Table 7C-1 identifies several minor interactions (scored "0" or "1") for surface water quality. The pathways of effects for these minor interactions are not generally associated with mobilization and transport of metal contaminants from the site. Instead, they relate mainly to potential release of particulates, which tends to occur episodically in response to weather and/or specific work activities. Interactions involving potential effects of particulate releases will be minimized by BMPs and adherence to regulations respecting protection of fish and fish habitat. In addition, BMPs and regulatory requirements related to fuel and chemical (e.g., reagent) handling will mitigate any effects that might otherwise be associated with fuel or chemical spills during site investigations or accessory project activities. Consequently, all such interactions have been rated as a "1" in Table 7C-1. Based on past site experience and professional judgment, such interactions are considered very unlikely to result in a significant environmental effect, either in the absence of mitigation or with the application of standard mitigation practices. Residual effects of such practices, if any, are expected to be minor, so these interactions are not assessed further.

3.0 ASSESSMENT OF RESIDUAL EFFECTS

3.1 Approach

3.1.1 Assessment Scenarios and Indicators

Table 7C-1 identifies a series of "major interactions" (scored "2") between the IW and surface water quality, all of which are associated with on-going storage of mine waste materials, storage of contaminated water, and release of treated water. While these interactions will affect water quality to varying degrees at different surface water locations throughout and downstream of the FMC, the assessment considers the combined loads of mine-related chemicals on surface water quality around and downstream from the FMC. This was done based on predictions from a water balance and load model that incorporates inputs from all of the mine-related sources and develops estimates for key receiving environment locations.

Surface water quality was evaluated by considering relevant water uses. There is no agriculture in the vicinity of the FMC, so the assessment did not consider surface water quality guidelines for protection of agricultural uses. Consideration was initially given to assessing water quality relative to drinking water guidelines; however, this would be relevant only for the two areas within the FMC where First Nations have historically collected drinking water: station K8, located where a small tributary to the South Fork of Rose Creek (SFRC) (sometimes referred to as Reservoir Creek) crosses the mine Access Road, and GCULV, located where the upper SFRC crosses the mine Access Road (Figure 7C-1). These stations are located upstream of most existing and anticipated mine-related disturbances (e.g. the only upstream mine-related disturbance is the Haul Road crossing), so water quality is not expected to change at these stations relative to baseline conditions. Therefore, protection of aquatic life is considered to be the most relevant and sensitive water use at the site and in downstream areas. Also, the water quality guidelines for protection of aquatic life tend to be most stringent of the different guidelines, providing a relatively conservative basis for surface water quality evaluation. By considering surface water quality relative to guidelines for protection of aquatic life, the surface water quality assessment also addresses potential effects on fish and fish habitat that may occur as a result of exposure to mine-related contaminants (i.e., toxicity). In this context, fish habitat includes the aquatic plant and invertebrate communities that contribute to ecosystem function and which represent a food source for fish. By comparison, potential effects of the IW on the physical characteristics of fish habitat are most likely to occur through particulate loads to surface water bodies, resulting in

increased suspended solids and turbidity concentrations and sedimentation on bottom substrates. As noted in Section 2.0, interactions involving particulate loads to surface waters were judged to be relatively minor, and will be controlled through BMPs. Water monitoring will also continue at these stations.

The effects assessment focuses mainly on a "normal" operating scenario, which uses a water and load balance model to predict water quality conditions in the streams affected by the FMC. A realistic adverse scenario was also assessed involving a localized, rapid increase in zinc load to surface water, which is assumed to affect water quality for a limited time period until a mitigation solution can be developed and implemented. Concentrations for this latter scenario are based on real data from recent events at the FMC.

The characterization of baseline water quality (Minnow 2014) showed that sulphate, cadmium, cobalt, iron, lead, manganese, and zinc are the mine-related contaminants that are sometimes observed at concentrations above water quality guidelines for protection of aquatic life at surface water stations located around and downstream of the FMC. Future surface water quality was predicted for all of these substances, except iron (see Appendix 7B - Description of Water Modeling and Results). Iron was excepted because elevated concentrations are usually associated with elevated particulate loads caused by snowmelt and rainfall events, as indicated by coincident elevated total suspended solids (TSS) concentrations (Figure 7C-2). Baseline data (2008-12) showed that TSS concentrations are relatively more elevated at far-field stations (e.g., station A1 at the mouth of Anvil Creek) than nearer the FMC (e.g., station X14) and occur even at minimally mine-disturbed areas (e.g., station R1 on SFRC). Also, contributions from the landslide mid-way down West Fork Vangorda Creek confound interpretation of relative mine-related inputs of suspended solids and iron. Lastly, mine-related particulate loads associated with the IW are expected to be modest and controllable through BMPs (Section 2.0, Table 7C-1). These mechanisms are expected to also control iron loading associated with IW activities. Therefore, the assessment of surface water quality is based on evaluation of expected sulphate, cadmium, cobalt, lead, manganese, and zinc concentrations.

Of the mine-related contaminants included in the assessment, zinc is considered to be an important indicator of future geochemical changes at the site and is the mine-related substance considered most likely to be observed at concentrations above water quality guidelines for protection of aquatic life. Consequently, zinc is identified as an indicator separately from the other mine-related variables in the effects assessment (Table 7C-2). However, concentrations of zinc and the other mine-related variables were assessed in a

Table 7C-2: Assessment criteria for effects on surface water quality and associated chemical effects on fish and fish habitat for Faro Mine Interim Works Project

Valued Components	Effects Assessment Indicator	Rationale for Selection	Measurements	Effect Attributes	Significance Ranking	Ranking Criteria
Surface Water Quality and Associated Chemical Effects on Fish and Fish Habitat	Water quality (zinc)	Protection of aquatic species is predicated on exposure to water concentrations that do not cause impairment. Water quality concentrations can be predicted and concentrations toxic to aquatic organisms have been characterized in the scientific literature. Mine-related effects on surface water quality are expected to be dominated by zinc.	Concentrations of zinc in fish-bearing reaches relative to baseline and predicted conditions, water quality guidelines, toxicity thresholds.	Magnitude and Likelihood/Duration	Low	Water concentrations, after effluent mixing in the receiver are predicted to usually meet water quality guidelines (i.e., ≥50% of months) and will rarely or never exceed fish toxicity thresholds (<50% of months) throughout the 10-year project period.
					Medium	Concentrations after effluent mixing may frequently exceed water quality guidelines (>50% of months) but will usually not exceed toxicity thresholds for relevant fish (<25% of months). Temporary exceptions may occur when a new source or pathway results in a sudden increase in zinc concentration; during this time fish toxicity thresholds may be temporarily (<1 year) exceeded while a mitigation plan is developed and implemented.
					High	Water concentrations are predicted to be above levels likely to harm fish species in >25% of samples for indefinite periods (>1 year).
				Geographic Extent	Low	"Low" water quality effects will apply to all surface waters within and downstream of the FMC footprint (local and regional study areas).
					Medium	"Medium" water quality effects described above will be limited to the Rose Creek and Vangorda Creek system (i.e., mainly confined to local study, possibly extending to mouths of both creeks). In Anvil Creek and Pelly River, water quality effects are predicted to be "low" as defined above.
					High	"High" water quality effects described above may occur within the Rose Creek or Vangorda Creek system and "medium" or "high" water quality effects described above may extend into Anvil Creek and/or the Pelly River (regional study area).
				Reversibility	Low	Periods of elevated concentrations will naturally be followed by periods of lower concentration as a result of normal seasonal cycles of contaminant release and available dilution.
					Medium	Water quality effects are likely reversible through mitigation, although it may take months for solutions to be found and mitigation to be put in place.
					High	Water quality effects are not expected to be reversible.
	Water quality (sulphate, cadmium, cobalt, lead, manganese)	Protection of aquatic species is predicated on exposure to water concentrations that do not cause impairment. Water quality concentrations can be predicted and concentrations toxic to aquatic organisms have been characterized in the scientific literature. Next to zinc, sulphate, cadmium, cobalt, lead, and manganese are the mine-related variables having greatest potential to adversely influence surface water quality.	Concentrations of sulphate, cadmium, cobalt, lead, manganese, and zinc relative to baseline and predicted conditions, water quality guidelines, toxicity thresholds.	Magnitude and Likelihood/Duration	Low	Water concentrations, after effluent mixing, are predicted to meet water quality guidelines in most (≥95% of) months and are not predicted to exceed toxicity thresholds for relevant fish species throughout the 10-year project period.
					Medium	Concentrations are predicted to often meet water quality guidelines (>50% of months) and rarely or never (<5% of months) exceed concentrations shown in the literature to be harmful to relevant fish species.
					High	Water concentrations are predicted to sometimes or often (>5% of months) exceed levels expected to be harmful to relevant fish species.
				Geographic Extent	Low	"Low" water quality effects will apply to all surface waters within and downstream of the FMC footprint (local and regional study areas).
					Medium	"Medium" water quality effects described above will be limited to the Rose Creek and Vangorda Creek system (i.e., mainly confined to local study, possibly extending to mouths of both creeks). In Anvil Creek and Pelly River, water quality effects are predicted to be "low" as defined above.
					High	"High" water quality effects described above may occur within the Rose Creek or Vangorda Creek system and "medium" or "high" water quality effects described above may extend into Anvil Creek and/or the Pelly River (regional study area).
				Reversibility	Low	Periods of elevated concentrations will naturally be followed by periods of lower concentration as a result of normal seasonal cycles of contaminant release and available dilution.
					Medium	Water quality effects are likely reversible through mitigation, although it may take months for solutions to be found and mitigation to be put in place.
					High	Water quality effects are not expected to be reversible.

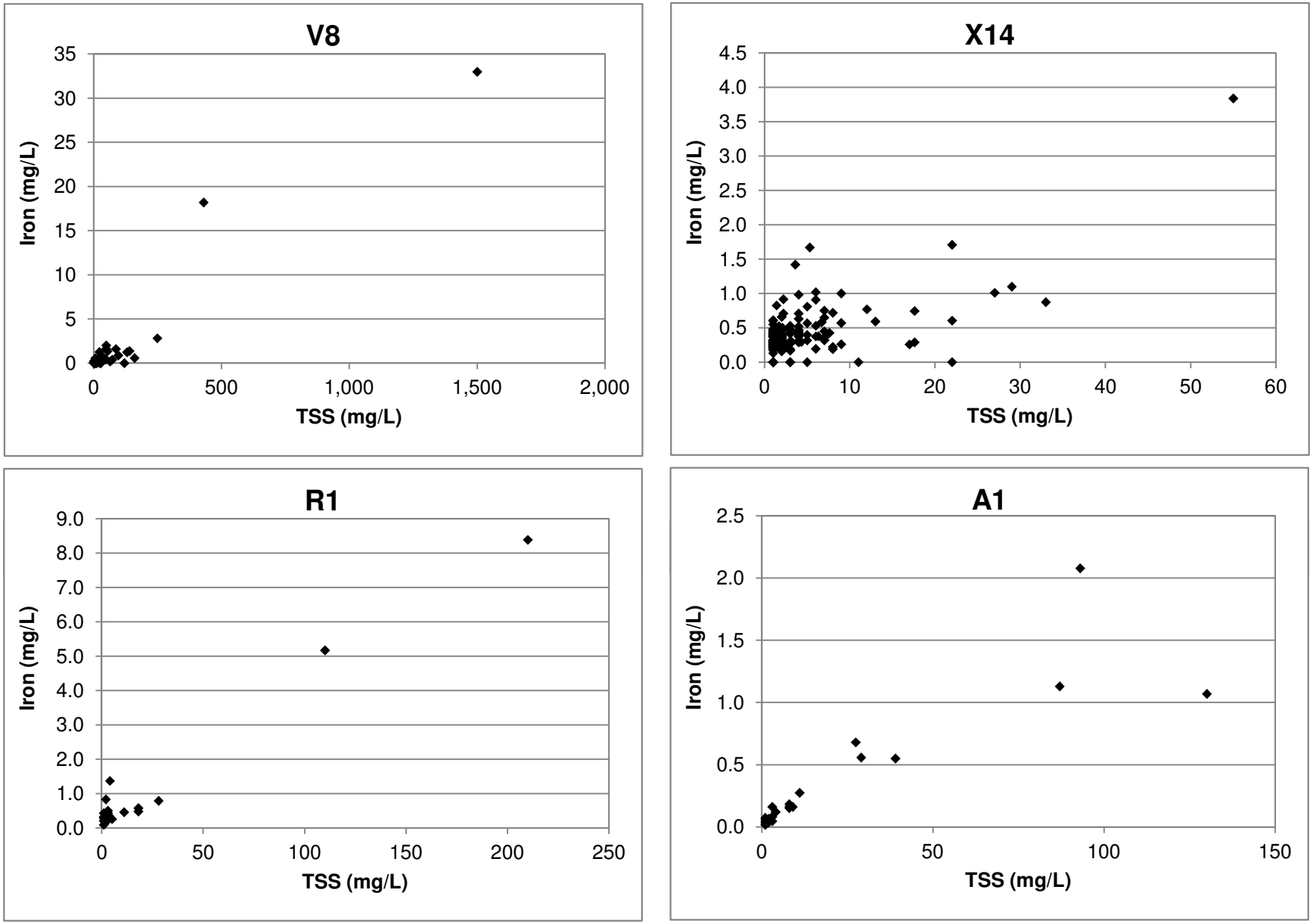


Figure 7C-2: Water concentrations of iron relative to total suspended solids at routine monitoring stations V8, X14, R1 and A1, 2008 - 2011.

similar manner, namely by comparison to baseline concentrations (2008-12), water quality guidelines for protection of aquatic life, and toxicity data presented in the scientific literature for relevant aquatic species.

3.1.2 Spatial Boundaries

Both local and regional study areas are shown in Figure 7C-3 and described below, although, in the context of describing aquatic effects, these two areas are not functionally separate or distinct. Therefore, the effects assessment refers to local and regional study areas, where it is appropriate to do so, and otherwise refers to conditions in specific streams and locations within streams. Figure 7C-1 depicts locations of routine water monitoring stations that are specifically referenced within this document.

3.1.2.1 Local Study Area

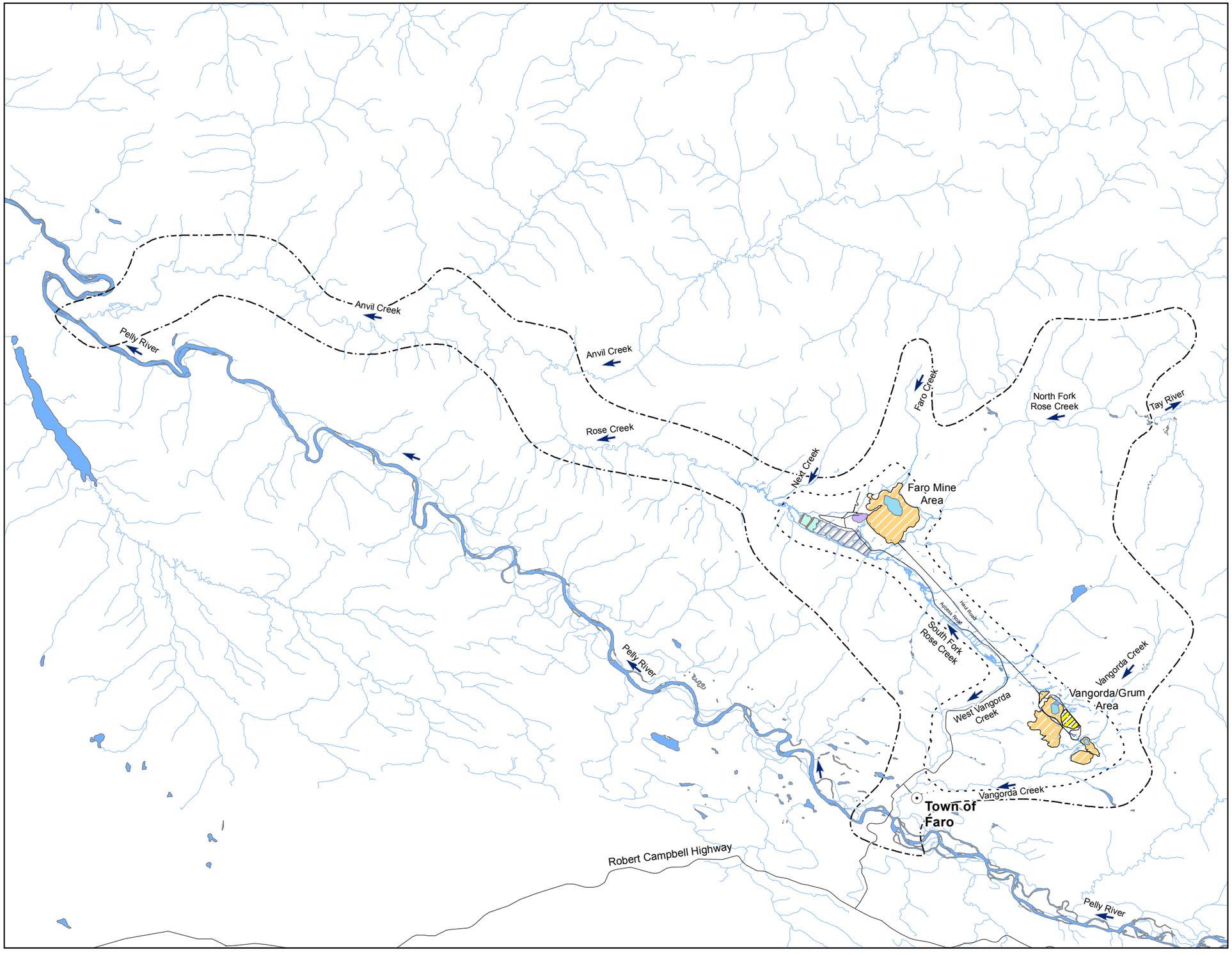
The local study area (LSA) is the area within which the activities of the IW will take place and where associated effects, if any, are most likely to be realized. The LSA encompasses the footprint of the former FMC operations and streams within approximately 500 metres (m) of the mine disturbance footprint (Figure 7C-3). The mine disturbance footprint includes the Faro Mine Area to the west, and the Vangorda/Grum Area to the east, as well as the area between the two in which the mine Access Road and the Haul Road are located. The western and middle portions of the LSA include portions of Faro Creek and NFRC/SFRC, as well as the Rose Creek Diversion and Rose Creek immediately downstream from the tailings impoundment area (Figure 7C-3). The eastern portion of the LSA, includes sections of the west and main branches of Vangorda Creek.

3.1.2.2 Regional Study Area

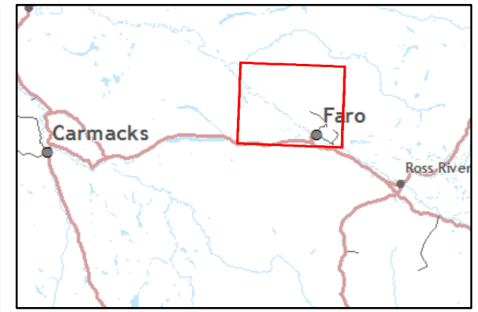
The regional study area (RSA) is defined as the maximum area over which there is potential for measureable project-related effects. For the purpose of the IW Project, the RSA has been defined as the drainages downstream from the LSA to the Pelly River, including the areas within the Pelly River immediately upstream and downstream of the mouths of Anvil and Vangorda creeks (Figure 7C-3).

3.1.3 Protection Goals and Determining the Significance of Effects

An important context for determining the significance for aquatic environmental effects is that the FMC is an abandoned mine site storing a huge volume of potentially mobilizable contaminants in open pits, waste rock dumps, and tailings (Appendix 6A, Geochemical Characterization Report). Much is known about the site geochemistry and the sources that are currently contributing contaminant loads to surface water, and various forms of



VICINITY MAP



LEGEND

- Aquatic Local Study Area
- Aquatic Regional Study Area
- Direction of Flow

Mine Infrastructure:

- Open Pit
- Waste Rock Dump
- Impoundment Area
- Overburden Dump
- Tailings Pond
- Dam
- Mill Building Area

N

0 1 2 4 km

Created by: J. Wilson

minnow environmental inc.

FIGURE 7C-3

Aquatic Regional and Local Assessment Study Areas

Faro Mine Interim Works

Minnow Project No.: 2499 Date: January 2014

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mitigation have been put in place to mitigate effects (e.g., clean water diversions, contaminated water collection and treatment systems). However, there is potential for new pathways to develop between source areas and surface waters over time. Despite extensive groundwater monitoring programs, groundwater pathways, in particular, may go undetected until surface water quality begins to change. Consequently, an important component of future site management will continue to be the AMP, which is designed to allow for rapid detection of, and response to, emerging changes. Nevertheless, months may elapse between identification of and response to a newly emerged condition, during which time water quality may be unavoidably degraded. This means that it may not be possible to consistently control the magnitude of adverse effects, only the duration (i.e., response time). This situation contrasts starkly to that of an environmental assessment at a Greenfield site, where effects can be wholly prevented through appropriate design or denial of regulatory approval to proceed. At the FMC, YG and Aboriginal Affairs and Northern Development Canada (AANDC) are seeking regulatory approval to authorize continued maintenance and management activities that will mitigate environmental impacts, to the degree practicable, and to move the site towards an acceptable closure plan.

The purposes of the IW, as stated in section 1.2 of the Project Proposal are to control and reduce the effects of the existing FMC on human health and safety, and the environment and to compile sufficient site and environmental information to support design, assessment and permitting for the FMRP. Significant adverse environmental effects on the aquatic environment would almost certainly occur in the absence of the proposed project activities. With respect to fish and fish habitat, the overall protection goal of the IW is to avoid significant, direct, adverse effects on fish species. Criteria were developed to allow for the ranking of surface water quality effects as low, medium, or high based on the magnitude, likelihood, duration, geographic extent, and reversibility of predicted changes in water quality (Table 7C-2). Magnitude and likelihood/duration are considered together because potential effects on aquatic biota depend on the combined effects of these exposure characteristics at any given location.

As noted above, potential zinc effects were considered differently than those associated with the other mine-related contaminants (e.g., sulphate, cadmium, cobalt, lead, and manganese), because it is the dominant contaminant of concern at the FMC and a key indicator of changing geochemical conditions. Baseline data indicate that zinc concentrations in surface water around the FMC currently exceed water quality guidelines more often at more stations than do the other mine-related variables (Minnow, 2014).

Therefore, for the aquatic effects assessment, predicted surface water zinc concentrations are considered to have low significance if they do not exceed toxicity thresholds for relevant fish species throughout the local and regional study areas, based on normal seasonal cycles of water flow and concentration (Table 7C-2). An effect of medium significance was defined as the situation in which water concentrations may occasionally exceed the water quality guideline and fish toxicity thresholds for zinc; however, the latter condition could prevail only in the event of a new load source and would be sustained only as long as would be required to develop and implement a mitigation plan (likely less than 8 months) to return prevailing concentrations below fish effect thresholds (i.e., temporary condition). Effects would also be considered to be of medium significance if limited to the LSA or possibly extending to the mouth of Rose Creek or Anvil Creek, but not extending into Anvil Creek or the Pelly River. Predicted zinc concentrations are considered to have high significance if sustained indefinitely at levels that might be expected to harm fish, especially if such concentrations might extend into Anvil Creek or the Pelly River.

Concentrations of the other mine-related variables (e.g., sulphate, cadmium, cobalt, lead, and manganese) are considered to be of low significance if they are predicted to always, or almost always, meet water quality guidelines throughout the local and regional study areas, based on normal seasonal cycles of water flow and concentration (Table 7C-2). Potential effects of water concentrations of these variables are assigned medium significance if levels are expected to sometimes exceed water quality guidelines in the LSA and perhaps in lower Rose Creek or Anvil Creek, but are not expected to exceed toxicity thresholds for relevant fish species. Effects are ranked highly significant if concentrations are expected to be above levels that may harm relevant fish species, especially if such concentrations were to be sustained over time and extend into Anvil Creek or the Pelly River.

3.1.4 Water Quality Predictions

“Normal” surface water quality associated with the 2014-2023 period of the IW was modeled as described by Appendix 7B - Description of Water Modeling and Results. Resulting predictions are presented in Attachment A Figures A.1 to A.4, which show the results of 200 stochastic simulations for representative mine-related variables (zinc, cadmium, cobalt, manganese), including predicted 5th, 50th and 95th percentiles for each month over the 10-year period at representative stations. Monthly summary statistics derived from all stochastic realizations of the predictions are presented for these and additional variables (sulphate, lead, hardness) in Attachment A Tables A.1 to A.9.

Hardness was included because of its effect in modifying the toxicity of some of the relevant water quality variables.

The predicted monthly concentrations presented in the tables of Attachment A are values that were not exceeded in x percent of months, where "x" represents the 5th, 50th and 95th percentiles of all simulation results. For example, 95th percentiles mean that 95 percent of the months had concentrations below the value shown on the tables. In other words, 1,900 out of the 2,000 individual months simulated (10 years multiplied by 200 stochastic simulations) had concentrations below that value. Each table summarizes, for a specific location, the monthly concentrations at the three percentiles for hardness, sulphate, cadmium, cobalt, lead, manganese, and zinc, and the percentage of months that applicable water quality guidelines will likely be exceeded at each location (i.e., "monthly exceedance probabilities"). The monthly exceedance probability represents the percentage of months that guidelines were exceeded out of the total 24,000 months considered in the simulation. For example, a 3 percent monthly exceedance value for cadmium means that predicted cadmium concentrations were above the guidelines in 720 months out of the 24,000 months considered in the stochastic simulation. The 24,000 months are from the monthly model results of a 10-year stochastic simulation with 200 realizations (12 months times 10 years times 200 stochastic realizations). Further details regarding the modelling assumptions and approach are presented in Appendix 7B - Description of Water Modeling and Results.

Annual variation in water quality at the FMC is generally associated with three seasons: winter baseflow, spring freshet, and the summer/fall ice-free period. Therefore, water quality predictions were further summarized according to season and compared to baseline conditions and water quality guidelines (Attachment A Tables A.10 to A.17).

Predicted concentrations were first compared to water quality guidelines for protection of aquatic life (Table 7C-3), using federal guidelines, if available (e.g., cobalt, cadmium, lead, zinc), otherwise guidelines developed by the British Columbian Ministry of Environment were used (e.g., sulphate, manganese). Predictions were then compared to toxicity data presented in the literature for any variables predicted to exceed water quality guidelines during the 10-year IW period.

3.1.5 Aquatic Toxicity Data

For water quality variables predicted to exceed guidelines for protection of aquatic life at some stations (cadmium, cobalt, manganese, zinc; see Section 3.2), the predicted concentrations were also compared to toxicity data reported in the scientific literature for

Table 7C-3: Summary of water quality guidelines relevant to selected stations at FMC (units mg/L)

Variable	Generic Guideline	Guideline Applied to Each Station for Evaluation of Water Quality Predictions[a] (and median station hardness 2008-12)							
		NF1 (91 mg/L)	X2 (108 mg/L)	X3 (115 mg/L)	X14 (217 mg/L)	R4 (156 mg/L)	V8 (301 mg/L)	A1 (161 mg/L)	P4 (173 mg/L)
Sulphate[b]	0-30 mg/L hardness = 128, 31-75 mg/L hardness = 218, 76-180 mg/L hardness = 309, 181-250 mg/L hardness = 429	309	309	309	429	309	429	309	309
Total Cadmium[c]	$(10^{0.83(\log\{\text{hardness}\})-2.46})/1000$	0.00015	0.00017	0.00018	0.00030	0.00023	0.00040	0.00024	0.00025
Total Cobalt[d]	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Total Lead[c]	$(3.31 + e^{(1.273\ln(\text{mean hardness})-4.704)})/1000$	0.006	0.007	0.007	0.012	0.009	0.016	0.009	0.01
Total Manganese[b]	(0.0044 x hardness) + 0.605	1.0	1.1	1.1	1.6	1.3	1.9	1.3	1.4
Total Zinc[c]	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

[a] Guideline was adapted to median station hardness, where appropriate, based on generic guideline.

[b] BCMOE (British Columbia Ministry of the Environment). 2013. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia. Accessed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html, November 2013.

[c] CCME (Canadian Council for Ministers of the Environment). 2014a Canadian Water Quality Guidelines for the Protection of Aquatic Life. Accessed at: http://st-ts.ccme.ca, February 2014. The zinc guideline is currently being updated to incorporate relevant scientific literature published since the original guideline was developed (1987) and is expected to be based on water hardness.

[d] Environment Canada. 2013. Federal Environmental Quality Guidelines: Cobalt. February 2013.

aquatic biota. Data were compiled for both acute (short-term) exposures and chronic (long-term) exposures (Attachments B-E). Raw data tables present the available details of each toxicity test. Depending on the species and life-stage tested, short-term exposures were typically defined as less than one day (algae), four days (invertebrates and larval fish), or seven days (older fish), consistent with current Environment Canada protocols (CCME 2007). However, long-term exposure data are generally considered most relevant and conservative for assessing potential effects of predicted concentrations, because conditions cannot be reliably predicted for periods as brief as hours or a few days.

Cobalt toxicity data were taken from the federal water quality guideline recently developed by Environment Canada (2012) as well as the guideline used in British Columbia (Nagpal 2004) (Attachment D, Tables D.1 to D.3). The aquatic toxicity of the other metals of interest (cadmium, manganese, zinc) is influenced by water hardness, although the current guideline for zinc, developed in 1987, does not reflect this[2]. In order to rank the relative sensitivities of different aquatic species to these metals, it was necessary to convert reported effect concentrations to a common water hardness. Data sources and the approaches used for adjusting toxicity data to the different water hardnesses are discussed below for each metal.

3.1.5.1 Cadmium

The federal water quality guideline for cadmium (CCME 2014a) was used as the basis for assessing potential effects to aquatic species. The guideline rationale document (CCME 2014b) presents the water hardness-cadmium toxicity slopes for a range of aquatic species and explains how the data were combined to derive average slopes for both short-term and long-term exposures. For species that were tested in water with different water hardness, the derived slopes were used to adjust all toxicity data to a common water hardness of 50 milligrams per litre (mg/L). The tables of toxicity data presented by CCME (2014b), adjusted to a common water hardness of 50 mg/L, are presented in Attachment C, Tables C.1 and C.2, and the same slope factors were used to also express the toxicity data for water hardnesses of 100 and 200 mg/L.

3.1.5.2 Manganese

No federal water quality guideline exists for manganese but guidelines have been developed in British Columbia (Reimer 1999) and the United States (GEI 2009). Data

[2] An update is underway and the revised guideline is expected to be hardness-based.

from these sources, plus USEPA (2010) were combined and hardness-toxicity slopes derived by GEI (2009) were used to convert all toxicity to water hardnesses of 50, 100, and 200 mg/L (Attachment E, Tables E.1-E.3)

3.1.5.3 Zinc

For zinc, hardness-toxicity relationships were developed from data reported in the scientific literature following procedures similar to those used by other authors for cadmium (CCME 2014b) and manganese (GEI 2009) (Attachment B, Figure B.1). Raw data were examined to identify toxicity tests for which the hardness of the exposure water was reported and then identify species for which there were data for the same or similar endpoints over a range of exposure water hardness levels (>2-fold range), including at least one exposure with water hardness of at least 100 mg/L. Only zinc toxicity tests that were conducted at pH ≥ 7.4 were included to minimize the confounding influence of pH on the available toxicity data[3]. If there were replicate test results within a study for the same endpoint at the same or similar water hardness, geometric mean hardness and effect concentrations were computed before using the data to define the hardness-toxicity relationship for the substance.

The resulting data were then plotted for each species based on a regression of natural logarithm (Ln) of toxicant concentration as the dependent variable against Ln of hardness as the independent variable. This yielded the species-specific slopes for the hardness-toxicity relationship. There were sufficient data to derive a slope for at least one plant/alga, invertebrate, and fish species. The slopes for the hardness-toxicity relationships were tested for differences among species and then, not being different, were combined to derive an average slope.

To assess relative species sensitivity, the lowest toxic effect concentration corresponding to an exposure hardness of 100 mg/L was identified for each study and species. A hardness of 100 mg/L as $CaCO_3$ was selected as the basis for ranking species sensitivities, because water hardness downstream of the Faro Mine is rarely lower than this level (Minnow 2014). For studies not including an exposure hardness of 100 mg/L, the toxic effect concentration for each study-species combination was adjusted to an exposure hardness of 100 mg/L based on the combined slope for the hardness-toxicity relationship. The lowest value for each species (at hardness of 100 mg/L) was then identified and used to rank all species in terms of relative sensitivity. In cases where there

[3] Also, more relevant toxicity data were available for a basic than neutral-acidic range of exposure pH and the pH range for surface waters around and downstream from the FMC are expected to usually be circum-neutral to slightly basic.

were both effect (e.g., EC10, IC25, maximum acceptable toxicant concentration [MATC], etc.) and no-effect (NOEC) endpoints reported, the lowest effect concentration was selected.

For species for which the original test hardness was reported, the same slope factors described above were also used to estimate toxicity at water hardness values other than 100 mg/L. If test hardness was not reported, an adjustment could not be made and the same reported effect concentration for the species was assumed for all water hardness.

3.2 Analysis of Potential Effects

As noted in Section 3.1.1 the assessment focuses on potential effects associated with a normal operating scenario for the IW. However, there is potential for worse conditions to periodically develop, and water quality may be degraded relative to normal conditions until a remedial solution can be developed and implemented (e.g., a period of up to 8 months). In such circumstances, it is expected that, as during normal operations, zinc will be the dominant contaminant of concern. So the assessment also considers the potential effects of zinc during an episodic adverse scenario.

3.2.1 Initial Evaluation of Predicted Water Quality

For the normal operating scenario, predicted concentrations were initially compared to baseline concentrations for representative local and regional monitoring stations (Table 7C-4) and to water quality guidelines (Table 7C-3). Some water quality guidelines vary based on water hardness, so station specific guidelines were developed based on observed water hardness over the baseline period (Table 7C-4). Future median surface water concentrations of sulphate, cadmium, and lead are expected to be below water quality guidelines for protection of aquatic life during winter baseflow, spring freshet, and summer/fall periods at all stations (Table 7C-4; Attachment Tables A.10-A.17). Even predicted 95th percentile values for sulphate and lead are not expected to exceed the guidelines[4] (Attachment Tables A.1-A9). Therefore, it is assumed that no significant adverse effects to aquatic biota will arise as a result of exposure to sulphate or lead, and these substances were not evaluated further. However, the predicted range of values for cadmium suggests that peak concentrations may occasionally exceed guidelines at some locations (Attachment Tables A.1-A.9) so potential effects of cadmium were evaluated. Also, median as well as peak concentrations of cobalt, manganese, and zinc are predicted to be above guidelines at some stations and/or seasons (Table 7C-4; Attachment Tables

[4] Only the 95th percentile values at X14 in April and V8 in August were slightly above the sulphate guideline and judged to be inconsequential in the context of all other results.

Table 7C-4: Current (2008-2012) versus predicted (2014-2023) median (50th percentile) of seasonal water concentrations for key mine-related variables. Shaded values are above the water quality guideline.

Variable	Station	Local (L) versus Regional (R)	Guideline[a] (mg/L)	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
				Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Sulphate	NF1	L	309	19	5	12	24	14	16
	X2	L	309	28	7	12	26	15	18
	X3	L	309	28	8	13	22	12	14
	X14	L	429	277	72	110	212	109	179
	R4	R	309	109	33	52	115	88	143
	R5	R	309	-[b]	-[b]	-[b]	82	45	72
	A1	R	309	54	19	34	70	36	56
	V8	R	429	165	60	100	129	85	193
Total Cadmium	NF1	L	0.00015	0.00003	0.00004	0.00005	0.00005	0.00005	0.00005
	X2	L	0.00017	0.00003	0.00004	0.00002	0.00015	0.00009	0.00010
	X3	L	0.00018	0.00002	0.00003	0.00002	0.00012	0.00007	0.00008
	X14	L	0.00030	0.00009	0.00006	0.00004	0.00015	0.00011	0.00014
	R4	R	0.00023	0.00001	0.00006	0.00003	0.00010	0.00009	0.00012
	R5	R	0.00023	-[b]	-[b]	-[b]	0.00009	0.00007	0.00008
	A1	R	0.00024	0.00002	0.00009	0.00003	0.00008	0.00006	0.00007
	V8	R	0.00040	0.00006	0.00017	0.00008	0.00015	0.00035	0.00032
Total Cobalt	NF1	L	0.0025	0.00037	0.00036	0.00042	0.00030	0.00019	0.00023
	X2	L	0.0025	0.00019	0.00022	0.00010	0.00030	0.00019	0.00023
	X3	L	0.0025	0.00011	0.00014	0.00007	0.00026	0.00017	0.00020
	X14	L	0.0025	0.00304	0.00100	0.00143	0.00215	0.00281	0.00452
	R4	R	0.0025	0.00004	0.00059	0.00034	0.00127	0.00224	0.00363
	R5	R	0.0025	-[b]	-[b]	-[b]	0.00090	0.00111	0.00177
	A1	R	0.0025	0.00003	0.00092	0.00014	0.00078	0.00087	0.00136
	V8	R	0.0025	0.00009	0.00100	0.00017	0.00018	0.00079	0.00042
Total Lead	NF1	L	0.006	0.0015	0.0020	0.0022	0.0013	0.0013	0.0013
	X2	L	0.007	0.0006	0.0026	0.0010	0.0013	0.0013	0.0013
	X3	L	0.007	0.0004	0.0012	0.0006	0.0013	0.0013	0.0013
	X14	L	0.012	0.0004	0.0016	0.0006	0.0017	0.0021	0.0031
	R4	R	0.009	0.0001	0.0029	0.0004	0.0015	0.0019	0.0027
	R5	R	0.007	-[b]	-[b]	-[b]	0.0014	0.0016	0.0019
	A1	R	0.009	0.0001	0.0023	0.0003	0.0014	0.0015	0.0018
	V8	R	0.016	0.0003	0.0031	0.0006	0.0026	0.0050	0.0030
Total Manganese	NF1	L	1.0	0.08	0.04	0.09	0.12	0.05	0.07
	X2	L	1.1	0.08	0.03	0.04	0.13	0.05	0.08
	X3	L	1.1	0.06	0.04	0.03	0.10	0.04	0.05
	X14	L	1.6	3.9	0.62	1.0	2.4	2.5	4.2
	R4	R	1.3	0.03	0.39	0.34	1.3	2.0	3.3
	R5	R	1.3	-[b]	-[b]	-[b]	0.88	0.91	1.6
	A1	R	1.3	0.01	0.18	0.08	0.73	0.68	1.2
	V8	R	1.9	0.01	0.08	0.02	0.03	0.25	0.37
Total Zinc	NF1	L	0.03	0.020	0.009	0.023	0.084	0.028	0.045
	X2	L	0.03	0.027	0.025	0.017	0.088	0.029	0.047
	X3	L	0.03	0.021	0.006	0.008	0.066	0.019	0.030
	X14	L	0.03	0.088	0.040	0.039	0.066	0.032	0.056
	R4	R	0.03	0.006	0.025	0.015	0.038	0.026	0.045
	R5	R	0.03	-[b]	-[b]	-[b]	0.028	0.015	0.025
	A1	R	0.03	0.004	0.011	0.006	0.024	0.013	0.020
	V8	R	0.03	0.013	0.032	0.013	0.013	0.048	0.053

[a] Table 7C-3

[b] Insufficient data

A.1-A.17). Therefore, potential surface water quality effects associated with cobalt, manganese, and zinc are also discussed in detail below.

3.2.2 Cadmium

3.2.2.1 Aquatic Chemistry

Cadmium is a relatively rare element, ranking 64th in relative abundance of elements in the earth's crust at concentrations of about 0.2 milligrams per kilogram (mg/kg) (CCREM 1987). It is a minor nutrient for plants at low concentrations (Lane and Morel 2000, Lee et al. 1995, Price and Morel 1990), but has no nutritional value for animals (USEPA 2001). Cadmium concentrations in uncontaminated surface waters are typically <0.1 micrograms per litre (µg/L) (Hollis et al. 2000a). In most well oxygenated fresh waters with low organic carbon content, free divalent cadmium (Cd^{2+}) will be the predominant form (USEPA 2001).

Cadmium has only a moderate affinity for dissolved organic material and binding decreases with increased water hardness (Pentinnen et al. 1998). Adsorption of cadmium onto soil particles, silicon or aluminum oxides is strongly pH-dependent, increasing as conditions become more alkaline (USEPA 2008). However, cadmium has considerably less affinity for such absorbents than copper, zinc, and lead and is therefore relatively more mobile in aquatic environments (USEPA 2008). The portion of cadmium absorbed to mineral surfaces (e.g., clay) or organic materials may be released in the dissolved state when sediments are disturbed (USEPA 2008). Cadmium found in association with carbonate minerals, precipitated as stable solid compounds, or co-precipitated with hydrous iron oxides may be less readily mobilized by re-suspension of sediments or biological activity (USEPA 2008). Desorption from sediment particles may also be enhanced at pH below 6 or 7 (Van Deuren et al. 2002). Overall, precipitation of cadmium by carbonate or hydroxide and formation of soluble complexes by chloride, sulfate, carbonate, and hydroxide is usually of limited importance in aquatic environments (USEPA 2001).

3.2.2.2 Mode of Toxicity

The Cd^{2+} ion is the most bioavailable and toxic form of Cd to aquatic organisms (Pagenkopf 1983). Cadmium is taken up through chloride cells in external membranes of fish (e.g., gills) and invertebrates (Verbost et al. 1989, Wicklund-Glynn et al. 1994; Silvestre et al. 2004). These are the cells regulating calcium uptake from water (Galvez et al. 2006). At cell surfaces, Cd^{2+} competes with Ca^{2+} for specific, high-affinity calcium-binding sites (Playle 1998, Playle et al. 1993a and 1993b; Croteau and Luoma 2007), although low-affinity, high-capacity binding sites may also play a role in cadmium toxicity,

at least for some aquatic species (Niyogi et al. 2004). Binding site characteristics are altered in chronic versus acute exposures to calcium or cadmium (Hollis et al. 2000a and 2000b; Niyogi et al. 2004).

The effect of the above is that cadmium blocks calcium uptake and causes calcium deficiency (hypocalcemia) (Roch and Maly 1979; Verbost et al. 1987 and 1989). Unlike for zinc (Section 4.2.2), the inhibition of calcium uptake by cadmium may not be readily reversible (Reid and McDonald 1988). Internally, cadmium accumulates primarily in kidney, liver, and gills of fish (Benoit et al. 1976, Hollis et al. 1999, 2000a, and 2000b).

At acute waterborne concentrations, cadmium severely disrupts calcium homeostasis, which ultimately leads to death (Verbost et al. 1987; Reid and McDonald 1988). Cadmium effects may also be manifested as reduced growth (Peterson et al. 1983, Borgmann and Ralph 1986) and/or reduced reproductive performance (Dobson 1992, Brown 1994), although growth is not always a more sensitive endpoint than survival (Eaton et al. 1978, Anderson 1980; Hollis et al. 2000a and 2000b). Survival was the most sensitive test endpoint for *Hyalella azteca* exposed to cadmium in water whereas *H. azteca* exposed to dietary cadmium showed growth effects at concentrations lower than those affecting survival (Ball et al. 2006). This suggests that dietary cadmium may have a different mechanism of toxicity than water-borne cadmium. Reproduction of *Daphnia magna* was affected at aqueous cadmium concentrations almost an order of magnitude lower than those causing mortality (Barata and Baird 2000). Typically, the maximum cadmium concentration that can be tolerated by a species is 0.002 times the acute lethal concentration or higher (Marshall 1979, U.S. EPA 2001). Among fish, swim-up alevins or young juveniles appear to be more sensitive to cadmium exposure than younger or older life-stages (Benoit et al. 1976, Chapman 1978, Eaton et al. 1978, Buhl and Hamilton 1991).

Cadmium toxicity to biota may be greater from waterborne exposure than dietary exposure (Abel and Barlocher 1988, Spry et al. 1988, Sofyan et al. 2007) or the converse (Roy and Hare 1999). Greatly elevated Cd levels in diet were required compared to waterborne exposures to achieve the same gill burden in rainbow trout, suggesting that the gut provides a better barrier than the gill to internal accumulation (Szebedinszky et al. 2001). At similar cadmium burden in gills, trout with dietary pre-exposure had lower accumulation in liver and kidney of new Cd from water than in trout pre-exposed to cadmium via water only, indicating the route of cadmium exposure affects cadmium uptake and tissue distribution characteristics (Szebedinszky et al. 2001).

Among various water quality characteristics that could potentially influence Cd uptake and toxicity (e.g., hardness, pH, alkalinity, and dissolved organic matter (DOM)), hardness is often reported to be the dominant factor (Calamari et al. 1980; Hollis et al. 1997 and 2000b; Pentinnen et al. 1998; Hansen et al. 2002).

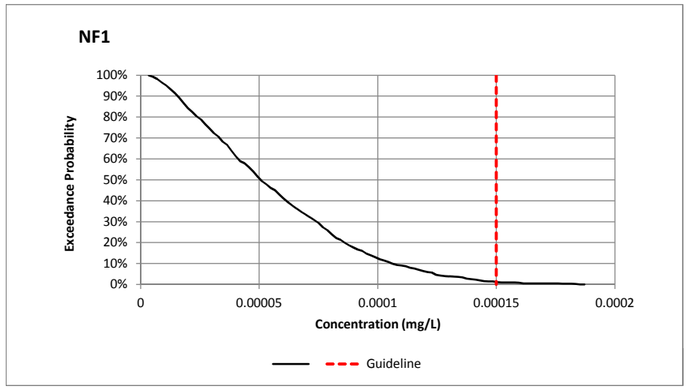
3.2.2.3 Predicted Concentrations and Effects

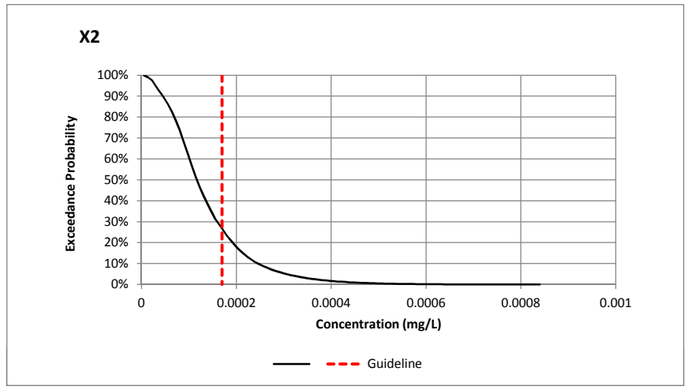
Under the normal operating scenario, median concentrations of cadmium are predicted to be slightly higher than baseline conditions during the IW period, but will still be less than water quality guidelines for protection of aquatic life (Table 7C-4). However, peak concentrations may occasionally exceed the guidelines in lower NFRC (X2), RCD (X3), in Rose Creek immediately downstream of the Faro Mine Area (X14) and in lower Vangorda Creek (V8) (Attachment Tables A.2-A.4, A.9). The probabilities of such exceedances range from approximately 3 percent at X14 to 25 percent at X2 (Figure 7C-4). However, toxicity to most aquatic species occurs at concentrations of 0.0005 mg/L or more, and fish are typically unaffected until concentrations are at or above approximately 0.0017 mg/L (Table 7C-5). Concentrations are not expected to be above 0.0005 mg/L in the Rose-Anvil creek system and will be below 0.0007 in lower Vangorda Creek (Figure 7C-4). Therefore, cadmium concentrations associated with the IW are not expected to affect fish and will likely also have negligible effects on most other aquatic biota in both local and regional study areas.

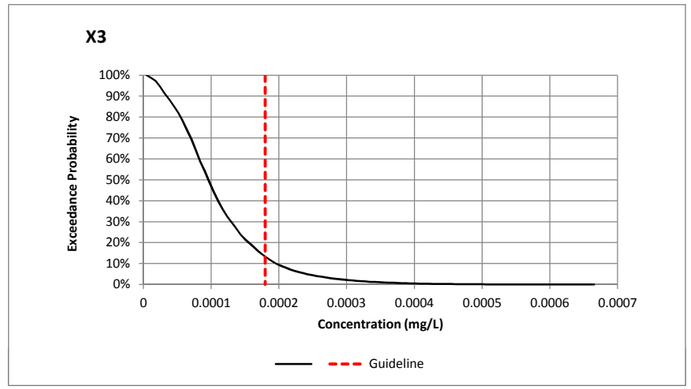
3.2.3 Cobalt

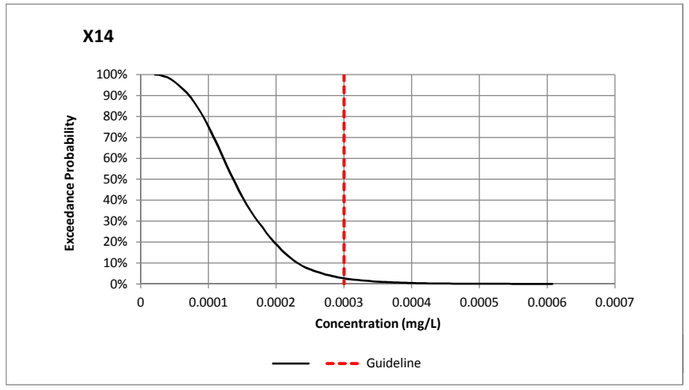
3.2.3.1 Aquatic Chemistry

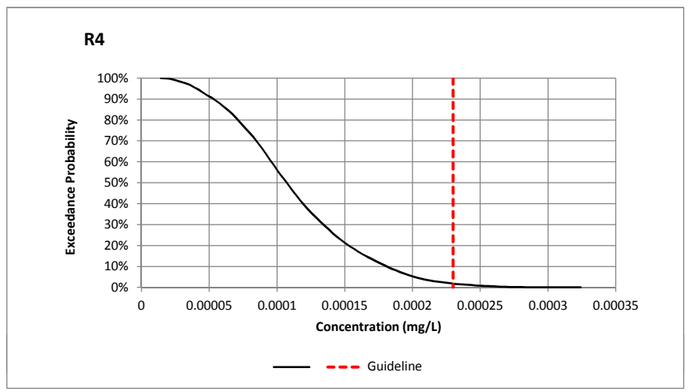
Cobalt is the 33rd most abundant metal in earth's crust and is usually found only in a chemically combined form (Hamilton 1994; Blust 2012). In aquatic environments, cobalt mainly occurs in Co(II) and Co(III) valence oxidation states, forming organic and inorganic salts and complexes (Nagpal 2004). The solubility of cobalt salts is highly variable in water, depending on its form. Dominant species in fresh water are Co^{2+}, $CoCO_3$, $Co(OH)_3$ and CoS (Moore 1991). Cobalt strongly associates with dissolved and colloidal organic carbon (Blust 2012) and also adsorbs to particles and settles into sediment (Hamilton 1994). Cobalt tends to be associated with particulate phases in aquatic systems, with a lower proportion being present in dissolved form (Horowitz 1985, Environment Canada 2013). Concentrations of cobalt in aquatic environments have been shown to correlate inversely with pH and positively with suspended solids (Moore 1991).

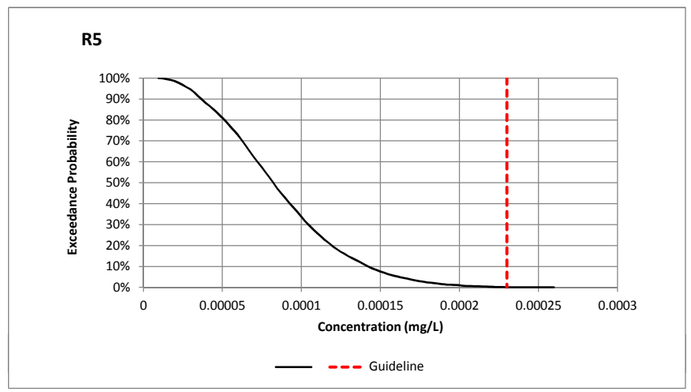


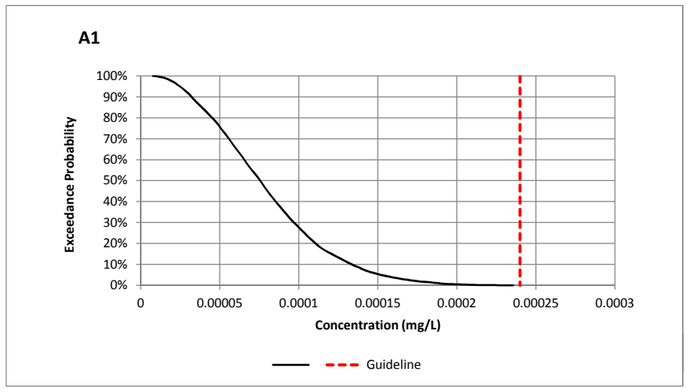


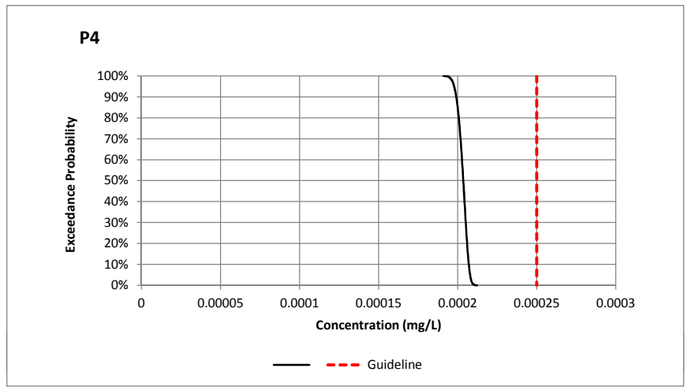












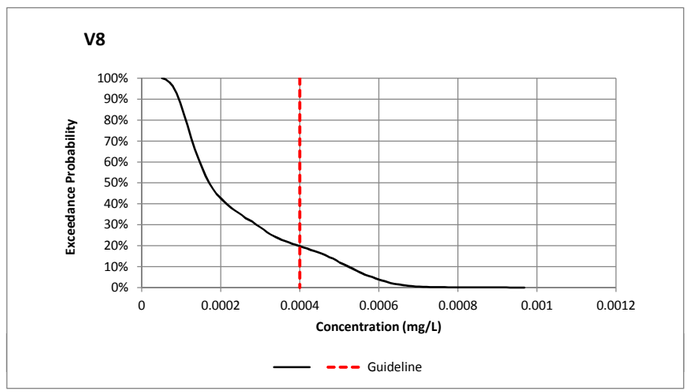


Figure 7C-4: Percentage of months when water concentrations of cadmium are expected to be above the water quality guideline.

Table 7C-5: Water quality guidelines for protection of aquatic life and approximate toxicity thresholds for key mine-related variables at the FMC. Detailed toxicity data for each metal are presented in Attachments B - E.

Exposure Duration	Endpoints Considered in Assessing Potential Aquatic Effects	Cobalt (mg/L)	Values Adjusted for Water Hardness of 100 vs. 200 mg/L. Water Hardness of 100 vs 200 mg/L					
			Cadmium		Manganese		Zinc	
			100 mg/L	200 mg/L	100 mg/L	200 mg/L	100 mg/L	200 mg/L
Long-term (weeks)	Water Quality Guidelines - CCME (except Co[b])	0.0025[b]	0.00016[a]	0.00028[a]	-	-	0.03[a]	0.03[a]
	Water Quality Guidelines - BCMOE	0.0040[d]	0.00003[c]	0.00006[c]	1.0[d]	1.5[d]	0.015[d]	0.09[d]
	Water Quality Guidelines - USEPA (except Mn[f])	-	0.00027[e]	0.00046[e]	1.7[f]	2.1[f]	-	-
	Possible effects to sensitive plants or invertebrates, but not likely relevant fish species	0.02[h]	0.0005	0.0010	1.6[h]	2.0[h]	0.04	0.07
	Possible threshold for effects to relevant fish species	0.30[h]	0.0017	0.0030	1.6[h]	2.0[h]	0.06	0.11
Short-term (hours, days)	Water Quality Guidelines - CCME[a]	-	0.0021[b]	0.0042[b]	-	-	-	-
	Water Quality Guidelines - BCMOE	0.11[d]	-	-	1.6[d]	2.7[d]	0.04[d]	0.12[d]
	Water Quality Guidelines - USEPA	-	0.0020[e]	0.0043[e]	3.0[f]	3.7[f]	0.12[g]	0.22[g]
	Lethal effects to sensitive plants or invertebrates	0.30[h]	0.0020	0.0035	3.0[h]	5.0[h]	0.04	0.07
	Lethal effects to relevant fish species	0.50[h]	0.0035	0.0071	3.0[h]	5.0[h]	0.15	0.27

[a] CCME (Canadian Council for Ministers of the Environment). 2014a. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Accessed at http://st-ts.ccme.ca/, February 2014.

[b] Environment Canada. 2013. Federal Environmental Quality Guidelines: Cobalt. February 2013.

[c] BCMOE (British Columbia Ministry of the Environment). 2006. A Compendium of Working Water Quality Guidelines for British Columbia. Environmental Protection Division, Victoria, British Columbia.

[d] BCMOE (British Columbia Ministry of the Environment). 2013. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia. Accessed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html, November 2013.

[e] USEPA (United States Environmental Protection Agency). 2001. 2001 Update of Ambient Water Quality Criteria for Cadmium. April 2011. Dissolved conversion factor was not used in calculating criteria.

[f] GEI (GEI Consultants Inc.). 2009. Ambient Water Quality Standards for Manganese. July 2009.

[g] USPEA (United States Environmental Protection Agency). 1996. 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life.

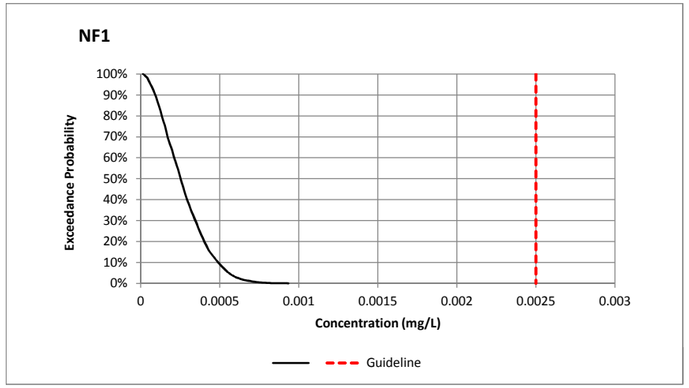
[h] Limited data.

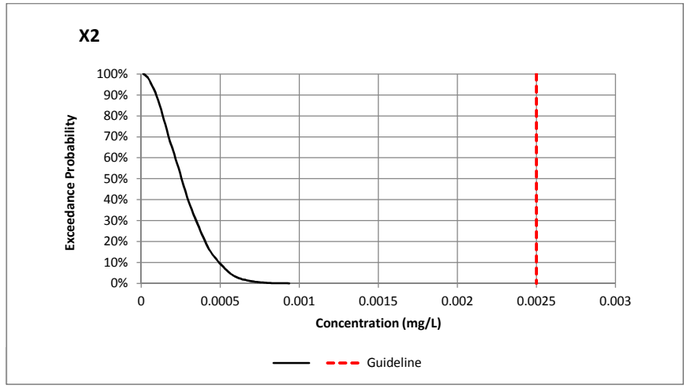
3.2.3.2 Mode of Toxicity

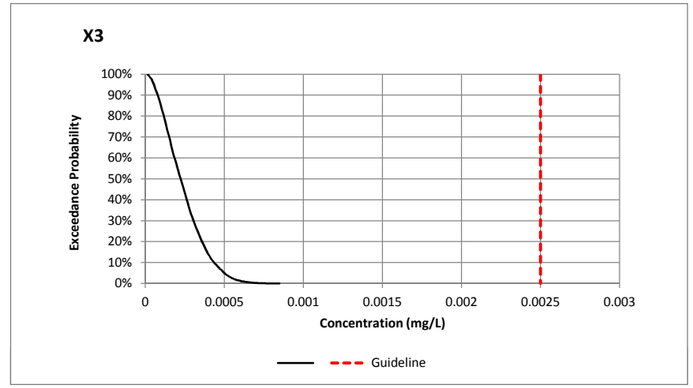
Cobalt is an essential element to animals, being an intrinsic part of vitamin B_{12} (cobalamin) and is also an active nutrient for bacteria, algae, and fungi (Blust 2012). Uptake of cobalt in freshwater fish is strongly dependent on speciation and calcium concentrations (Blust 2012). However, very little is known about the specific molecular mechanisms of cobalt uptake and toxicity and most inferences regarding mechanisms are from mammalian studies (Blust 2012). Generally, it is thought that cobalt inhibits various enzymes which causes a reduction in tissue respiration and metabolism (Smith and Carson 1981, as cited in Environment Canada 2013). For example, cobalt impedes the citric acid cycle and can also inhibit or stimulate different enzymes in the liver (Environment Canada 2013). In its Co(II) oxidation state, the cobalt ion can substitute for other divalent cations, reacting with the thio group of amino acids, proteins and other coenzymes and cofactors, resulting in altered enzyme activity (Smith and Carson 1981). In aquatic environments, invertebrates are generally more sensitive to cobalt exposure than fish (Environment Canada 2013).

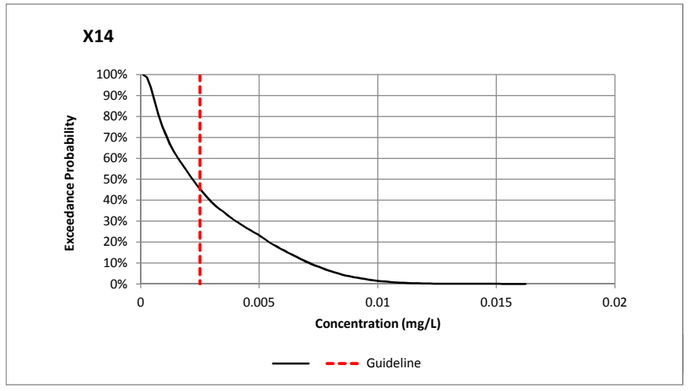
3.2.3.3 Predicted Concentrations and Effects

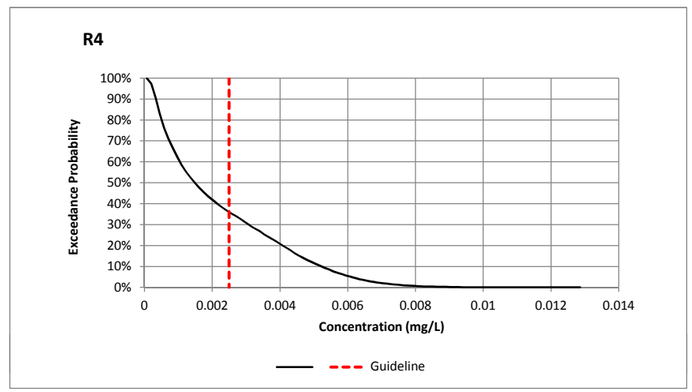
For the normal operating scenario, median concentrations of cobalt associated with the IW are predicted to be comparable to the range observed during the baseline period at most stations, but may increase in Rose Creek at X14 and R4 during the ice-free period, and also at V8 (Table 7C-5). A water quality guideline for cobalt of 0.0025 mg/L was recently developed by Environment Canada (2013) to protect against effects associated with long-term exposure. Water concentrations higher than the guideline are predicted for some stations in the Rose-Anvil system but not in Vangorda Creek (V8) (Figure 7C-5 and Attachment A). Concentrations in Rose Creek at X14 and R4 are predicted to exceed the guideline in approximately 45 percent and 35 percent of months, respectively (Figure 7C-5). The toxicity data used to derive the Environment Canada guideline are provided in Attachment D, Table D.3. In addition, toxicity data associated with acute exposures to cobalt were summarized by Nagpal (2004) (Attachment Tables D.1-D.2). Effects to sensitive invertebrates and algae have been reported at cobalt concentrations as low as 0.003 mg/L, but most organisms are not affected at concentrations below 0.02 mg/L (Tables 7C-5). Maximum cobalt concentrations are not expected to rise above 0.02 mg/L at any stations during the IW period (Figure 7C-5). Therefore, cobalt concentrations associated with the IW are not expected to affect fish and effects on most other aquatic biota are expected to be negligible.

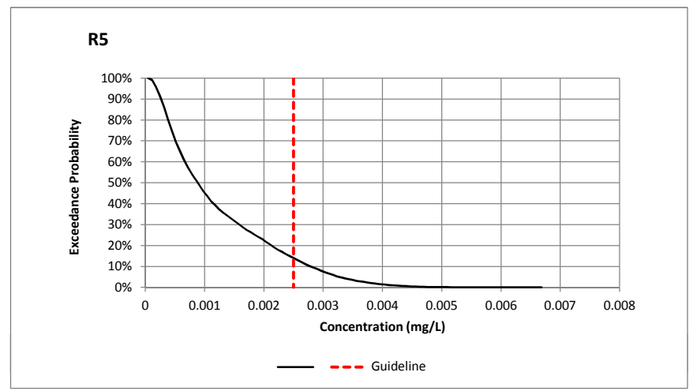


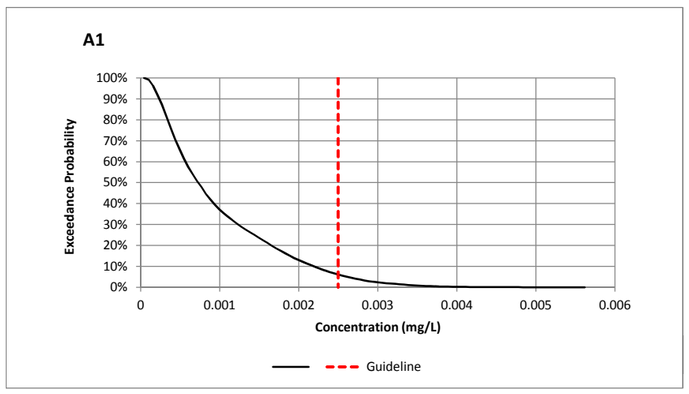


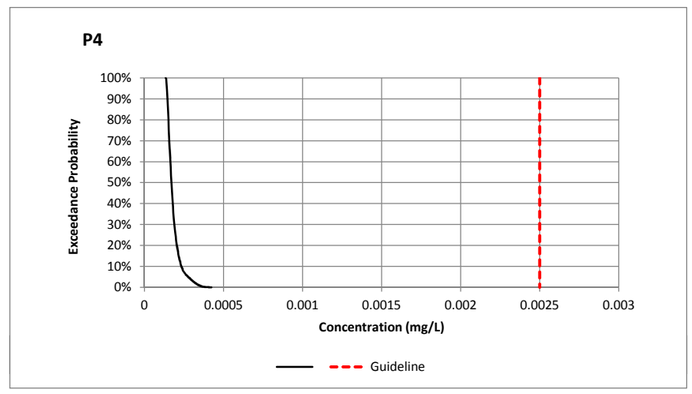












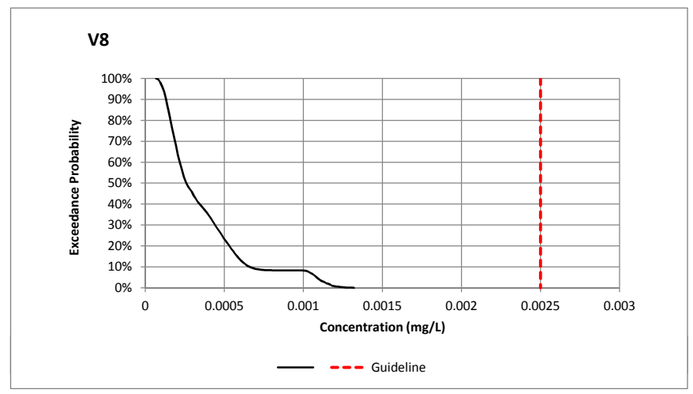


Figure 7C-5: Percentage of months when water concentrations of cobalt are expected to be above the water quality guideline.

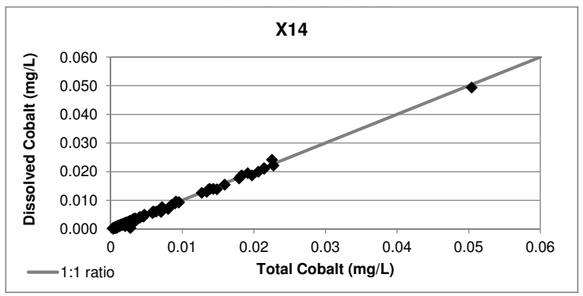
Furthermore, as noted in Section 3.2.3.1, cobalt tends to be associated with particulate phases in aquatic systems. Therefore, although cobalt is released at X14 mainly in the dissolved phase, highest concentrations in areas farther downstream tend to be increasingly associated with particulates than the dissolved phase (Figure 7C-6). Metals tend to be more bioavailable to interact with aquatic organisms in the free ion form than when complexed or speciated with other components in water (Luoma 1983, Morel 1983, Pagenkopf 1983, DiToro et al. 2001, Luoma and Rainbow 2008). Therefore, aquatic cobalt concentrations are expected to be increasingly less bioavailable farther downstream from the FMC as a result of partitioning to suspended and bottom sediments.

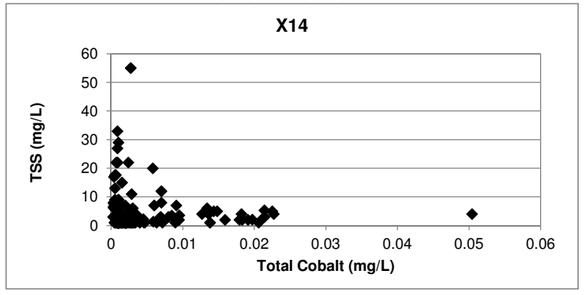
Based on all of the information presented above, it is expected that cobalt concentrations associated with the IW will have negligible effects on aquatic biota in either the local or regional study areas.

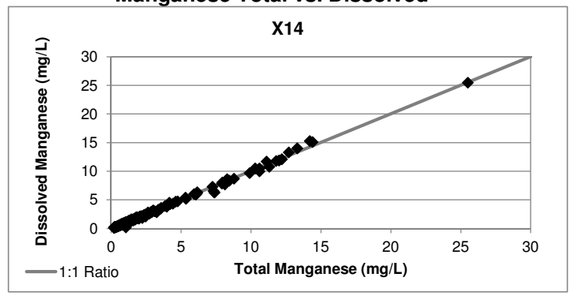
3.2.4 Manganese

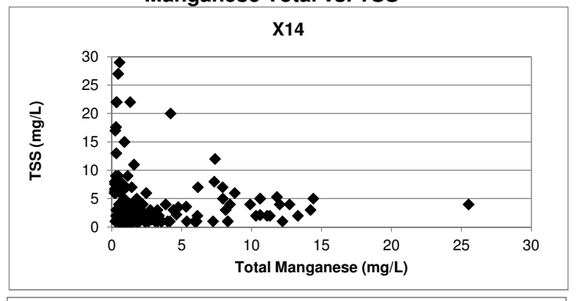
3.2.4.1 Aquatic Chemistry

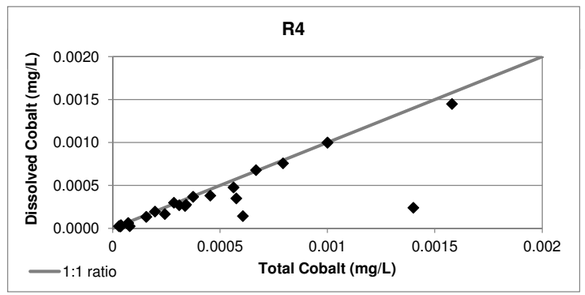
Manganese is the 12th most common element, the 4th most abundant metal, and is universally distributed in the earth's crust and waters (IMI 2013). Manganese naturally occurs in rocks and soils, most abundantly in metamorphic and sedimentary rocks, with overall crustal abundance of 0.085 percent to 0.095 percent (Reimer 1999). In aerobic surface waters with pH above 7, concentrations of dissolved manganese are low due to equilibrium reactions that favour conversion to Mn(IV), which tends to precipitate in the form of manganese oxides (MnO_2) (Moore 1991; Stumm and Morgan 1996). However, Mn(IV) is readily reduced under anoxic conditions to the soluble Mn(II) species (Stokes et al. 1988). Manganese solubility also increases under low pH conditions. As a result, manganese is most common in the Mn(II) and Mn(IV) oxidation states in aquatic systems, precipitating mainly as Mn(IV) and re-solubilizing in the water mainly as Mn(II) (Moore 1991). The binding constant for manganese with organic ligands is relatively weak (Irving and Williams 1953); consequently, divalent manganese exchanges rapidly between water and ligands (Baden and Eriksson 2006). Typically, 90 percent to 95 percent of the total waterborne manganese residue is associated with particulate matter (Nagpal 2001). Total manganese concentrations in surface water are usually highest during high runoff periods (e.g., spring snow melt), when particulate concentrations are high, and lower during periods of stable stream flow (Reimer 1999).

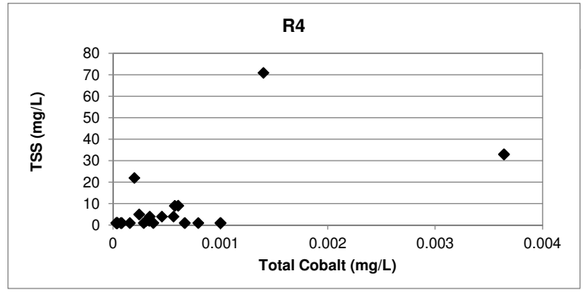


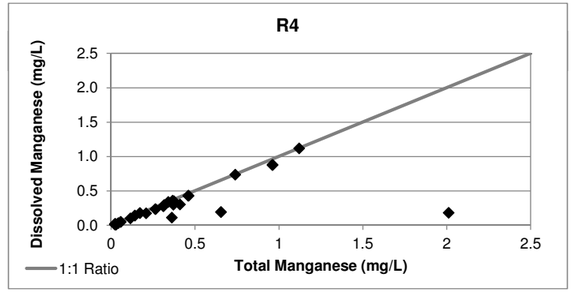


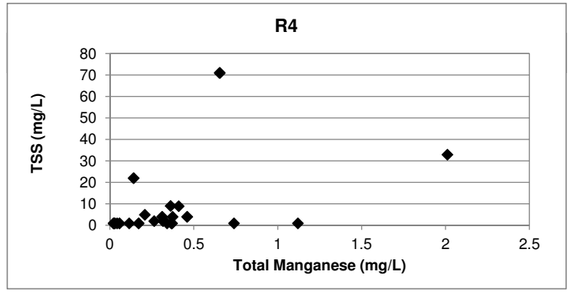


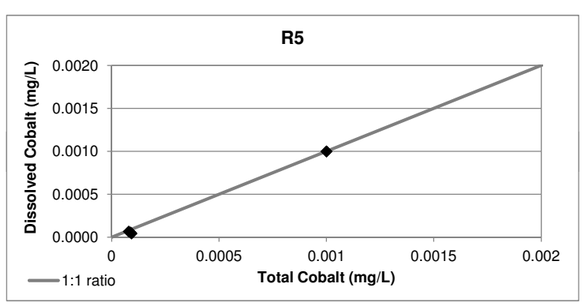


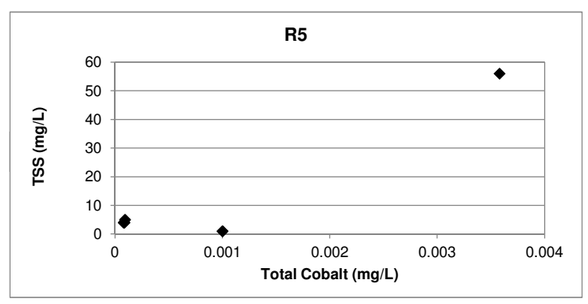


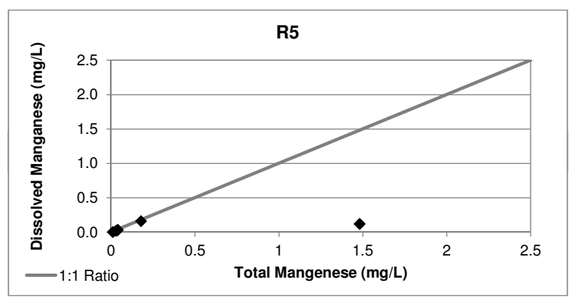


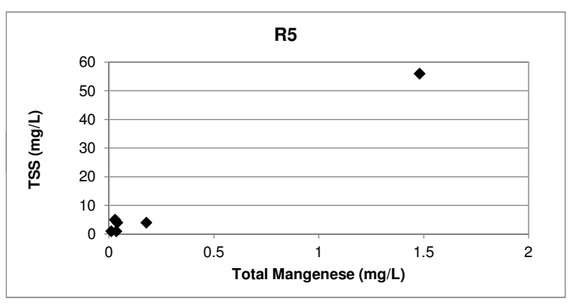


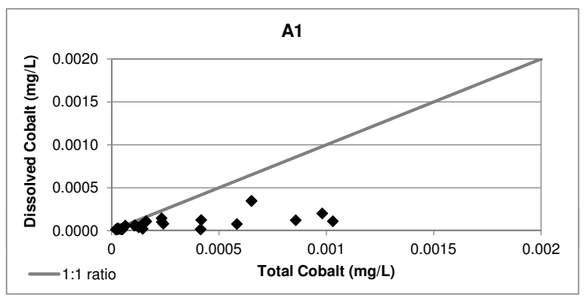


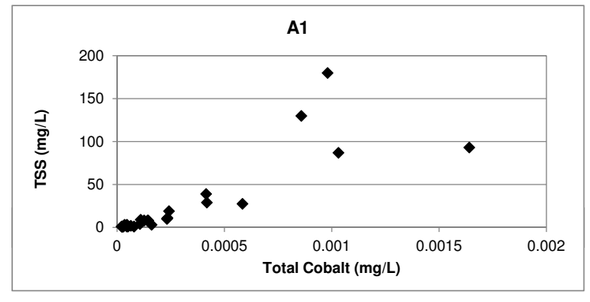


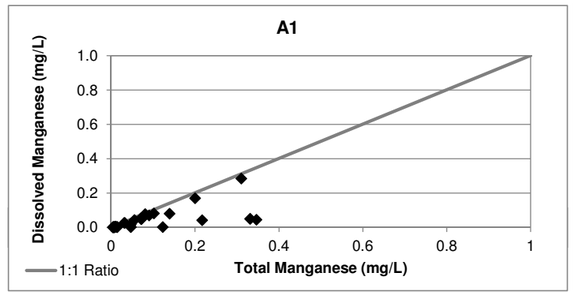












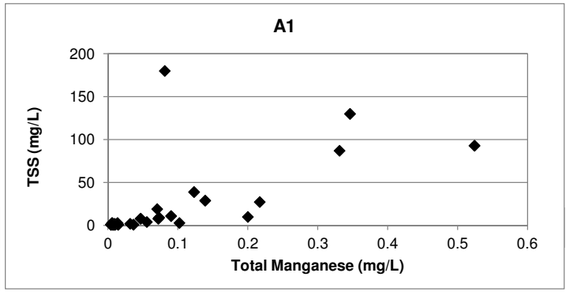


Figure 7C-6: Concentrations of total cobalt and manganese compared to dissolved concentrations and total suspended solids concentrations at stations X14, R4, R5 and A1 in the Rose-Anvil Creek system.

3.2.4.2 Mode of Toxicity

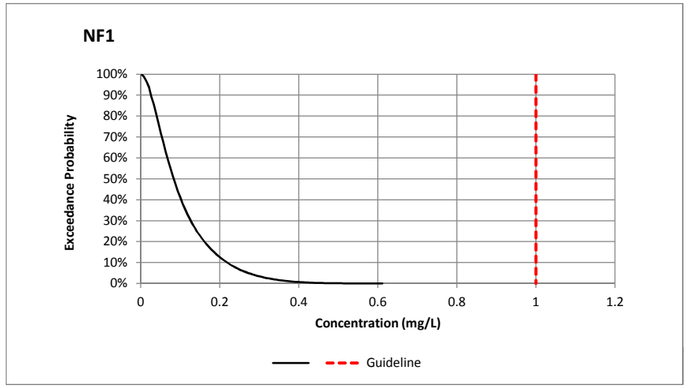
Manganese is an essential nutrient for optimal cellular function (Lasier et al. 2000; Strydom et al. 2006). Relative to many other metals it is considered only slightly to moderately toxic to aquatic organisms, and its presence often ameliorates the effects of other metals (Nagpal 2001). Soluble manganese species, which are readily available for biological reactions, are considered to be the most toxic (Nagpal 2001), but as noted above, most manganese in aerobic freshwater forms insoluble oxide precipitates or is bound to particulates. Consequently, the British Columbia water quality guideline recommends interpretation relative to the dissolved metal fraction in circumstances when elevated levels are associated with high particulate concentrations and there are no obvious concurrent adverse effects (Nagpal 2001). Information on the specific mode of toxicity to aquatic organisms is lacking, presumably because it is considered relatively non-toxic and it tends to precipitate to sediments in most aerobic receiving waters. In mammals manganese is known to cause neurotoxicity by increasing oxidative stress and also disturbing neurotransmitter metabolism (Erikson et al. 2004). As Mn(II), manganese has a relatively high affinity for sulphur and nitrogen in functional groups of proteins and other molecules, which enables Mn to interfere in a wide spectrum of biological processes (Simkiss 1979).

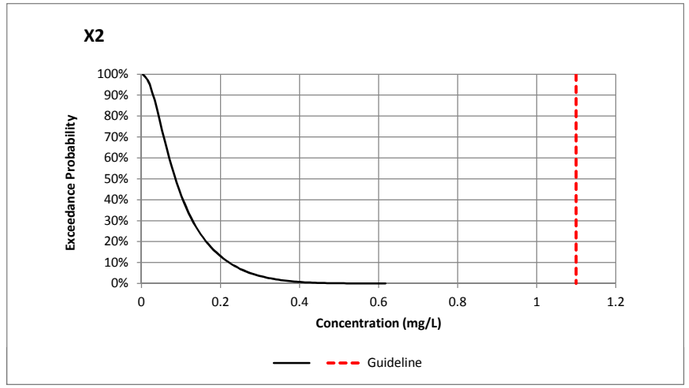
Manganese toxicity decreases as water hardness increases, so the water quality guideline varies depending on water hardness (Nagpal 2001).

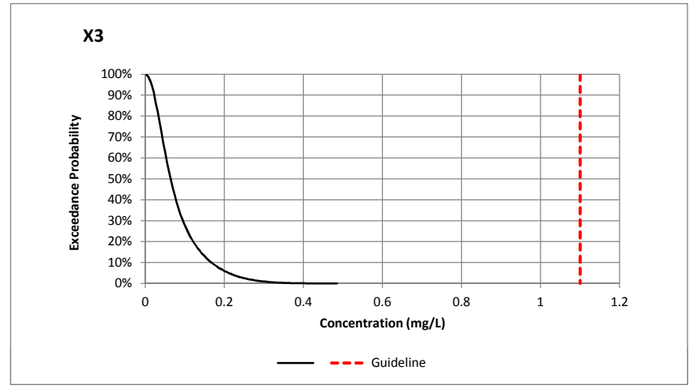
3.2.4.3 Predicted Concentrations and Effects

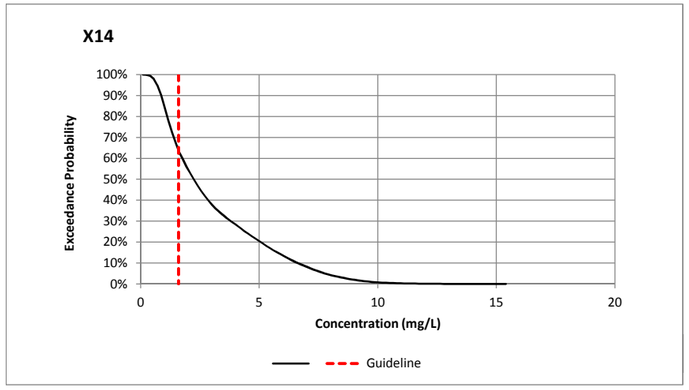
For the normal operating scenario, manganese concentrations are not predicted to change substantially from baseline conditions, except that concentrations may decrease slightly in winter months and increase slightly in other months at Rose Creek stations at, and downstream from, X14 (Table 7C-4). There is no federal water quality guideline for manganese, but British Columbia has established a guideline that varies based on water hardness (Table 7C-5). Manganese concentrations are predicted to be above the hardness-adjusted guidelines in a substantial percentage of months at X14 (65 percent) and in an increasingly lower percentage of months at stations increasing farther downstream (Figure 7C-7).

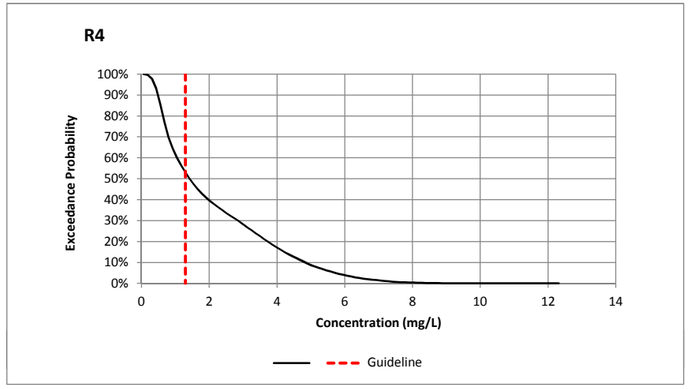
Toxicity data for manganese, particularly for long-term exposures, are sparse and there are no data for the specific fish species found near the FMC (Table 7C-5). The available data suggest that aquatic toxicity could occur at the manganese concentrations predicted at X14 (median 2.4 to 4.2 mg/L). However, winter manganese concentrations at X14

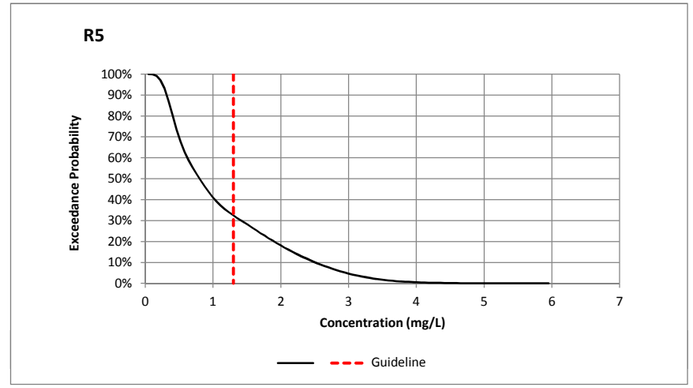


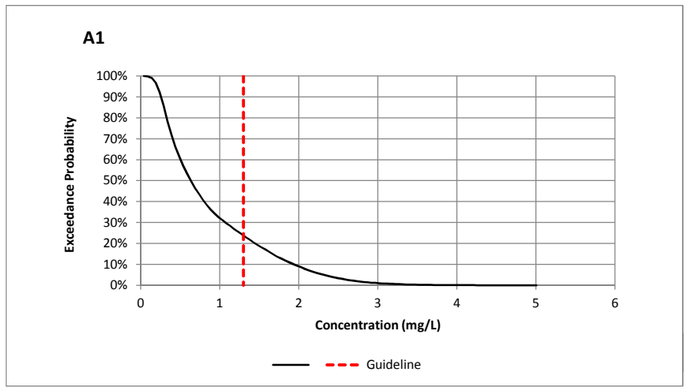


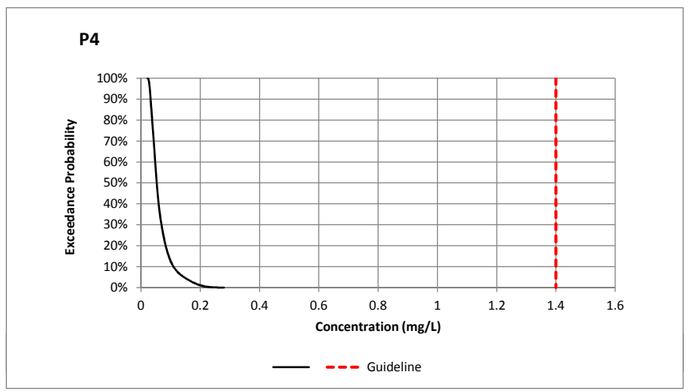












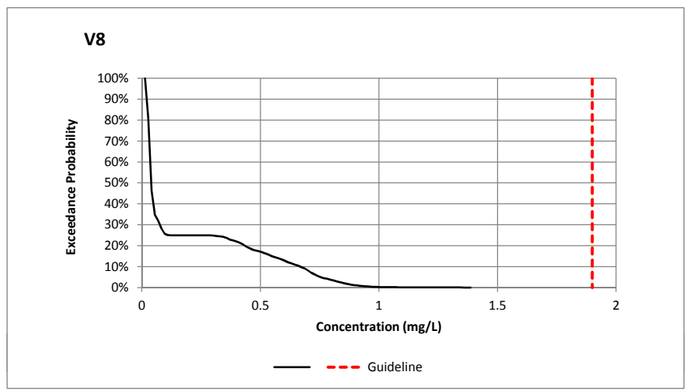


Figure 7C-7: Percentage of months when water concentrations of manganese are expected to be above the water quality guideline.

averaged 3.9 mg/L over the baseline period (Table 7C-4) and baseline biological studies concluded that mine-related effects on aquatic biota (e.g., benthic invertebrate surveys) were undetectable or relatively minor at X14/R2 (Minnow 2014). Also, the predicted median concentrations at X14 are unlikely to cause acute lethality to fish (Table 7C-5).

As noted in Section 3.2.4.1, manganese (like iron, Section 3.1.1, and cobalt, Section 3.2.3) tends to partition to particulate phases of freshwater aquatic systems. Therefore, although manganese is released at X14 largely in the dissolved form, highest concentrations in areas farther downstream tend to be increasingly associated with suspended solids and less in dissolved form (Figure 7C-6). Metals tend to be more bioavailable to interact with aquatic organisms in the free ion form than when complexed or speciated with other components in water (Luoma 1983, Morel 1983, Pagenkopf 1983, DiToro et al. 2001, Luoma and Rainbow 2008). Consequently, any effects associated with manganese are expected to be limited to the area immediately downstream of X14, with gradual reduction of bioavailable manganese farther downstream as a result of partitioning to suspended and bottom sediments.

Overall, the data indicate that aquatic effects, if any, of manganese in surface waters around the FMC would be limited to Rose Creek in the vicinity of X14 (i.e., within the LSA) and would likely be minor in magnitude.

3.2.5 Zinc

3.2.5.1 Aquatic Chemistry

Zinc ranks as the 24th most abundant element in the earth's crust, with an average concentration of 70 mg/kg (CCREM 1987). Zinc concentrations in uncontaminated freshwater are usually ≤ 10 µg/L (USEPA 1987). Zinc occurs in many forms in surface waters, including suspended and dissolved forms. Complexes of zinc with the common ligands of surface waters are soluble in neutral and acidic solutions, so it is readily transported and considered one of the most mobile of the heavy metals (USEPA 1987). Aqueous pH is an important factor influencing zinc speciation (Heijerick et al. 2002b and 2003; Wilde et al. 2006). In freshwater with pH around 6.0, the dominant inorganic forms are the free ion (98 percent) and zinc sulphate (2 percent), whereas at pH of 9.0, the dominant forms are the monohydroxide ion (78 percent), zinc carbonate (16 percent), and the free ion (6 percent) (Turner et al. 1981). Decreasing alkalinity and pH both favour the free metal ion (CCME 1999), which is considered to be the form responsible for aquatic toxicity (Heijerick et al. 2002a, De Shamphelaere et al. 2005).

In the presence of dissolved organic materials, much of the dissolved zinc may be in the form of zinc-organic complexes (Lu and Chen 1977; De Schamphelaere et al 2005), but some studies have shown that only a small proportion of zinc was complexed by organic ligands (CCME 1999; De Shampheleare and Janssen 2004). As with inorganic zinc speciation, formation of organo-zinc complexes is probably at least partially pH-dependent. Greater zinc sorption to dissolved organic carbon likely occurs at higher pH and higher concentrations of dissolved organic matter relative to the amount of zinc present (USEPA 1987; CCME 1999; Heijerick et al. 2003; De Shamphelaere et al. 2005).

Thus, zinc speciation is controlled by pH, alkalinity, and the concentrations of various other inorganic and organic ligands (CCME 1999). Most the zinc introduced to aquatic environments is eventually partitioned into sediment by sorption onto hydrous iron and manganese oxides, clay minerals, and organic materials (USEPA 1987).

3.2.5.2 Mode of Toxicity

Zinc is an essential micronutrient for all living organisms, being involved in nucleic acid synthesis and occurring in many enzymes (CCME 1999). Aquatic toxicity of zinc is primarily attributable to waterborne exposure to the free ion (Zn^{2+}) (Heijerick et al. 2002a, De Shamphelaere et al. 2005), although aquatic invertebrates and some fish may also be affected by ingestion of suspended, particulate, or colloidal zinc. Consequently, zinc toxicity is influenced by the factors affecting zinc speciation. Also, although most studies have focused on the toxic effects of water-borne zinc exposures, dietary exposure to zinc may play a significant role in zinc toxicity to aquatic biota. Reproductive effects on *Daphnia magna* were observed after feeding on algae that had been exposed to 28 µg/L Zn, (De Shamphaleare et al. 2004), whereas daphnid toxicity occurred at concentrations of >100 µg/L in water-only tests conducted at the same laboratory (Heijerick et al. 2005b).

At extremely high waterborne levels, zinc causes gross morphological alterations at the teleost gill (Skidmore and Tovell 1972) and fish usually die within a few hours as a result of tissue hypoxia from impaired gas exchange (Lappivaara et al. 1995). At lower waterborne concentrations that more realistically reflect contaminated environments, zinc (Zn^{2+}) disrupts calcium uptake by chloride cells of the gills (Spry and Wood 1985, Heijerick et al. 2002b, Hogstrand et al. 1995 and 1996). Calcium and zinc appear to compete for binding sites at the channels that regulate calcium uptake, such that while elevated levels of zinc inhibit calcium uptake, the converse is also true (Santore et al. 2002). Inhibition of calcium uptake leads to hypocalcemia, which may culminate in the death of the fish within a few days, depending on the zinc concentration. Survival of fish is equally or more sensitive than other endpoints in chronic exposures to zinc (De Shampheleare and

Janssen 2004). Swim-up alevins or young juveniles appear to be more sensitive to zinc than either younger or older life stages (Buhl and Hamilton 1990).

As with fish, it appears that zinc toxicity to aquatic invertebrates (Heijerick et al. 2005b; Muyssen et al. 2006) and algae (Wilde et al. 2006) may occur through disruption of calcium regulation by chloride cells. However, there may be differences in the specific mechanisms controlling acute versus chronic toxicity, at least for some invertebrates (Pauluskis and Winner 1988; Heijerick et al. 2005b).

The aquatic toxicity of zinc is influenced by a number of chemical factors including pH, hardness and the presence of other inorganic or organic ligands (USEPA 1987, CCME 1999). These affect zinc toxicity either by influencing the speciation of zinc or by influencing the sorption or binding of available zinc to biological tissues (e.g., competition for binding sites at gills).

As noted above, aqueous pH influences zinc speciation, which in turn influences zinc toxicity to aquatic biota. Toxicity test results expressed on the basis of total zinc concentrations often show a pattern of reduced toxicity at basic, as compared to neutral, pH because formation of hydroxides at elevated pH reduce the quantities of available Zn^{2+} ion (Heijerick et al. 2002b, Santore et al. 2002). However, the toxicity of the free ion (Zn^{2+}) is decreased at lower pH as a result of increased competition between H^{+} and Zn^{2+} for binding sites on biotic ligands, particularly at pH <7 (Santore et al. 2002; Heijerick et al. 2002a, 2003, and 2005b; De Shampheleare and Janssen 2004; Wilde et al. 2006). The effects of pH on zinc toxicity to algae may be quite large, while pH effects on toxicity to invertebrates and fish are modest (Minnow 2008). Aqueous pH appears to also affect the number and/or characteristics of binding sites of algae, whereas the binding characteristics for higher organisms is believed to be independent of the test medium characteristics (Heijerick et al. 2002a).

Hardness is probably the strongest single water quality factor influencing acute and chronic zinc toxicity to aquatic biota, with the calcium component of hardness being particularly effective in protecting fish from zinc toxicity (Santore et al. 2002). Magnesium appears to be as, or more, effective than calcium in reducing zinc toxicity to invertebrates and algae (Heijerick et al. 2002a; Niyogi and Wood 2004).

Dissolved organic carbon (DOC) plays a varying role in mitigating zinc toxicity to aquatic biota, with the magnitude of influence dependent on factors such as the quantity and type of DOC present (e.g., humic versus fulvic acids), aqueous pH (affecting Zn sorption to DOC) (Heijerick et al. 2003; De Shamphelaere et al. 2005), and the relative

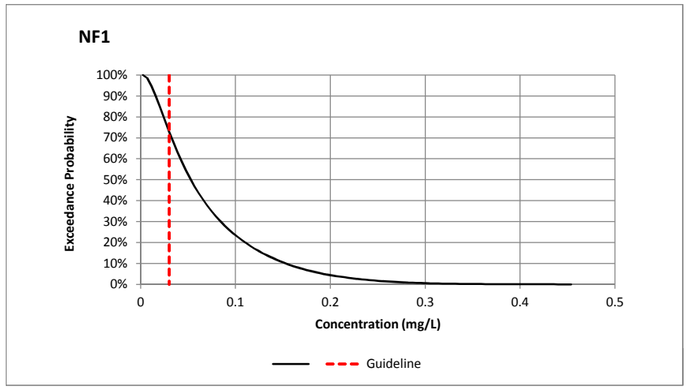
concentrations of zinc and other ions (e.g., calcium and magnesium) (Paulauskis and Winner 1988). The protective effect of DOC is probably greater in soft than hard water (Paulauskis and Winner 1988, Vignault et al. 2004)

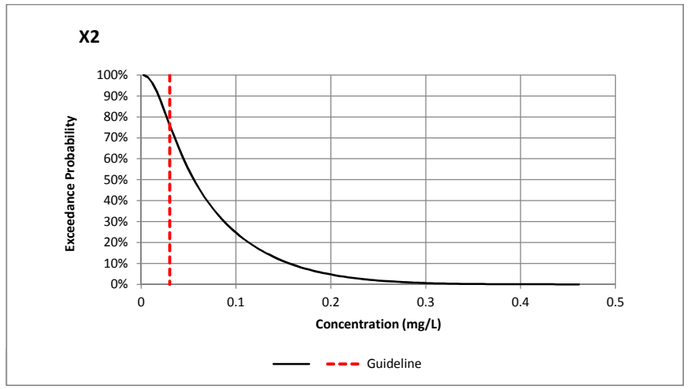
Numerous studies have shown that acclimation of aquatic organisms to low (non-toxic) levels of zinc results in greater tolerance to toxic zinc concentrations (Bradley et al. 1985, Hobson and Birge 1989; Hogstrand and Wood 1995, Anadu et al. 1989, Muyssen et al. 2002, Muyssen and Janssen 2005). This response happens and is lost quickly (i.e., within a few days of zinc exposure) (Bradley et al. 1985; Anadu et al. 1989). As a result, acclimated organisms may be able to tolerate lethal concentrations up to 5 times higher than unacclimated organisms (Anadu et al. 1989; Muyssen et al. 2002). In some cases, sublethal, rather than lethal, tolerance may be increased by pre-exposure to zinc (Muyssen and Janssen 2005).

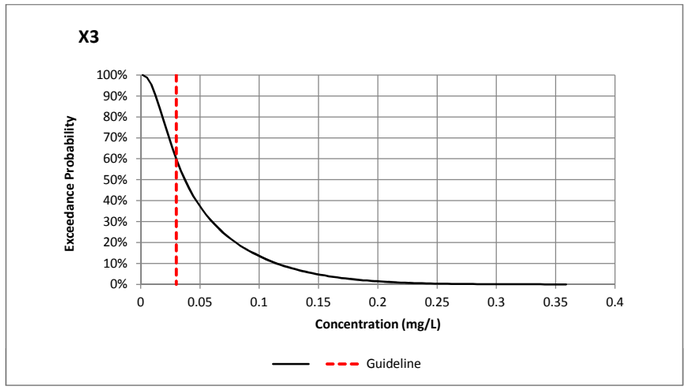
3.2.5.3 Predicted Concentrations and Effects

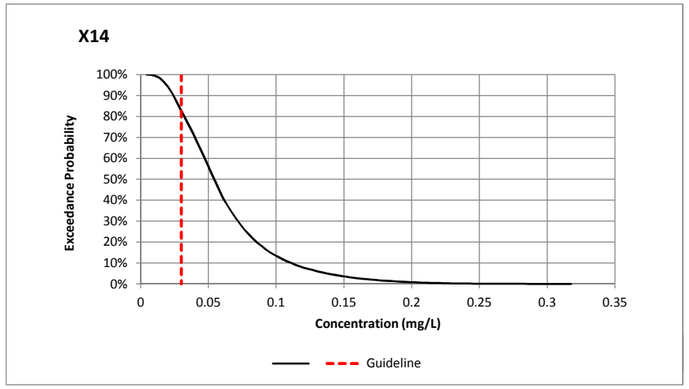
During the baseline period median concentrations of zinc were above the water quality guideline only at X14 (Table 7C-3). However, during the 10-year IW period it is predicted that winter and summer/fall concentrations will sometimes be above guidelines throughout the Rose Creek system downstream of NF1 to the mouth at Anvil Creek (R4). At these stations, probabilities of monthly guideline exceedance range from 60 percent to 80 percent (Figure 7C-8). The exceedance probability declines from 80 percent at X14 to 70 percent at the mouth of Rose Creek (R4) and 30 percent after the confluence of Rose Creek and Anvil Creek (R5), but remains close to 20 percent even at the mouth of Anvil Creek (A1) (Figure 7C-8). Predictions do not assume attenuation with distance downstream and thus may be overly conservative. The water quality guideline for zinc is also expected to be exceeded in approximately 30 percent of months at V8, near the mouth of Vangorda Creek, but will not be exceeded at P4 in the Pelly River downstream of Vangorda Creek and Anvil Creek (Figure 7C-8). These represent predicted “normal” operating conditions at the FMC.

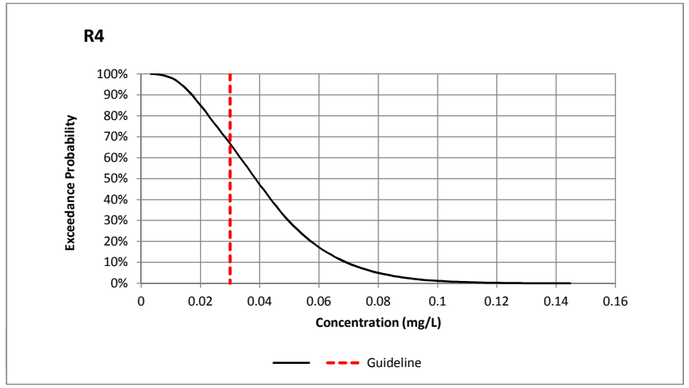
Aquatic toxicity data associated with water hardness around 100 mg/L indicate that toxicity to sensitive aquatic species may occur at zinc concentrations that are only slightly above the water quality guideline of 0.03 mg/L (Table 7C-5). However, winter baseline zinc concentrations at X14 have averaged triple this value at approximately 0.09 mg/L (Table 7C-4) and baseline studies concluded that mine-related effects on biota (e.g., benthic invertebrate surveys) have been undetectable or relatively minor at X14/R2 (Minnow 2014). Although median zinc concentrations are expected to increase at most stations in Rose, Anvil, and Vangorda creeks relative to baseline conditions, they are

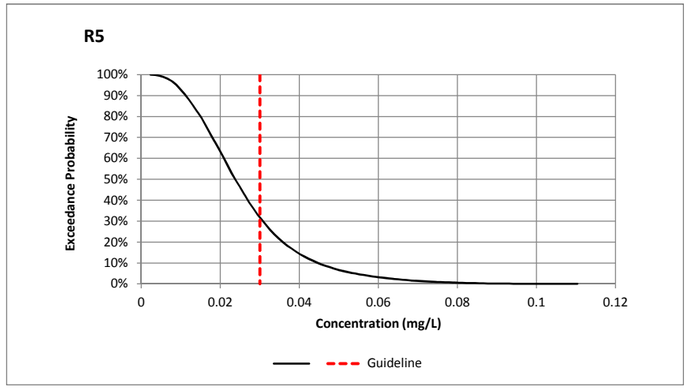


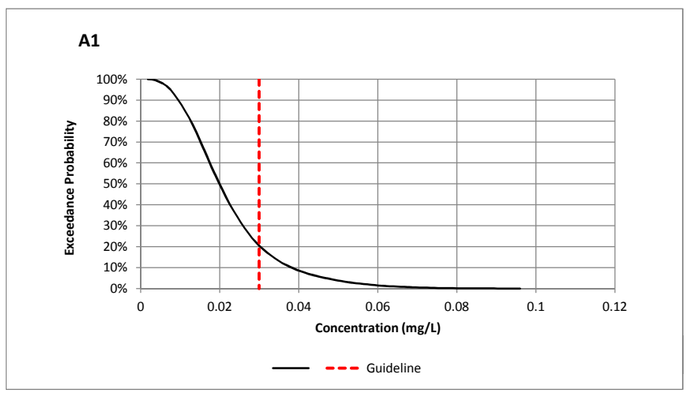


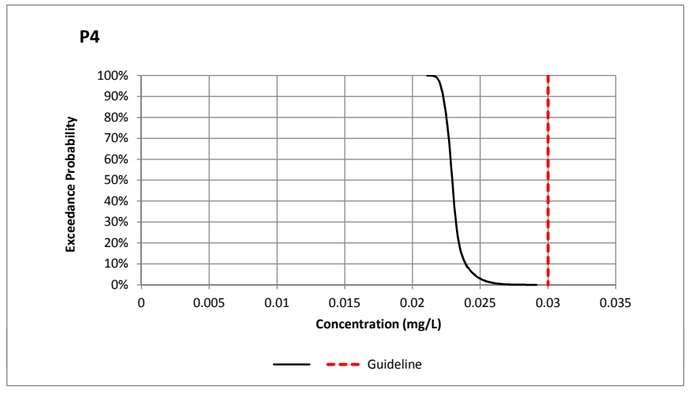












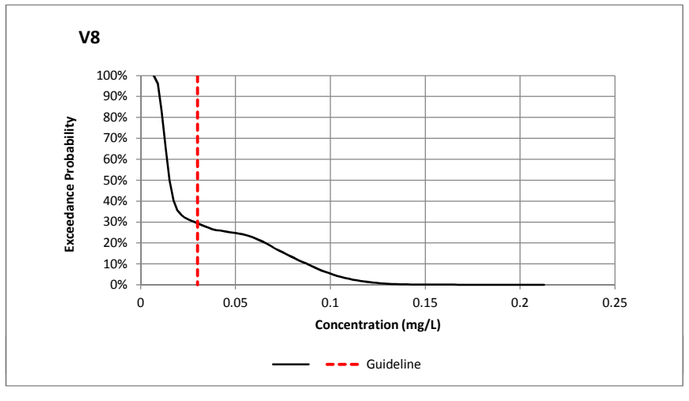


Figure 7C-8: Percentage of months when water concentrations of zinc are expected to be above the water quality guideline.

predicted to be comparable to or less than medians observed at X14 in the period from 2008 to 2012, depending on the season (Table 7C-4). Also, the predicted median concentrations are unlikely to cause acute lethality to fish (Table 7C-5). There is a very small potential for periodic lethal effects to fish in NFRC during winter based on predicted winter 95th percentile concentrations of up to 0.23 mg/L compared to baseline maxima of 0.13 mg/L (Attachment Tables A.10, A.11). Overall, the data indicate that aquatic effects, if any, in surface waters around, and downstream from, the FMC would generally be comparable to those currently observed at X14 (i.e., relatively minor) and aquatic toxicity would be unlikely to occur outside of the LSA.

As noted in Section 3.1.1, there is also potential for new pathways to periodically and unpredictably develop between mine source areas and surface waters over time, particularly via groundwater. These may result in zinc concentrations that temporarily exceed those associated with the "normal" operating scenario described above. Such a condition previously developed south of the Faro waste rock dumps and was detected as a rising trend in winter zinc concentrations in the NFRC that led to installation of the S-wells interception system and subsequent reduction in stream zinc concentrations that is apparent in monitoring results. More recently, a new load source to the NFRC had developed at the Haul Road crossing, which had increased zinc concentrations in the NFRC (NF2, X2) and at X14 such that concentrations in November 2013 (Table 7C-6) were above the maxima predicted for the normal operating scenario (Table 7C-4 and Attachment Tables A.1 to A.4). Average zinc concentrations of 0.2 mg/L or more, such as were observed in November, are in the range for potential lethal effects on biota, including fish. However, a study tracking Arctic grayling around the FMC local and regional study areas using radio telemetry showed two grayling in the RCD on December 10th (EDI 2013), where concentrations in November averaged 0.34 mg/L (at X3A) (Table 7C-6). The literature suggests that concentrations of approximately 0.24 mg/L may be acutely lethal to this species, but the literature also shows that fish can acclimate to low-level zinc exposure levels such that they develop increased tolerance to subsequently elevated zinc exposure concentrations (Bradley et al. 1985, Alsop et al. 1998; Stubblefield et al. 1999).

Consistent with the AMP, the current situation of elevated zinc in the NFRC and downstream areas is being closely monitored while a remedial solution is concurrently being developed and implemented. During the IW, under this type of scenario, there is increased potential for toxicity to aquatic biota to temporarily occur (estimation of 6 to 8 months), possibly including toxicity to fish (see maximum load predictions in Table 7C-6 compared to guidelines and toxicity data in Table 7C-5), until remediation can be

Table 7C-6: Predicted adverse scenario based on recent observations of new zinc load source to North Fork Rose Creek at Haul Road.

Station	November 2013		Predicted water quality during low flow if load stays the same as Nov. 2013		Predicted water quality assuming 2x load during low flow	
	Average Zn (mg/L)	Max Zn (mg/L)	Average Zn (mg/L)	Max Zn (mg/L)	Average Zn (mg/L)	Max Zn (mg/L)
NF2	0.48	0.91	1.4	2.7	2.8	5.4
X2	0.34	0.38	1.0	1.1	2.0	2.3
X3A	0.34	0.49	0.7	0.8	1.4	1.6
X14	0.18	0.20	0.7	0.8	1.3	1.5
A1	-	-	0.21	0.24	0.41	0.48
P4	-	-	0.01	0.01	0.02	0.02

Flow Assumptions

NF2 Nov 28,2013 Discharge (L/s)	570	
X14 Nov 28 Discharge scaled from Oct ratio (L/s)	1,117	
X2 GoldSim low flow (L/s)	193	*compares to NF2 April 4, 2013 - 200 L/s*
X14 GoldSim low flow (L/s)	295	*compares to X14 April discharge average to 2009 - 290 L/s*
A1 GoldSim low flow (L/s)	948	
P4 GoldSim low flow (L/s)	23856	

implemented. Thereafter, it is expected that concentrations will return to those associated with the normal operating scenario described previously, with associated recovery of biological communities to conditions typically associated with normal operations.

3.2.6 Summary of Chemical Effects

3.2.6.1 Sulphate, Cd, Co, Pb, Mn During Normal Operations

Neither sulphate nor lead concentrations are expected to exceed water quality guidelines for protection of aquatic life during the IW period. Median concentrations of cadmium will be less than the hardness-adjusted water quality guidelines in all local and regional study areas, but the guidelines may sometimes be exceeded in localized stream reaches within the LSA (e.g., NFRC and in Rose Creek immediately downstream from the Faro Mine Area); however, the predicted concentrations are not expected to be toxic to fish and effects on other aquatic biota are expected to be minimal. Cobalt concentrations are expected to exceed the water quality guideline in Rose Creek at X14 and R4 in approximately 45 percent and 35 percent of months, respectively, particularly during the ice-free seasons; however, predicted concentrations are not expected to be toxic to fish and effects on other aquatic biota are expected to be minimal. Manganese concentrations are not predicted to change substantially from baseline conditions, except that concentrations may decrease slightly in winter months and increase slightly in other months at Rose Creek stations at, and downstream from, X14. Overall, manganese concentrations are predicted to be above the hardness-adjusted guidelines in approximately 65 percent of months at X14 (65 percent) and in an increasingly lower percentage of months at stations farther downstream. The available data indicate that aquatic effects, if any, of manganese in surface waters around the FMC would be limited to the vicinity of X14 (i.e., within the LSA) and would likely be minor in magnitude.

3.2.6.2 Zn During Normal and Operations

During the 10-year IW period it is predicted that, under normal operating conditions, winter and summer/fall zinc concentrations will be above guidelines throughout the Rose Creek system downstream of NF1 to the mouth at Anvil Creek (R4). At these stations, probabilities of monthly guideline exceedance range from 60 percent to 80 percent but declines from 80 percent at X14 to 70 percent at the mouth of Rose Creek (R4), to 30 percent after the confluence of Rose Creek, and to 20 percent at the mouth of Anvil Creek (R5). The water quality guideline for zinc is also expected to be exceeded in approximately 30 percent of months at V8, near the mouth of Vangorda Creek, but will not be exceeded at P4 in the Pelly River downstream of Vangorda Creek and Anvil Creek.

Despite these conditions of elevated zinc, the available data indicate that aquatic effects, if any, in surface waters around the FMC would be comparable to those currently observed at X14. This means that concentrations would rarely exceed fish toxicity thresholds, effects to other aquatic biota would be minor (i.e., affecting only a few sensitive species), and the effects would be limited to the LSA.

3.2.6.3 Zn During Adverse Events

There is potential for periodic, unpredictable, and unpreventable breakthroughs of contamination to surface waters from mine sources via new groundwater pathways, such as is currently occurring in the NFRC. Under such conditions, increased toxicity may temporarily occur (estimation of six to eight months), possibly including toxicity to fish, until remediation can be implemented. Thereafter, it is expected that concentrations will return to those associated with the normal operating scenario described previously, with associated recovery of biological communities to conditions typically associated with normal operations

3.3 Fish and Fish Habitat Effects

Fish habitat includes the physical structure of the areas inhabited by fish, such as stream and bank morphology, substrate and cover characteristics, and water quality, depth and elevation, as well as the aquatic plant and invertebrate communities that contribute to ecosystem function and represent a food source for fish. Potential chemical effects associated with the IW on fish and on the biological components of fish habitat were described in Section 3.2. Potential effects of the IW on physical aspects of fish habitat will be minimal, relating mainly to potential mobilization of particulates into surface waters. Such effects will be mitigated through BMPs for control of erosion and sediment transport (see Section 2.0). Temporary disruption of fish habitat may also occur during the IW if a new road crossing is required to transport site investigation equipment (e.g., drill rigs) to appropriate locations. The effects on fish habitat will be mitigated through control of particulates during associated construction and also adherence to applicable sections of the federal *Fisheries Act.* There are no other aspects of the IW that are expected to affect physical characteristics of fish habitat (e.g., diversions, channel realignment, flow alterations). Therefore, no residual effects are anticipated on physical fish habitat. Proposed monitoring will track the condition of physical and biological aspects of fish habitat during the IW period (Section 3.6).

3.4 Additional Mitigation

No additional, standard mitigation practices are available that could be expected to lessen chemical loads from the FMC to surface waters during the IW. However, an objective of site investigations conducted during the IW will be to identify opportunities for further mitigation or remediation that could be implemented as part of the long-term mine closure plan.

3.5 Significance of Effects

Predicted changes in water quality associated with the IW, described in Section 3.2.6 correspond with significance rankings of low to medium for all relevant chemical variables (sulphate, cadmium, cobalt, lead, manganese, and zinc) and all relevant effect attributes (magnitude, likelihood and duration, geographic extent, and reversibility) as defined in Table 7C-2.

3.6 Monitoring

Monitoring of the aquatic environment will be undertaken to confirm predicted environmental performance and demonstrate compliance with regulatory requirements. Monitoring results will be presented in comprehensive reports that will assess conditions relative to predictions and provide recommendations for future actions allowing for adaptive management of the mine. A brief description of the recommended monitoring is provided below with additional details provided in the Environmental Monitoring, Surveillance and Reporting Plan (Appendix 5E of the IWPP). Detailed monitoring plans will be further developed to address regulatory requirements.

During normal operations of the IW, surface water should be monitored on a monthly basis at representative stations on NFRC (e.g., R9, R10, NF1, NF2, X2), SFRC (R1), RCD (X3), Rose Creek (X14, R4), Anvil Creek (R5, A1), West Vangorda Creek (VW1, VW2, VW3, V5), and Vangorda Creek (V4, V27, VGMAIN, V8). Water data should be assessed on a regular basis relative to baseline conditions and water quality guidelines. Water data should also be regularly evaluated with respect to potential trends or thresholds that may be indicative of non-normal conditions, as outlined in the AMP.

Should water quality monitoring indicate a substantial adverse change in surface water quality that might be associated with a change in toxicity to aquatic biota, samples of surface water should be collected from the affected areas for laboratory toxicity testing. The tests should include a variety of species representing different trophic levels and

effects endpoints. Testing should be repeated if water quality continues to change, but would not need to be repeated if concentrations stabilize.

Benthic invertebrate communities should be assessed every 3 years at all of the water monitoring locations that are accessible to fish. Community characteristics should be compared to those observed during the baseline period and to any other such surveys conducted at the site in the interim. Data should also be evaluated relative to an appropriate suite of synoptically sampled regional reference areas (i.e., having similar habitat characteristics) and should consider any changes in water quality that have been since the last cycle of study.

Monitoring of fish health and population characteristics and fish tissue metal concentrations is not recommended unless specific questions arise that necessitate fish sampling. This is because locally relevant species such as Chinook and grayling can move large distances between winter and summer habitats so the characteristics of individual fish may not reflect conditions in the areas in which they are captured. Also, population densities of these species, and slimy sculpin, are sufficiently low that it is very difficult to obtain sufficient sample sizes in any given area to support statistical comparisons of conditions among reference and mine-exposed areas. Also, lethal sampling should be avoided, if possible, to prevent population impacts that might be associated with the sampling program.

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ATTACHMENT A

WATER QUALITY PREDICTIONS

Table A.1: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at NF1, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NF1	Hardness	NA	NA	5th percentile	47	46	50	47	35	42	41	40	41	42	44	45
				50th percentile	93	92	99	93	76	84	83	82	83	85	89	90
				95th percentile	153	151	161	153	130	140	138	137	138	140	147	148
	SO4	309	0%	5th percentile	8	8	10	8	5	4	5	5	6	6	7	8
				50th percentile	24	23	29	25	15	14	14	15	17	19	20	22
				95th percentile	49	47	60	49	27	24	25	28	32	36	38	43
	Cd	0.00015	1%	5th percentile	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
				50th percentile	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
				95th percentile	0.00012	0.00012	0.00013	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012
	Co	0.0025	0%	5th percentile	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
				50th percentile	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003
				95th percentile	0.0006	0.0006	0.0007	0.0006	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006
	Pb	0.006	0%	5th percentile	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0002	0.0002	0.0002	0.0002
				50th percentile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
				95th percentile	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	Mn	1.0	0%	5th percentile	0.02	0.02	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
				50th percentile	0.13	0.12	0.16	0.13	0.05	0.05	0.1	0.1	0.08	0.08	0.11	0.11
				95th percentile	0.32	0.30	0.41	0.32	0.1	0.1	0.1	0.2	0.2	0.20	0.3	0.27
	Zn	0.03	74%	5th percentile	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
				50th percentile	0.09	0.08	0.11	0.09	0.03	0.03	0.03	0.04	0.05	0.05	0.07	0.07
				95th percentile	0.23	0.22	0.30	0.24	0.06	0.07	0.08	0.11	0.13	0.14	0.17	0.20

Table A.2: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at X2, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
X2	Hardness	NA	NA	5th percentile	50	49	54	50	35	42	41	40	42	43	46	47
				50th percentile	96	95	103	96	77	85	84	83	85	86	90	92
				95th percentile	156	154	165	157	131	141	139	139	142	143	149	151
	SO4	309	0%	5th percentile	11	11	13	11	6	5	6	7	8	8	8	10
				50th percentile	27	25	32	27	16	14	15	17	19	20	21	24
				95th percentile	51	49	62	52	28	25	26	30	34	37	39	45
	Cd	0.00017	29%	5th percentile	0.00004	0.00004	0.00005	0.00004	0.00002	0.00002	0.00002	0.00002	0.00003	0.00003	0.00003	0.00004
				50th percentile	0.00015	0.00015	0.00018	0.00015	0.00008	0.00009	0.00009	0.00010	0.00011	0.00012	0.00012	0.00014
				95th percentile	0.00037	0.00035	0.00046	0.00037	0.00017	0.00018	0.00019	0.00021	0.00024	0.00025	0.00029	0.00032
	Co	0.0025	0%	5th percentile	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
				50th percentile	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003
				95th percentile	0.0006	0.0006	0.0007	0.0006	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006
	Pb	0.007	0%	5th percentile	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
				50th percentile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
				95th percentile	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	Mn	1.1	0%	5th percentile	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.0	0.0
				50th percentile	0.1	0.1	0.2	0.1	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1
				95th percentile	0.3	0.3	0.4	0.3	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3
	Zn	0.03	82%	5th percentile	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
				50th percentile	0.09	0.08	0.11	0.09	0.03	0.03	0.03	0.05	0.05	0.06	0.07	0.08
				95th percentile	0.23	0.22	0.30	0.24	0.06	0.07	0.08	0.11	0.13	0.14	0.17	0.20

Table A.3: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at X3, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
X3	Hardness	NA	NA	5th percentile	46	45	49	46	34	38	37	36	37	39	41	43
				50th percentile	90	89	96	90	74	80	79	78	80	81	84	86
				95th percentile	149	147	156	149	128	135	133	133	134	136	140	143
	SO4	309	0%	5th percentile	9	9	11	9	4	4	4	5	6	6	6	8
				50th percentile	22	22	27	22	13	12	12	13	15	16	16	20
				95th percentile	41	40	51	41	23	23	23	24	26	28	29	35
	Cd	0.00018	14%	5th percentile	0.00004	0.00003	0.00004	0.00004	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00003
				50th percentile	0.00013	0.00013	0.00015	0.00013	0.00007	0.00007	0.00007	0.00008	0.00009	0.00009	0.00010	0.00011
				95th percentile	0.00030	0.00028	0.00037	0.00030	0.00014	0.00015	0.00015	0.00017	0.00018	0.00019	0.00021	0.00025
	Co	0.0025	0%	5th percentile	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
				50th percentile	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
				95th percentile	0.0005	0.0005	0.0006	0.0005	0.0004	0.0004	0.0004	0.0005	0.0004	0.0005	0.0005	0.0005
	Pb	0.007	0%	5th percentile	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.000	0.0002
				50th percentile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
				95th percentile	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	Mn	1.1	0%	5th percentile	0.0	0.0	0.0	0.0	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
				50th percentile	0.1	0.1	0.1	0.1	0.04	0.04	0.0	0.1	0.1	0.1	0.1	0.1
				95th percentile	0.3	0.2	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
	Zn	0.03	65%	5th percentile	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
				50th percentile	0.07	0.07	0.09	0.07	0.02	0.02	0.02	0.03	0.03	0.04	0.05	0.06
				95th percentile	0.18	0.17	0.24	0.18	0.04	0.04	0.05	0.07	0.08	0.09	0.11	0.14

Table A.4: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at X14, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
X14	Hardness	NA	NA	5th percentile	206	205	222	322	114	171	225	243	258	119	187	154
				50th percentile	277	278	295	441	170	243	318	339	359	171	254	213
				95th percentile	362	378	396	587	235	323	426	454	484	229	336	286
	SO4	429	1%	5th percentile	138	141	152	220	60	95	132	146	156	70	120	99
				50th percentile	199	215	227	313	85	134	187	206	222	100	171	146
				95th percentile	291	335	349	446	115	179	255	280	302	138	246	222
	Cd	0.0003	3%	5th percentile	0.00006	0.00005	0.00006	0.00010	0.00004	0.00006	0.00008	0.00008	0.00009	0.00004	0.00005	0.00004
				50th percentile	0.00015	0.00013	0.00016	0.00020	0.00009	0.00012	0.00014	0.00016	0.00017	0.00010	0.00013	0.00012
				95th percentile	0.00030	0.00028	0.00035	0.00034	0.00017	0.00019	0.00023	0.00025	0.00027	0.00020	0.00023	0.00025
	Co	0.0025	47%	5th percentile	0.0009	0.0003	0.0004	0.0033	0.0010	0.0016	0.0024	0.0025	0.0030	0.0005	0.0012	0.0002
				50th percentile	0.0017	0.0005	0.0008	0.0070	0.0021	0.0035	0.0052	0.0053	0.0065	0.0010	0.0023	0.0005
				95th percentile	0.0026	0.0010	0.0015	0.0108	0.0037	0.0055	0.0083	0.0084	0.0102	0.0016	0.0034	0.0010
	Pb	0.012	0%	5th percentile	0.0005	0.0002	0.0003	0.001	0.001	0.001	0.001	0.002	0.002	0.0005	0.001	0.0002
				50th percentile	0.002	0.001	0.001	0.003	0.002	0.002	0.003	0.004	0.004	0.002	0.002	0.001
				95th percentile	0.004	0.003	0.003	0.005	0.004	0.004	0.005	0.006	0.006	0.004	0.004	0.003
	Mn	1.6	68%	5th percentile	1.2	0.5	0.7	3.3	0.9	1.5	2.3	2.4	2.8	0.6	1.3	0.4
				50th percentile	2.1	1.1	1.4	6.2	1.8	3.2	4.8	5.1	5.9	1.0	2.4	0.9
				95th percentile	3.1	1.7	2.0	9.8	3.2	5.3	8.0	8.4	9.6	1.5	3.5	1.3
	Zn	0.03	83%	5th percentile	0.02	0.02	0.02	0.04	0.01	0.02	0.04	0.05	0.05	0.01	0.02	0.02
				50th percentile	0.07	0.06	0.08	0.08	0.03	0.04	0.05	0.06	0.07	0.04	0.05	0.05
				95th percentile	0.16	0.15	0.21	0.17	0.05	0.06	0.08	0.10	0.11	0.09	0.11	0.13

Table A.5: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at R4, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
R4	Hardness	NA	NA	5th percentile	123	111	121	203	96	145	189	204	214	98	127	106
				50th percentile	177	163	174	283	148	207	268	288	301	145	181	156
				95th percentile	238	227	238	379	208	278	359	383	405	200	245	216
	SO4	309	0%	5th percentile	73	65	72	127	47	76	106	119	126	54	74	61
				50th percentile	106	99	108	182	68	108	150	167	179	76	106	91
				95th percentile	154	152	163	260	92	143	205	227	243	106	151	136
	Cd	0.00023	2%	5th percentile	0.00004	0.00003	0.00004	0.00007	0.00004	0.00005	0.00006	0.00007	0.00007	0.00003	0.00004	0.00003
				50th percentile	0.00010	0.00009	0.00010	0.00014	0.00008	0.00010	0.00013	0.00014	0.00014	0.00009	0.00010	0.00009
				95th percentile	0.00019	0.00017	0.00020	0.00023	0.00015	0.00018	0.00020	0.00022	0.00023	0.00018	0.00018	0.00018
	Co	0.0025	37%	5th percentile	0.0005	0.0001	0.0002	0.0020	0.0008	0.0013	0.0019	0.0020	0.0024	0.0004	0.0008	0.0002
				50th percentile	0.0009	0.0003	0.0005	0.0040	0.0017	0.0028	0.0042	0.0043	0.0052	0.0008	0.0015	0.0004
				95th percentile	0.0014	0.0006	0.0008	0.0062	0.0029	0.0044	0.0066	0.0068	0.0082	0.0013	0.0021	0.0007
	Pb	0.009	0%	5th percentile	0.0004	0.0002	0.0002	0.0009	0.0005	0.0008	0.001	0.001	0.002	0.0004	0.0006	0.0002
				50th percentile	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.001
				95th percentile	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.004	0.004	0.003
	Mn	1.3	53%	5th percentile	0.6	0.24	0.3	1.9	0.7	1.2	1.8	2.0	2.3	0.5	0.8	0.2
				50th percentile	1.1	0.5	0.6	3.5	1.4	2.5	3.8	4.1	4.7	0.8	1.4	0.5
				95th percentile	1.6	0.8	0.9	5.6	2.5	4.2	6.4	6.8	7.6	1.1	2.1	0.8
	Zn	0.03	69%	5th percentile	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.04	0.01	0.01	0.01
				50th percentile	0.04	0.03	0.04	0.05	0.02	0.03	0.04	0.05	0.06	0.03	0.03	0.03
				95th percentile	0.09	0.07	0.10	0.10	0.04	0.05	0.06	0.08	0.09	0.07	0.07	0.08

Table A.6: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at R5, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
R5	Hardness	NA	NA	5th percentile	98	91	100	154	61	86	109	117	122	64	87	78
				50th percentile	145	140	149	219	105	133	163	173	179	106	134	124
				95th percentile	203	199	209	295	160	192	225	237	246	162	192	180
	SO4	309	0%	5th percentile	53	50	55	90	23	38	52	59	62	28	45	40
				50th percentile	78	76	84	129	35	55	74	83	88	42	64	60
				95th percentile	112	116	126	184	48	73	101	112	120	57	91	89
	Cd	0.00023	0%	5th percentile	0.00003	0.00003	0.00003	0.00005	0.00002	0.00003	0.00004	0.00004	0.00004	0.00002	0.00003	0.00002
				50th percentile	0.00009	0.00008	0.00009	0.00011	0.00006	0.00007	0.00008	0.00009	0.00009	0.00007	0.00008	0.00008
				95th percentile	0.00017	0.00016	0.00018	0.00020	0.00013	0.00014	0.00015	0.00016	0.00016	0.00014	0.00015	0.00016
	Co	0.0025	15%	5th percentile	0.0004	0.0001	0.0002	0.0014	0.0004	0.0007	0.0010	0.0010	0.0012	0.0002	0.0005	0.0001
				50th percentile	0.0007	0.0003	0.0004	0.0028	0.0008	0.0014	0.0020	0.0021	0.0025	0.0005	0.0009	0.0003
				95th percentile	0.0011	0.0005	0.0007	0.0044	0.0014	0.0021	0.0032	0.0033	0.0039	0.0007	0.0013	0.0005
	Pb	0.007	0%	5th percentile	0.0003	0.0002	0.0002	0.0007	0.0003	0.0005	0.0007	0.0008	0.0010	0.0003	0.0004	0.0002
				50th percentile	0.001	0.001	0.001	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001
				95th percentile	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.003
	Mn	1.3	33%	5th percentile	0.5	0.18	0.3	1.3	0.31	0.57	0.84	0.92	1.06	0.22	0.47	0.16
				50th percentile	0.8	0.4	0.5	2.5	0.65	1.18	1.8	1.9	2.2	0.4	0.8	0.3
				95th percentile	1.1	0.6	0.7	3.9	1.1	1.9	3.0	3.2	3.6	0.6	1.2	0.5
	Zn	0.03	33%	5th percentile	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01
				50th percentile	0.03	0.02	0.03	0.04	0.01	0.02	0.02	0.03	0.03	0.02	0.02	0.02
				95th percentile	0.06	0.05	0.08	0.07	0.02	0.03	0.03	0.04	0.05	0.04	0.04	0.05

Table A.7: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at A1, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
A1	Hardness	NA	NA	5th percentile	87	83	91	135	53	72	90	96	100	56	75	69
				50th percentile	134	130	139	195	95	117	139	146	151	97	120	113
				95th percentile	190	188	197	266	151	173	198	207	213	154	177	169
	SO4	309	0%	5th percentile	45	43	48	76	18	30	40	45	48	22	36	33
				50th percentile	67	67	74	109	28	43	57	64	68	33	53	50
				95th percentile	96	101	110	156	40	57	79	87	93	46	74	74
	Cd	0.00024	0%	5th percentile	0.00003	0.00002	0.00003	0.00004	0.00002	0.00002	0.00003	0.00003	0.00003	0.00002	0.00002	0.00002
				50th percentile	0.00008	0.00008	0.00009	0.00010	0.00006	0.00007	0.00007	0.00008	0.00008	0.00006	0.00007	0.00007
				95th percentile	0.00016	0.00015	0.00017	0.00018	0.00013	0.00014	0.00014	0.00015	0.00015	0.00014	0.00014	0.00015
	Co	0.0025	6%	5th percentile	0.0003	0.0001	0.0002	0.0012	0.0003	0.0005	0.0007	0.0008	0.0009	0.0002	0.0004	0.0001
				50th percentile	0.0006	0.0003	0.0004	0.0024	0.0007	0.0011	0.0015	0.0016	0.0019	0.0004	0.0007	0.0003
				95th percentile	0.0010	0.0005	0.0006	0.0037	0.0011	0.0017	0.0024	0.0025	0.0030	0.0006	0.0011	0.0005
	Pb	0.009	0%	5th percentile	0.0003	0.0002	0.0002	0.0006	0.0003	0.0004	0.001	0.001	0.001	0.0002	0.0003	0.0002
				50th percentile	0.001	0.001	0.001	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.001	0.001
				95th percentile	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.003
	Mn	1.3	24%	5th percentile	0.4	0.16	0.2	1.1	0.2	0.4	0.6	0.7	0.8	0.2	0.4	0.1
				50th percentile	0.7	0.3	0.4	2.1	0.5	0.9	1.3	1.4	1.6	0.3	0.6	0.3
				95th percentile	0.9	0.5	0.6	3.3	0.8	1.4	2.2	2.4	2.7	0.4	1.0	0.4
	Zn	0.03	22%	5th percentile	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
				50th percentile	0.03	0.02	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
				95th percentile	0.06	0.05	0.07	0.06	0.02	0.02	0.03	0.03	0.04	0.03	0.04	0.04

Table A.8: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at P4, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
P4	Hardness	NA	NA	5th percentile	208	207	208	211	206	212	212	212	212	210	209	208
				50th percentile	212	212	212	216	210	214	215	215	214	213	213	211
				95th percentile	216	216	216	220	213	216	217	217	217	215	216	215
	SO4	309	0%	5th percentile	67	66	67	69	65	67	67	68	67	66	66	66
				50th percentile	68	68	69	71	66	67	68	69	68	67	67	67
				95th percentile	70	70	71	73	67	68	69	70	69	67	68	68
	Cd	0.00025	0%	5th percentile	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020
				50th percentile	0.00020	0.00020	0.00020	0.00020	0.00020	0.00021	0.00021	0.00021	0.00020	0.00020	0.00020	0.00020
				95th percentile	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
	Co	0.0025	0%	5th percentile	0.0002	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0002	0.0001
				50th percentile	0.0002	0.0001	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0002	0.0001
				95th percentile	0.0002	0.0002	0.0002	0.0004	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002
	Pb	0.01	0%	5th percentile	0.0002	0.0002	0.0002	0.0003	0.0003	0.0002	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002
				50th percentile	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
				95th percentile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
	Mn	1.4	0%	5th percentile	0.04	0.03	0.03	0.09	0.03	0.03	0.05	0.05	0.05	0.03	0.04	0.03
				50th percentile	0.06	0.04	0.05	0.15	0.05	0.05	0.07	0.08	0.09	0.03	0.05	0.04
				95th percentile	0.09	0.05	0.07	0.22	0.07	0.07	0.10	0.12	0.13	0.04	0.07	0.05
	Zn	0.03	0%	5th percentile	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
				50th percentile	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
				95th percentile	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Table A.9: Summary of predicted monthly and seasonal water concentrations for key mine-related variables at V8, 2014-2023. Shaded values are above the water quality guideline.

Station	Variable	Guideline (mg/L)	Monthly Exceedance Probability	Endpoint	Monthly Concentrations (mg/L)											
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
V8	Hardness	NA	NA	5th percentile	268	295	310	280	132	166	295	364	199	206	248	256
				50th percentile	293	321	337	307	156	191	346	439	224	230	273	281
				95th percentile	323	352	368	337	186	224	409	531	255	260	304	312
	SO4	429	1%	5th percentile	110	122	140	128	43	95	196	238	78	82	92	99
				50th percentile	123	136	155	142	53	118	257	328	93	94	105	112
				95th percentile	137	151	171	159	64	152	332	441	108	108	118	126
	Cd	0.0004	20%	5th percentile	0.00008	0.00008	0.00009	0.00014	0.00022	0.00025	0.00041	0.00039	0.00008	0.00007	0.00007	0.00007
				50th percentile	0.00013	0.00015	0.00017	0.00022	0.00037	0.00032	0.00052	0.00054	0.00012	0.00011	0.00011	0.00012
				95th percentile	0.00020	0.00023	0.00026	0.00033	0.00064	0.00040	0.00064	0.00067	0.00018	0.00016	0.00017	0.00019
	Co	0.0025	0%	5th percentile	0.0001	0.0001	0.0001	0.0001	0.0010	0.0004	0.0005	0.0004	0.0003	0.0002	0.0001	0.0001
				50th percentile	0.0002	0.0001	0.0002	0.0002	0.0011	0.0005	0.0006	0.0005	0.0004	0.0002	0.0002	0.0002
				95th percentile	0.0004	0.0002	0.0002	0.0003	0.0012	0.0006	0.0007	0.0006	0.0005	0.0003	0.0003	0.0003
	Pb	0.016	0%	5th percentile	0.001	0.001	0.001	0.001	0.005	0.001	0.002	0.002	0.001	0.001	0.001	0.001
				50th percentile	0.003	0.002	0.003	0.003	0.007	0.003	0.004	0.003	0.003	0.002	0.002	0.002
				95th percentile	0.005	0.004	0.007	0.005	0.011	0.005	0.006	0.005	0.005	0.004	0.005	0.004
	Mn	1.9	0%	5th percentile	0.02	0.02	0.02	0.02	0.1	0.3	0.5	0.5	0.03	0.02	0.03	0.03
				50th percentile	0.03	0.03	0.03	0.03	0.1	0.4	0.7	0.7	0.04	0.03	0.04	0.03
				95th percentile	0.04	0.04	0.04	0.05	0.1	0.5	0.8	0.9	0.1	0.05	0.1	0.05
	Zn	0.03	30%	5th percentile	0.01	0.01	0.01	0.01	0.02	0.05	0.07	0.07	0.01	0.01	0.01	0.01
				50th percentile	0.01	0.01	0.01	0.02	0.03	0.06	0.09	0.10	0.01	0.01	0.01	0.01
				95th percentile	0.02	0.02	0.02	0.02	0.04	0.08	0.11	0.13	0.02	0.02	0.02	0.02

Table A.10: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at NF1. Shaded values are above the water quality guideline.

Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	5	5	6			
		5th percentile	117	31	73	46	38	41
		50th percentile	155	43	91	93	80	83
		95th percentile	166	54	176	152	135	138
SO4	309	n	5	5	7			
		5th percentile	13	0.4	8	8	5	6
		50th percentile	19	5	12	24	14	16
		95th percentile	20	8	44	48	26	30
Cd	0.00015	n	4	3	6			
		5th percentile	0.00002	0.00003	0.00002	0.00001	0.00001	0.00001
		50th percentile	0.00003	0.00004	0.00005	0.00005	0.00005	0.00005
		95th percentile	0.00006	0.00029	0.00019	0.00012	0.00012	0.00012
Co	0.0025	n	5	4	7			
		5th percentile	0.0001	0.0001	0.0002	0.0001	0.0000	0.0001
		50th percentile	0.0004	0.0004	0.0004	0.0003	0.0002	0.0002
		95th percentile	0.0005	0.0009	0.0039	0.0006	0.0004	0.0005
Pb	0.006	n	5	4	7			
		5th percentile	0.0003	0.0018	0.0009	0.0002	0.0002	0.0002
		50th percentile	0.001	0.002	0.002	0.001	0.001	0.001
		95th percentile	0.003	0.011	0.008	0.003	0.003	0.003
Mn	1.0	n	5	4	7			
		5th percentile	0.04	0.01	0.03	0.02	0.01	0.02
		50th percentile	0.08	0.04	0.1	0.12	0.05	0.1
		95th percentile	0.11	0.1	1.7	0.32	0.1	0.2
Zn	0.03	n	5	5	7			
		5th percentile	0.01	0.01	0.01	0.02	0.01	0.01
		50th percentile	0.02	0.01	0.02	0.08	0.03	0.05
		95th percentile	0.03	0.11	0.23	0.23	0.07	0.11

n/a - not applicable

Table A.11: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at X2. Shaded values are above the water quality guideline.

Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	29	12	25			
		5th percentile	115	31	56	49	39	42
		50th percentile	155	51	87	95	81	85
		95th percentile	172	108	115	155	136	141
SO4	309	n	30	13	25			
		5th percentile	20	2	7	11	6	7
		50th percentile	28	7	12	26	15	18
		95th percentile	39	17	19	50	26	32
Cd	0.00017	n	20	11	23			
		5th percentile	0.00001	0.00003	0.00001	0.00004	0.00002	0.00003
		50th percentile	0.00003	0.00004	0.00002	0.00015	0.00009	0.00010
		95th percentile	0.00006	0.00019	0.00005	0.00036	0.00017	0.00022
Co	0.0025	n	16	10	21			
		5th percentile	0.00015	0.00010	0.00007	0.00009	0.00005	0.00007
		50th percentile	0.00019	0.00022	0.00010	0.00030	0.00019	0.00023
		95th percentile	0.00028	0.00032	0.00038	0.00060	0.00043	0.00049
Pb	0.007	n	27	14	27			
		5th percentile	0.0002	0.0014	0.0004	0.0002	0.0002	0.0002
		50th percentile	0.0006	0.0026	0.0010	0.0013	0.0013	0.0013
		95th percentile	0.0017	0.0062	0.0057	0.0034	0.0034	0.0034
Mn	1.1	n	22	12	22			
		5th percentile	0.07	0.01	0.02	0.03	0.02	0.02
		50th percentile	0.08	0.03	0.04	0.13	0.05	0.08
		95th percentile	0.17	0.08	0.10	0.32	0.11	0.17
Zn	0.03	n	28	14	25			
		5th percentile	0.02	0.01	0.01	0.02	0.01	0.01
		50th percentile	0.03	0.03	0.02	0.09	0.03	0.05
		95th percentile	0.13	0.11	0.04	0.23	0.07	0.12

n/a - not applicable

Table A.12: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at X3. Shaded values are above the water quality guideline.

Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	29	10	20			
		5th percentile	116	36	62	45	36	37
		50th percentile	150	46	89	89	77	79
		95th percentile	170	125	114	147	132	134
SO4	309	n	28	10	19			
		5th percentile	21	6	9	9	4	5
		50th percentile	28	8	13	22	12	14
		95th percentile	37	22	19	40	23	25
Cd	0.00018	n	23	7	16			
		5th percentile	0.00001	0.00001	0.00001	0.00003	0.00002	0.00002
		50th percentile	0.00002	0.00003	0.00002	0.00012	0.00007	0.00008
		95th percentile	0.00010	0.00009	0.00002	0.00028	0.00015	0.00017
Co	0.0025	n	20	4	16			
		5th percentile	0.00009	0.00009	0.00005	0.00008	0.00004	0.00005
		50th percentile	0.00011	0.00014	0.00007	0.00026	0.00017	0.00020
		95th percentile	0.00019	0.00029	0.00012	0.00054	0.00040	0.00045
Pb	0.007	n	29	10	20			
		5th percentile	0.0001	0.0005	0.0002	0.0002	0.0002	0.0002
		50th percentile	0.0004	0.0012	0.0006	0.0013	0.0013	0.0013
		95th percentile	0.001	0.003	0.001	0.003	0.003	0.003
Mn	1.1	n	27	10	20			
		5th percentile	0.05	0.02	0.02	0.03	0.01	0.02
		50th percentile	0.06	0.04	0.03	0.10	0.04	0.05
		95th percentile	0.1	0.1	0.1	0.2	0.1	0.1
Zn	0.03	n	27	9	19			
		5th percentile	0.014	0.003	0.003	0.018	0.007	0.009
		50th percentile	0.021	0.006	0.008	0.066	0.019	0.030
		95th percentile	0.12	0.06	0.04	0.17	0.04	0.07

n/a - not applicable

Table A.13: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at X14. Shaded values are above the water quality guideline.

Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	57	53	81			
		5th percentile	200	59	119	216	142	211
		50th percentile	440	120	196	293	206	297
		95th percentile	811	520	320	391	279	398
SO4	429	n	52	47	77			
		5th percentile	77	26	47	145	77	126
		50th percentile	277	72	110	212	109	179
		95th percentile	612	415	220	315	147	244
Cd	0.0003	n	50	51	78			
		5th percentile	0.00004	0.00002	0.00002	0.00006	0.00005	0.00007
		50th percentile	0.00009	0.00006	0.00004	0.00015	0.00011	0.00014
		95th percentile	0.00020	0.00020	0.00020	0.00029	0.00018	0.00024
Co	0.0025	n	51	52	75			
		5th percentile	0.0010	0.0004	0.0007	0.0011	0.0013	0.0021
		50th percentile	0.0030	0.0010	0.0014	0.0021	0.0028	0.0045
		95th percentile	0.0194	0.0095	0.0034	0.0034	0.0046	0.0071
Pb	0.012	n	51	50	77			
		5th percentile	0.0001	0.0005	0.0002	0.0005	0.0008	0.0013
		50th percentile	0.0004	0.0016	0.0006	0.0017	0.0021	0.0031
		95th percentile	0.0020	0.0074	0.0014	0.0036	0.0042	0.0053
Mn	1.6	n	54	51	78			
		5th percentile	0.98	0.22	0.46	1.25	1.19	2.03
		50th percentile	3.92	0.62	1.04	2.35	2.53	4.19
		95th percentile	12.91	5.72	2.15	3.56	4.25	6.88
Zn	0.03	n	88	73	102			
		5th percentile	0.03	0.01	0.02	0.02	0.02	0.04
		50th percentile	0.09	0.04	0.04	0.07	0.03	0.06
		95th percentile	0.15	0.10	0.11	0.16	0.05	0.09

n/a - not applicable

Table A.14: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at R4. Shaded values are above the water quality guideline.

Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	10	5	11			
		5th percentile	168	64	115	132	121	176
		50th percentile	259	78	142	189	177	251
		95th percentile	355	132	222	257	243	337
SO4	309	n	10	6	9			
		5th percentile	38	27	37	79	62	101
		50th percentile	109	33	52	115	88	143
		95th percentile	212	66	98	169	118	195
Cd	0.00023	n	8	5	9			
		5th percentile	0.00001	0.00003	0.00002	0.00004	0.00004	0.00006
		50th percentile	0.00001	0.00006	0.00003	0.00010	0.00009	0.00012
		95th percentile	0.00005	0.00015	0.00004	0.00019	0.00017	0.00021
Co	0.0025	n	8	6	10			
		5th percentile	0.00003	0.00026	0.00019	0.00062	0.00108	0.00169
		50th percentile	0.00004	0.00059	0.00034	0.00127	0.00224	0.00363
		95th percentile	0.00088	0.00308	0.00123	0.00197	0.00365	0.00572
Pb	0.009	n	9	5	9			
		5th percentile	0.0000	0.0006	0.0002	0.0004	0.0007	0.0011
		50th percentile	0.0001	0.0029	0.0004	0.0015	0.0019	0.0027
		95th percentile	0.0004	0.0107	0.0008	0.0035	0.0040	0.0049
Mn	1.3	n	9	6	11			
		5th percentile	0.02	0.20	0.19	0.69	0.94	1.62
		50th percentile	0.03	0.39	0.34	1.29	1.99	3.34
		95th percentile	0.69	1.67	0.85	1.96	3.33	5.47
Zn	0.03	n	10	6	9			
		5th percentile	0.003	0.013	0.005	0.01	0.02	0.03
		50th percentile	0.01	0.02	0.02	0.04	0.03	0.05
		95th percentile	0.03	0.06	0.03	0.08	0.04	0.07

n/a - not applicable

Table A.15: Summary of predicted (2014-2023) seasonal water concentrations for key mine-related variables at R5. Shaded values are above the water quality guideline.

Variable	Guideline (mg/L)	Endpoint	Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	NA	5th percentile	101	74	103
		50th percentile	152	119	155
		95th percentile	213	176	217
SO4	309	5th percentile	55	31	50
		50th percentile	82	45	72
		95th percentile	120	61	97
Cd	0.00023	5th percentile	0.00003	0.00003	0.00003
		50th percentile	0.00009	0.00007	0.00008
		95th percentile	0.00017	0.00014	0.00015
Co	0.0025	5th percentile	0.0004	0.0006	0.0009
		50th percentile	0.0009	0.0011	0.0018
		95th percentile	0.0014	0.0018	0.0028
Pb	0.007	5th percentile	0.0003	0.0004	0.0007
		50th percentile	0.001	0.002	0.002
		95th percentile	0.003	0.004	0.004
Mn	1.3	5th percentile	0.5	0.44	0.76
		50th percentile	0.9	0.91	1.6
		95th percentile	1.3	1.5	2.6
Zn	0.03	5th percentile	0.01	0.01	0.02
		50th percentile	0.03	0.02	0.02
		95th percentile	0.06	0.03	0.04

Table A.16: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at A1. Shaded values are above the water quality guideline.

Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	12	6	8			
		5th percentile	162	34	118	90	63	86
		50th percentile	181	91	131	139	106	133
		95th percentile	214	117	177	198	162	193
SO4	309	n	12	7	9			
		5th percentile	42	16	30	47	24	39
		50th percentile	54	19	34	70	36	56
		95th percentile	84	44	60	102	48	76
Cd	0.00024	n	11	7	8			
		5th percentile	0.00001	0.00004	0.00002	0.00003	0.00002	0.00003
		50th percentile	0.00002	0.00009	0.00003	0.00008	0.00006	0.00007
		95th percentile	0.00006	0.00017	0.00006	0.00016	0.00013	0.00015
Co	0.0025	n	11	6	9			
		5th percentile	0.00002	0.00033	0.00007	0.00038	0.00043	0.00067
		50th percentile	0.00003	0.00092	0.00014	0.00078	0.00087	0.00136
		95th percentile	0.00028	0.00149	0.00048	0.00124	0.00138	0.00214
Pb	0.009	n	12	6	8			
		5th percentile	0.00003	0.00062	0.00012	0.00029	0.00036	0.00058
		50th percentile	0.00011	0.00229	0.00033	0.00141	0.00149	0.00177
		95th percentile	0.00101	0.00452	0.00067	0.00347	0.00359	0.00387
Mn	1.3	n	13	6	8			
		5th percentile	0.004	0.07	0.03	0.39	0.33	0.57
		50th percentile	0.01	0.18	0.08	0.73	0.68	1.17
		95th percentile	0.08	0.48	0.27	1.12	1.14	1.91
Zn	0.03	n	13	7	9			
		5th percentile	0.001	0.007	0.001	0.009	0.006	0.012
		50th percentile	0.004	0.011	0.006	0.024	0.013	0.020
		95th percentile	0.008	0.030	0.009	0.052	0.022	0.032

n/a - not applicable

Table A.17: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at P4. Shaded values are above the water quality guideline.

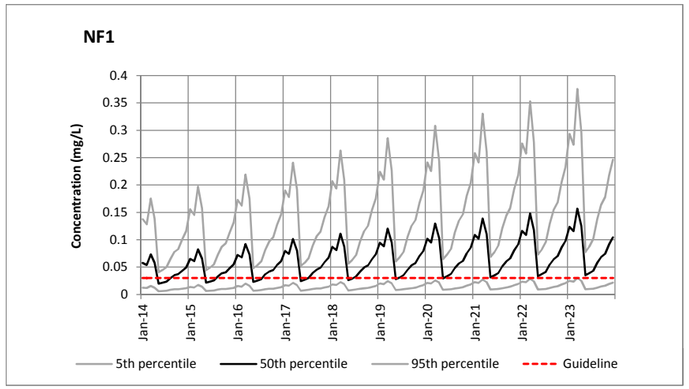
Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	8	4	7			
		5th percentile	176	93	136	209	209	212
		50th percentile	200	111	153	212	212	214
		95th percentile	215	120	188	216	215	217
SO4	309	n	8	5	8			
		5th percentile	35	27	41	67	66	67
		50th percentile	62	30	48	68	66	68
		95th percentile	68	46	65	70	67	69
Cd	0.00025	n	8	6	7			
		5th percentile	0.00005	0.00022	0.00007	0.00020	0.00020	0.00020
		50th percentile	0.00010	0.00047	0.00009	0.00020	0.00020	0.00021
		95th percentile	0.00047	0.00093	0.00016	0.00021	0.00021	0.00021
Co	0.0025	n	8	6	7			
		5th percentile	0.00002	0.00043	0.00004	0.00016	0.00015	0.00016
		50th percentile	0.00004	0.00111	0.00012	0.00018	0.00017	0.00019
		95th percentile	0.00072	0.00374	0.00023	0.00021	0.00020	0.00022
Pb	0.01	n	8	5	8			
		5th percentile	0.00002	0.00100	0.00009	0.00024	0.00025	0.00025
		50th percentile	0.00009	0.00248	0.00026	0.00031	0.00030	0.00030
		95th percentile	0.00164	0.00744	0.00036	0.00046	0.00042	0.00040
Mn	1.4	n	8	6	7			
		5th percentile	0.01	0.07	0.02	0.04	0.03	0.04
		50th percentile	0.02	0.16	0.03	0.07	0.05	0.07
		95th percentile	0.14	1.07	0.09	0.09	0.07	0.10
Zn	0.03	n	9	5	8			
		5th percentile	0.004	0.016	0.001	0.022	0.022	0.023
		50th percentile	0.013	0.027	0.007	0.023	0.023	0.023
		95th percentile	0.030	0.079	0.014	0.025	0.023	0.023

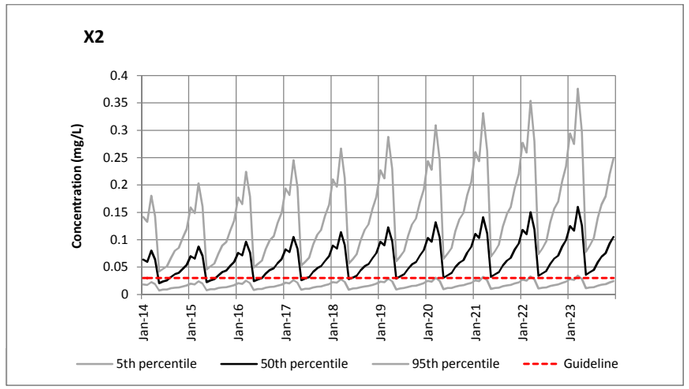
n/a - not applicable

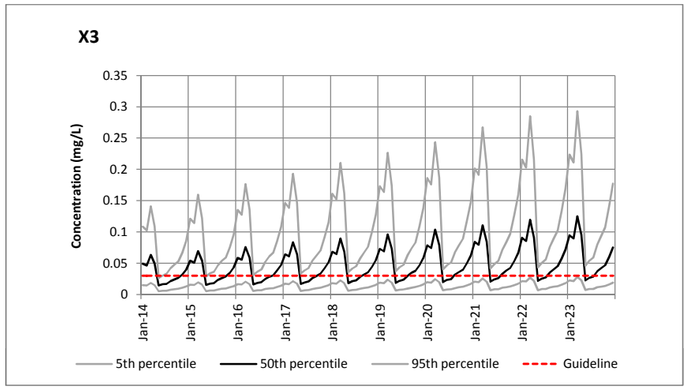
Table A.18: Summary of current (2008-2012) versus predicted (2014-2023) seasonal water concentrations for key mine-related variables at V8. Shaded values are above the water quality guideline.

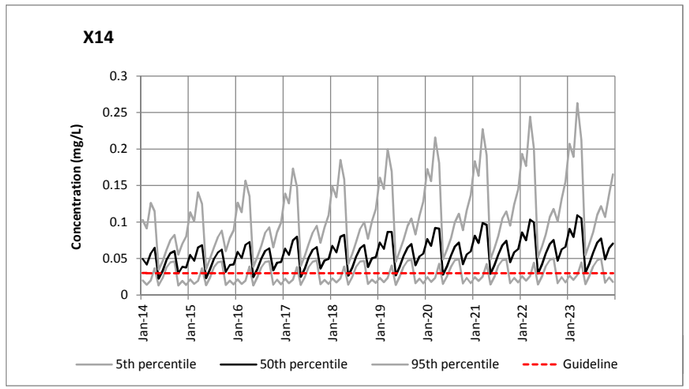
Variable	Guideline (mg/L)	Endpoint	Current Seasonal Concentrations (mg/L)			Predicted Seasonal Concentrations (mg/L)		
			Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)	Winter (NOV-APR)	Spring (MAY-JUN)	Summer/ Fall (JUL-OCT)
Hardness	n/a	n	29	16	23			
		5th percentile	300	105	170	276	149	266
		50th percentile	390	143	239	302	173	310
		95th percentile	465	237	378	333	205	364
SO4	429	n	27	14	23			
		5th percentile	113	30	65	115	69	148
		50th percentile	165	60	100	129	85	193
		95th percentile	207	114	227	144	108	247
Cd	0.0004	n	27	16	22			
		5th percentile	0.00004	0.00006	0.00004	0.00009	0.00023	0.00024
		50th percentile	0.00006	0.00017	0.00008	0.00015	0.00035	0.00032
		95th percentile	0.00020	0.00093	0.00020	0.00023	0.00052	0.00041
Co	0.0025	n	28	15	22			
		5th percentile	0.0001	0.0002	0.0001	0.0001	0.0007	0.0003
		50th percentile	0.0001	0.0010	0.0002	0.0002	0.0008	0.0004
		95th percentile	0.0010	0.0131	0.0010	0.0003	0.0009	0.0005
Pb	0.016	n	28	15	22			
		5th percentile	0.0001	0.0010	0.0002	0.0011	0.0032	0.0016
		50th percentile	0.0003	0.0031	0.0006	0.0026	0.0050	0.0030
		95th percentile	0.0018	0.0406	0.0022	0.0049	0.0082	0.0051
Mn	1.9	n	29	15	23			
		5th percentile	0.01	0.02	0.01	0.02	0.19	0.27
		50th percentile	0.01	0.08	0.02	0.03	0.25	0.37
		95th percentile	0.03	0.63	0.09	0.05	0.32	0.48
Zn	0.03	n	29	16	21			
		5th percentile	0.01	0.01	0.01	0.01	0.04	0.04
		50th percentile	0.01	0.03	0.01	0.01	0.05	0.05
		95th percentile	0.02	0.26	0.03	0.02	0.06	0.07

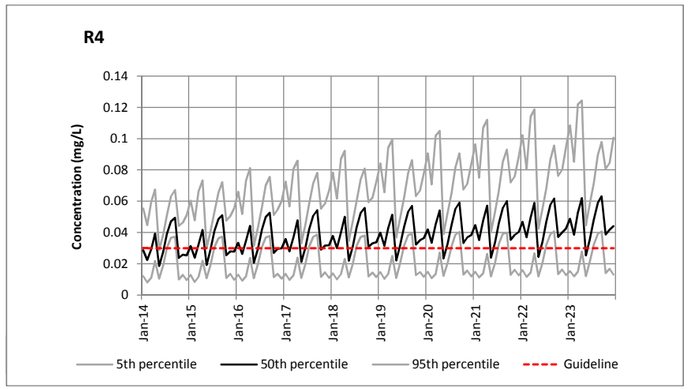
n/a - not applicable

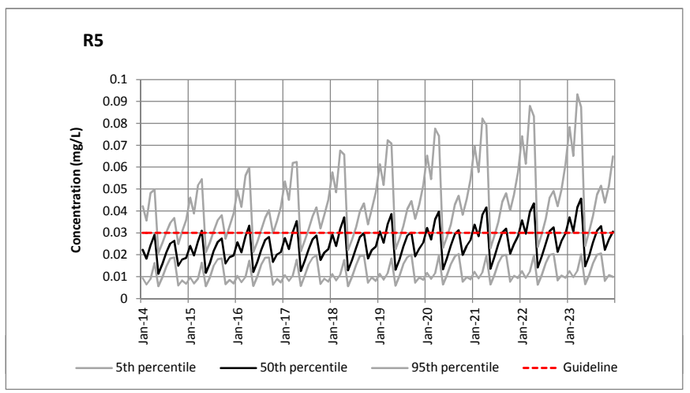


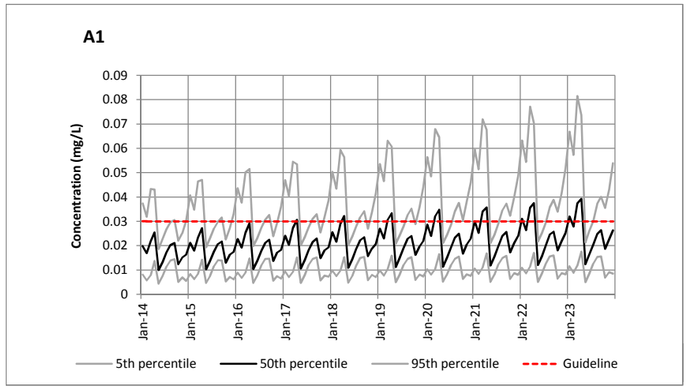


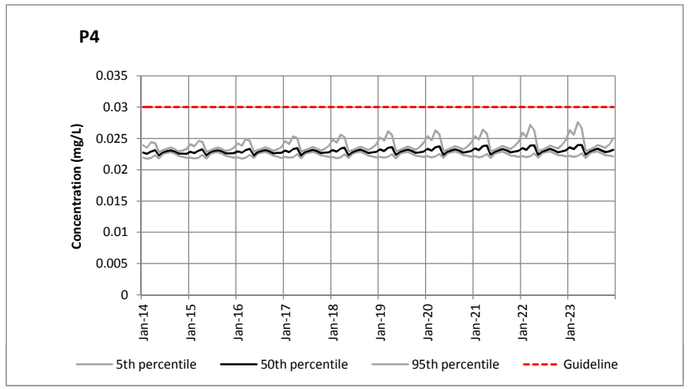












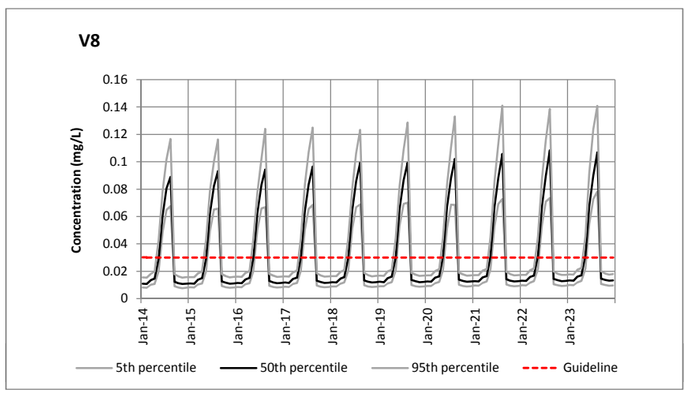
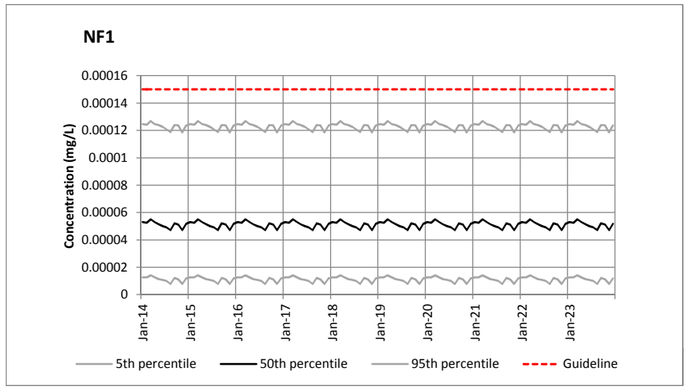
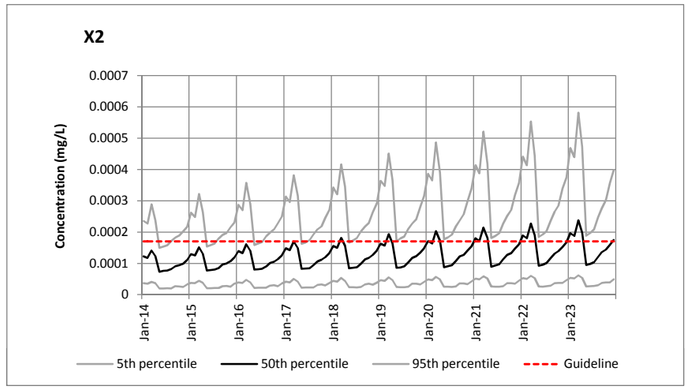
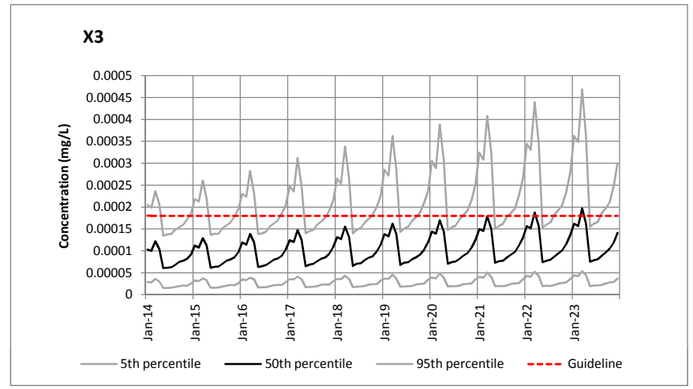
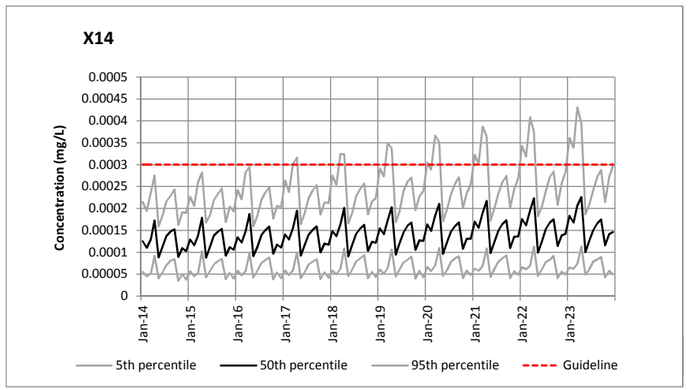


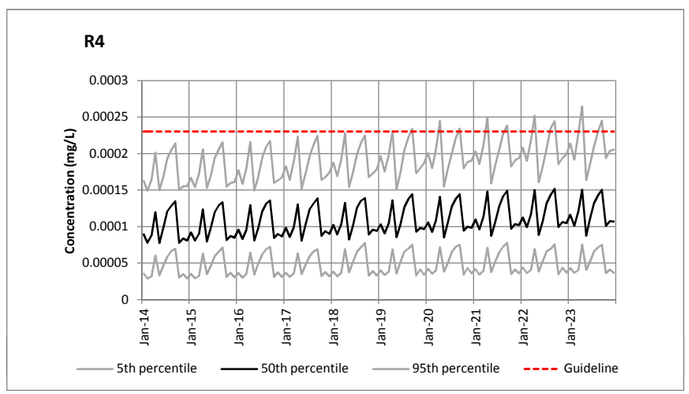
Figure A.1: Predicted (10-year) zinc concentrations relative to the Canadian water quality guideline for the protection of aquatic life. Estimated ranges based on recent measured water quality values, variability, and trends.

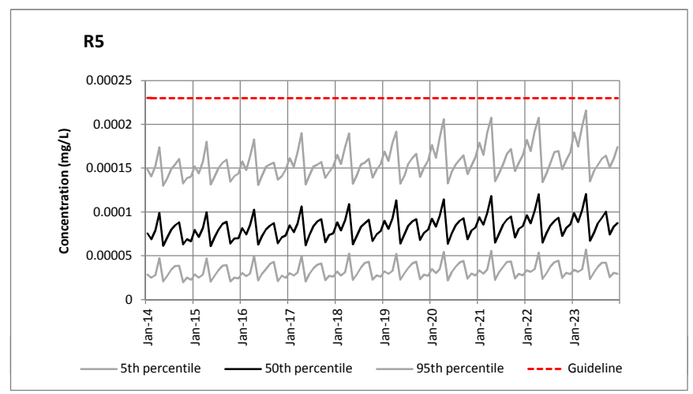


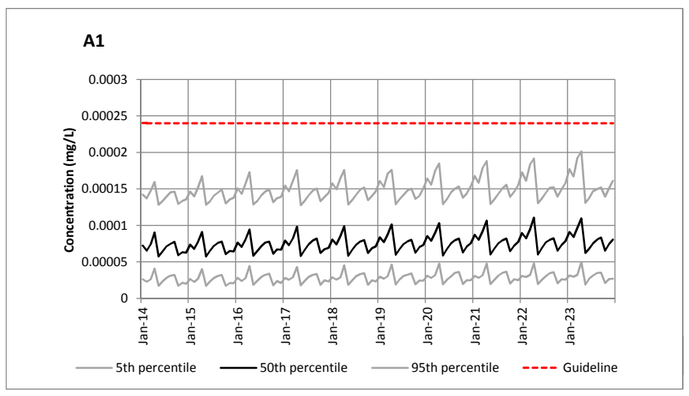


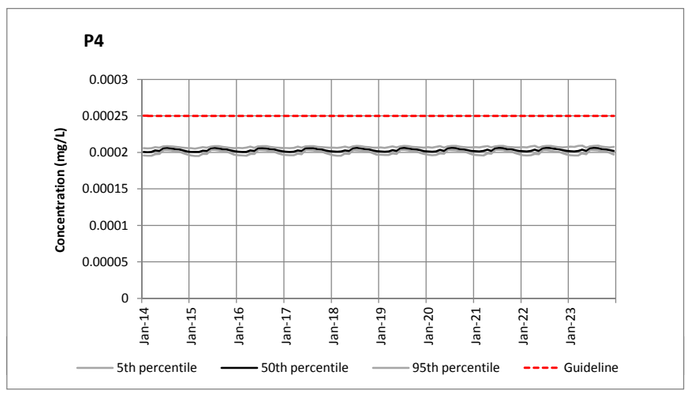












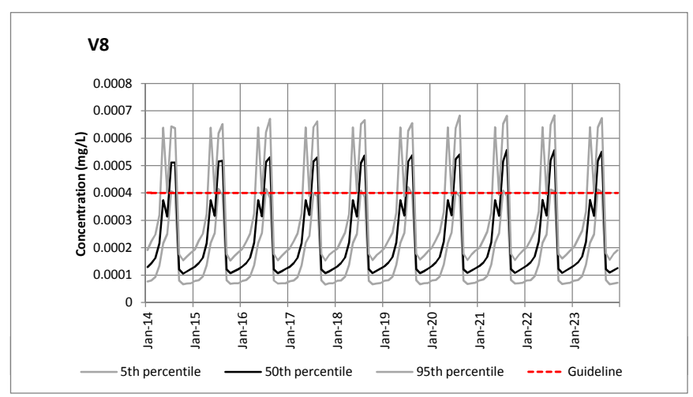


Figure A.2: Predicted (10-year) cadmium concentrations relative to the Canadian water quality guideline for the protection of aquatic life. Estimated ranges based on recent measured water quality values, variability, and trends.

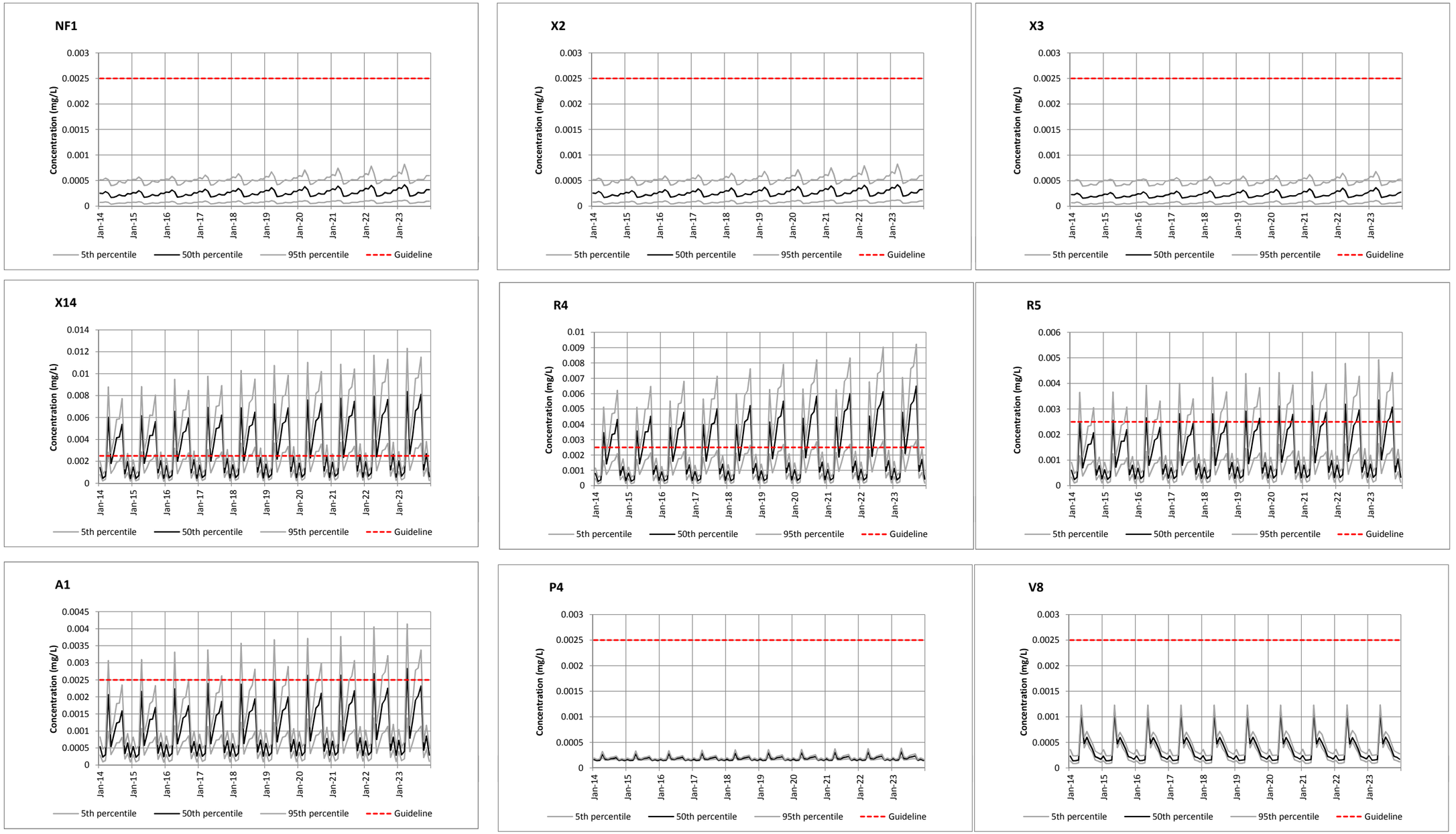
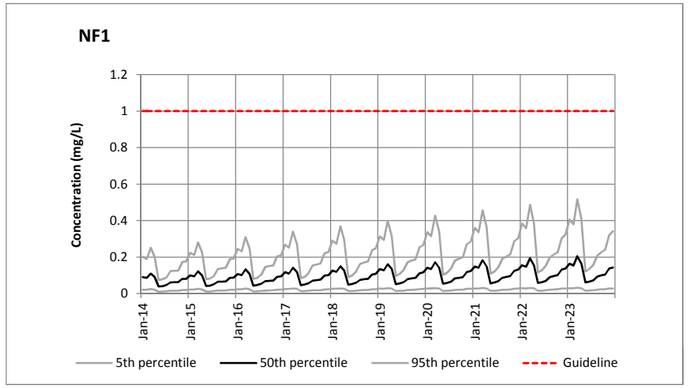
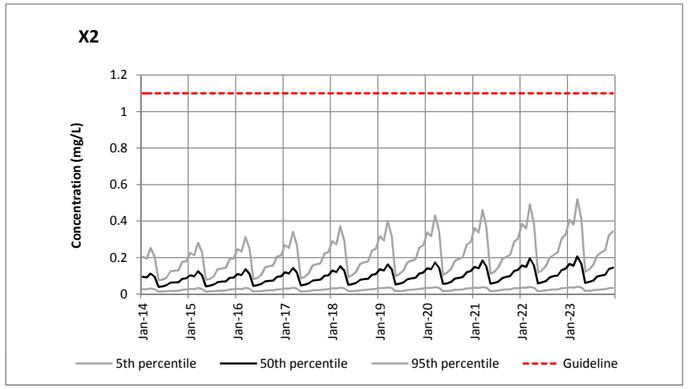
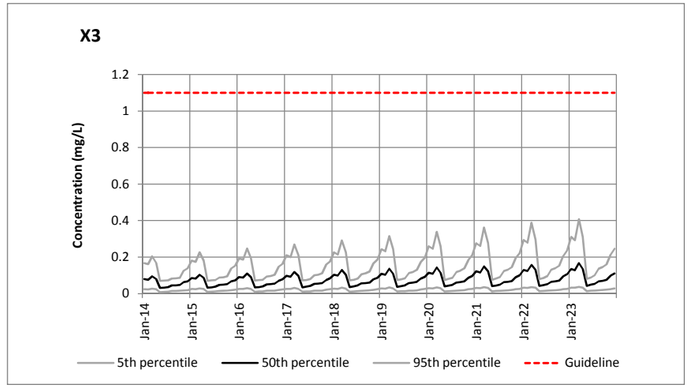
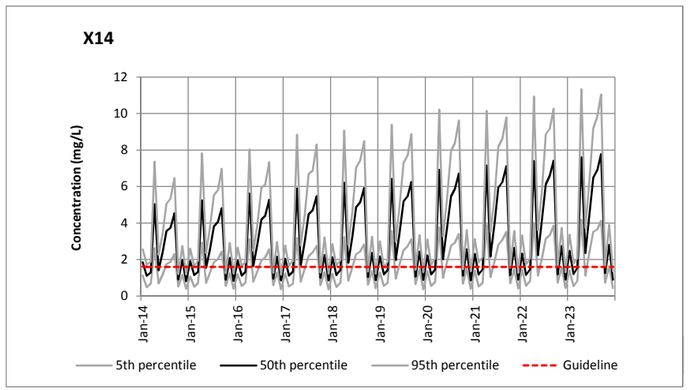


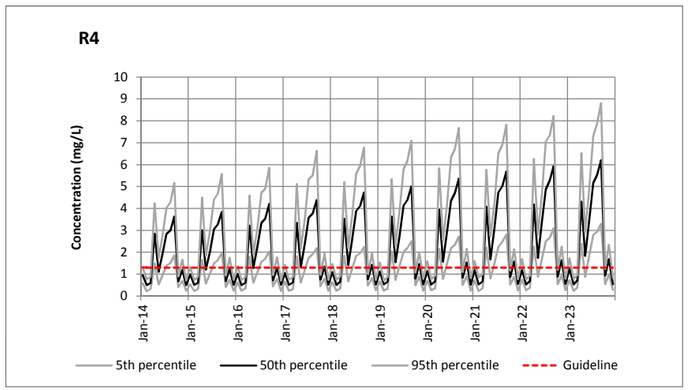
Figure A.3: Predicted (10-year) cobalt concentrations relative to the Canadian water quality guideline for the protection of aquatic life. Estimated ranges based on recent measured water quality values, variability, and trends.

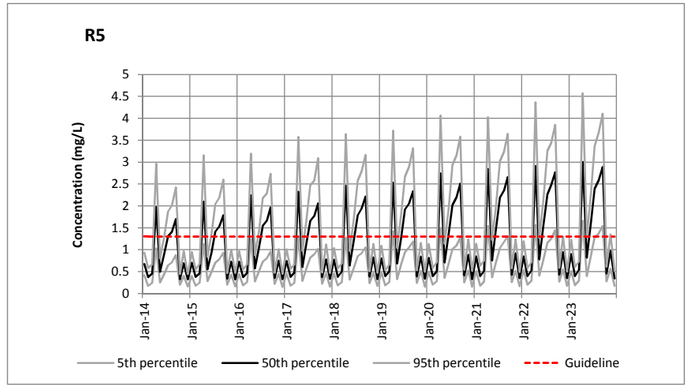


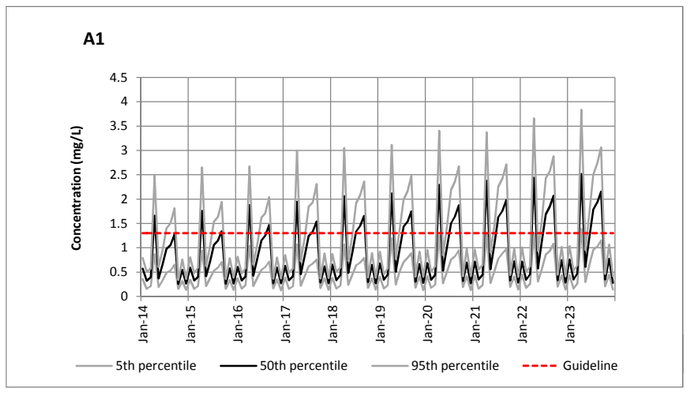


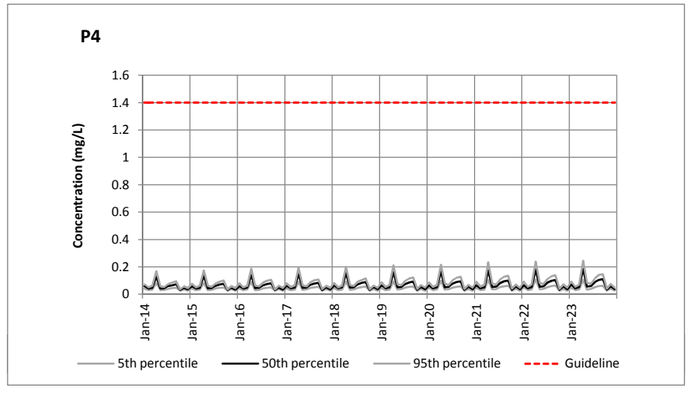












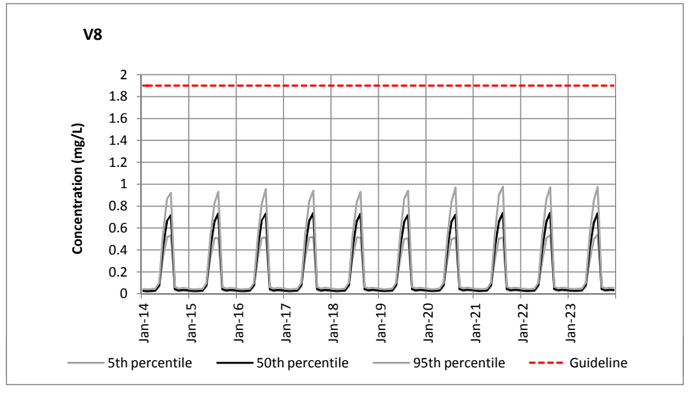


Figure A.4: Predicted (10-year) manganese concentrations relative to the Canadian water quality guideline for the protection of aquatic life. Estimated ranges based on recent measured water quality values, variability, and trends.

ATTACHMENT B

ZINC TOXICITY DATA

Table B.1: Lowest effect endpoint reported for each freshwater species after acute (short-term) exposure to zinc. See Table B.2 for test details and sources.

Species common name	Species latin name	Life stage	Duration	Endpoint	Observed effect	Reported Effect concentration (mg/L)	Reported Water Hardness (mg/L)	Effect Concentration (mg/L) at 50 mg/L Hardness [a]	Effect Concentration (mg/L) at 100 mg/L Hardness [a]	Effect Concentration (mg/L) at 200 mg/L Hardness [a]	Effect Concentration (mg/L) at 300 mg/L Hardness [a]
Water flea	*Ceriodaphnia dubia*	Less than 48h old	48 h	LC50	Mortality	0.10	290	0.02	0.04	0.07	0.10
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality	0.06	110	0.03	0.05	0.09	0.13
Water flea	*Daphnia magna*	Juvenile	96 h	LC50	Mortality	0.07	130	0.03	0.05	0.10	0.14
Green algae	*Selenastrum capricornutum*	Not reported	4 h	EC50	Growth	0.10	130	0.04	0.08	0.14	0.20
Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality	0.03	29	0.05	0.09	0.15	0.22
Scud	*Hyalella azteca*	7- to 14-d old	96 h	LC50	Mortality	0.29	290	0.07	0.12	0.21	0.30
Striped bass	*Morone saxatilis*	35-80 d old	96 h	LC50	Mortality	0.43	455	0.07	0.12	0.21	0.30
Fathead minnow	*Pimephales promelas*	Less than 24hrs	96 h	LC50	Mortality	0.33	290	0.07	0.13	0.24	0.34
Chinook salmon	*Oncorhynchus tshawytscha*	Juvenile	96 h	LC10	Mortality	0.04	21	0.08	0.15	0.27	0.38
Water flea	*Ceriodaphnia reticulata*	Less than 4h	48 h	LC50	Mortality	0.08	43	0.09	0.16	0.28	0.39
Cladocerans	*Daphnia longispina*	Less than 48h old	48 h	EC50	Immobility	0.38	250	0.10	0.17	0.31	0.44
Water flea	*Daphnia pulex*	Less than 24hrs	48 h	LC50	Mortality	0.11	43	0.12	0.22	0.39	0.55
Arctic grayling	*Thymallus arcticus*	Juvenile	96 h	LC50	Mortality	0.11	41	0.13	0.24	0.43	0.60
Zebra mussel	*Dreissena polymorpha*	Adult	48 h	EC50	Filtration rate	0.56	268	0.14	0.24	0.44	0.62
Sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality	0.46	205	0.14	0.25	0.45	0.64
Mottled sculpin	*Cottus bairdi*	newly hatched	96 h	LC50	Mortality	0.26	103	0.14	0.25	0.46	0.65
Cladocerans	*Simocephalus vetulus*	Less than 48h old	48 h	EC50	Immobility	0.85	250	0.22	0.39	0.70	0.99
Longfin dace	*Rhinichthys chrysogaster*	Juvenile	96 h	LC50	Mortality	0.79	217	0.23	0.41	0.74	1.0
Cladocerans	*Simocephalus exspinosus*	Less than 48h old	48 h	EC50	Immobility	0.91	250	0.23	0.42	0.75	1.1
Cladocerans	*Daphnia galeata*	Less than 48h old	48 h	EC50	Immobility	1.0	250	0.26	0.46	0.83	1.2
Cladocerans	*Ceriodaphnia pulchella*	Less than 48h old	48 h	EC50	Immobility	1.3	250	0.32	0.58	1.0	1.5
Cladocerans	*Chydorus sphaericus*	Less than 48h old	48 h	EC50	Immobility	1.3	250	0.34	0.61	1.1	1.5
Cladocerans	*Acroperus elongatus*	Less than 48h old	48 h	EC50	Immobility	1.6	250	0.41	0.74	1.3	1.9
Cladocerans	*Chydorus ovalis*	Less than 48h old	48 h	EC50	Immobility	1.6	250	0.42	0.75	1.3	1.9
Colorado Squawfish	*Ptychocheilus lucius*	Swim-up fry	96 h	LC50	Mortality	1.7	196	0.53	0.96	1.7	2.4
Snail	*Physa heterostropha*	Not reported	96 h	LC50	Mortality	0.82	50	0.82	1.5	2.7	3.7
Coho salmon	*Oncorhynchus kisutch*	Alevin	48 h	LC50	Mortality	0.73	41	0.85	1.5	2.8	3.9
Sockeye salmon	*Oncorhynchus nerka*	Alevin	115 h	LC50	Mortality	0.45	22	0.90	1.6	2.9	4.1
Razorback Sucker	*Xyrauchen texanus*	Juvenile	96 h	LC50	Mortality	2.9	199	0.91	1.6	2.9	4.1
Brook Trout	*Salvelinus fontinalis*	Embryo	6 h	LOEC	Embryo (6 hours old) survival to hatch	1.4	46	1.5	2.7	4.8	6.8
Bonytail	*Gila elegans*	Swim-up fry	96 h	LC50	Mortality	4.8	196	1.5	2.7	4.9	6.9
Worm	*Tubifex tubifex*	Not reported	96 h	LC50	Immobility	5.7	237	1.5	2.7	4.9	6.9
Snail	*Lymnaea luteola*	Adult	96 h	LC50	Mortality	5.0	200	1.5	2.8	5.0	7.0
Snail	*Physa gyrina*	Adult	96 h	LC50	Mortality	1.3	36	1.7	3.0	5.4	7.7
African clawed frog	*Xenopus laevis*	Embryo	4 d	EC50	malformation	3.6	100	2.0	3.6	6.5	9.1
Green hydra	*Hydra viridissima*	Not reported	96 h	LC50	Mortality	0.94	20	2.0	3.7	6.6	9.3
Carp	*Cyprinus carpio*	Not reported	96 h	LC50	Mortality	9.7	250	2.5	4.5	8.1	11
Isopod	*Lirceus alabamae*	Not reported	96 h	LC50	Mortality	8.3	152	3.2	5.8	10	15
Bluegill sunfish	*Lepomis macrochirus*	Not reported	96 h	LC50	Mortality	3.0	45	3.3	6.0	11	15
Perch	*Perca fluviatilis*	Not reported	5 d	LC50	Mortality	16	290	3.6	6.5	12	16
Flannelmouth sucker	*Catostomus latipinnis*	Larva	24 h	LC50	Mortality	8.9	144	3.6	6.5	12	17
N/A	*Rana hexadactyla*	Tadpole	96 h	LC50	Mortality	2.1	20	4.6	8.2	15	21
Bivalve	*Corbicula fluminea*	Not reported	96 h	LC50	Mortality	6.0	64	4.9	8.8	16	22
Pink hydra	*Hydra vulgaris*	Not reported	96 h	LC50	Mortality	2.3	20	5.0	9.0	16	23
White Sucker	*Catostomus commersoni*	Adult	96 h	LC50	Mortality	2.2	18	5.2	9.4	17	24
Northern pikeminnow	*Ptychocheilus oregonensis*	Juvenile	168 h	LC50	Mortality	2.9	25	5.3	9.5	17	24
Isopod	*Caecidotea bicrenata*	Not reported	96 h	LC50	Mortality	20	220	5.8	10	19	26
Coelenterate	*Hydra oligactis*	Not reported	72 h	LC50	Mortality	20	210	5.9	11	19	27
Asian toad	*Bufo melanostictus*	Tadpole	96 h	LC50	Mortality	20	185	6.6	12	21	30
White perch	*Morone americana*	Adult	48 h	TLM	Mortality	10	55	9.3	17	30	43
Oligochaete	*Lumbriculus variegatus*	Not reported	96 h	LC50	Mortality	6.3	30	9.7	17	31	44
Golden shiner	*Notemigonus crysoleucas*	Juvenile	24 h	LC50	Mortality	7.8	36	10	18	33	47
American eel	*anguilla rostrata*	Adult	96 h	TLM	Mortality	15	55	13	24	43	61
Annelid	*Aeolosoma headleyi*	Not reported	48 h	LC50	Mortality	14	45	15	27	48	67
Banded killifish	*Fundulus diaphanus*	Adult	96 h	TLM	Mortality	19	55	18	32	57	81
Pumpkinseed	*Lepomis gibbosus*	Adult	96 h	TLM	Mortality	20	55	19	33	60	85
Redbelly tilapia	*Tilapia zilli*	Juvenile	96 h	LC50	Mortality	13	21	27	49	88	124
Goldfish	*Carassius auratus*	Juvenile	24 h	LC50	Mortality	40	36	53	95	171	241
Mayfly	*Rhithrogena hageni*	nymph	96 h	LC50	Mortality	51	44	56	100	181	255

[a] Values adjusted based on hardness using an acute hardness:toxicity slope factor of 0.8473 from USEPA (1987) and the equation EXP(LN(EFFECT conc)-(0.8473)*(LN(measured water hardness)-LN(desired water hardness))).

Species not relevant to Faro

Table B.2: Detailed acute toxicity data for zinc. Lowest effect concentration for each species is highlighted.

Species Type	Species common name	Species latin name	Life stage	Duration	Endpoint	Observed effect	Effect concentration (mg/L)	Hardness	Effect Concentration (mg/L) at 100 mg/L Hardness [a]	Authors	Year
Algae/ Plant	Green algae	*Scenedesmus quadricauda*	Population	4 h	LOEC	Photosynthesis	0.25	ND	-	Starodub et al.	1987
	Green algae	*Selenastrum capricornutum*	Not reported	4 h	EC50	Growth (1)	0.10	130	0.08	Pardos et al	1998
	mosquito fern	*Azolla pinnata*	Adult	96 h	IC50	Growth (1)	0.95	ND	-	Gaur et al.	1994
Amphibians	Asian toad	*Bufo melanostictus*	Tadpole	96 h	LC50	Mortality (1)	19.86	185	11.79	Khangarot and Ray	1987
	Asian toad	*Bufo melanostictus*	Tadpole	48 h	LC50	Mortality (1)	25.65	185	15.23	Khangarot and Ray	1987
	Asian toad	*Bufo melanostictus*	Tadpole	24 h	LC50	Mortality (1)	47.26	185	28.06	Khangarot and Ray	1987
	Asian toad	*Bufo melanostictus*	Tadpole	12 h	LC50	Mortality (1)	50.03	185	29.71	Khangarot and Ray	1987
	N/A	*Rana hexadactyla*	Tadpole	96 h	LC50	Mortality (1)	2.10	20	8.21	Khangarot et al.	1985
	N/A	*Rana hexadactyla*	Tadpole	72 h	LC50	Mortality (1)	3.17	20	12.40	Khangarot et al.	1985
	N/A	*Rana hexadactyla*	Tadpole	48 h	LC50	Mortality (1)	3.66	20	14.31	Khangarot et al.	1985
	N/A	*Rana hexadactyla*	Tadpole	24 h	LC50	Mortality (1)	7.82	20	30.58	Khangarot et al.	1985
	African clawed frog	*Xenopus laevis*	Embryo	4 d	EC50	malformation	3.60	100	3.60	Dawson et al.	1988
	African clawed frog	*Xenopus laevis*	Embryo	4 d	LC50	Mortality (1)	3.45	100	3.45	Dawson et al.	1988
	African clawed frog	*Xenopus laevis*	Embryo	4 d	LOEC	Growth (1)	4.20	100	4.20	Dawson et al.	1988
Fish	american eel	*anguilla rostrata*	Adult	96 h	TLM	Mortality (1)	14.60	53	25.00	Rehwold et al.	1971
	american eel	*anguilla rostrata*	Adult	48 h	TLM	Mortality (1)	20.00	53	34.25	Rehwold et al.	1971
	american eel	*anguilla rostrata*	Adult	24 h	TLM	Mortality (1)	21.60	53	36.99	Rehwold et al.	1971
	american eel	*anguilla rostrata*	Adult	96 h	TLM	Mortality (1)	14.50	55	24.06	Rehwold et al.	1972
	american eel	*anguilla rostrata*	Adult	48 h	TLM	Mortality (1)	20.10	55	33.36	Rehwold et al.	1972
	american eel	*anguilla rostrata*	Adult	24 h	TLM	Mortality (1)	21.40	55	35.51	Rehwold et al.	1972
	Goldfish	*Carassius auratus*	Juvenile	24 h	LC50	Mortality (1)	103.00	36	244.78	Cairns et al.	1978
	Goldfish	*Carassius auratus*	Juvenile	24 h	LC50	Mortality (1)	40.00	36	95.06	Cairns et al.	1978
	White Sucker	*Catostomus commersoni*	Adult	96 h	LC50	Mortality (1)	2.20	18	9.41	Duncan and Klaverkamp	1983
	White Sucker	*Catostomus commersoni*	Adult	72 h	LC50	Mortality (1)	2.48	18	10.60	Duncan and Klaverkamp	1983
	White Sucker	*Catostomus commersoni*	Adult	48 h	LC50	Mortality (1)	2.96	18	12.66	Duncan and Klaverkamp	1983
	White Sucker	*Catostomus commersoni*	Adult	24 h	LC50	Mortality (1)	5.58	18	23.86	Duncan and Klaverkamp	1983
	Flannelmouth sucker	*Catostomus latipinnis*	Larva	24 h	LC50	Mortality (1)	8.89	144	6.53	Hamilton and Buhl	1997
	Mottled sculpin	*Cottus bairdi*	newly hatched	96 h	LC50	Mortality (1)	0.26	103	0.25	Besser et al	2007
	Mottled sculpin	*Cottus bairdi*	less than 2 months old	96 h	LC50	Mortality (1)	0.44	154	0.30	Brinkman and Woodling	2005
	Mottled sculpin	*Cottus bairdi*	newly emerged	96 h	LC50	Mortality (1)	0.16	48.6	0.29	Woodling et al	2002
	Carp	*Cyprinus carpio*	Not reported	96 h	LC50	Mortality (1)	9.74	250	4.48	Hattink et al	2006
	Common carp	*Cyprinus carpio*	Juvenile	96 h	LC50	Mortality (1)	3.12	19	12.74	Khangarot et al.	1983
	Common carp	*Cyprinus carpio*	Juvenile	72 h	LC50	Mortality (1)	5.56	19	22.71	Khangarot et al.	1983
	Common carp	*Cyprinus carpio*	Juvenile	48 h	LC50	Mortality (1)	7.28	19	29.73	Khangarot et al.	1983
	Common carp	*Cyprinus carpio*	Juvenile	24 h	LC50	Mortality (1)	9.04	19	36.92	Khangarot et al.	1983
	Common carp	*Cyprinus carpio*	Juvenile	12 h	LC50	Mortality (1)	10.77	19	43.99	Khangarot et al.	1983
	Carp	*Cyprinus carpio*	Adult	96 h	TLM	Mortality (1)	7.80	53	13.36	Rehwold et al.	1971
	Carp	*Cyprinus carpio*	Adult	48 h	TLM	Mortality (1)	9.30	53	15.93	Rehwold et al.	1971
	Carp	*Cyprinus carpio*	Adult	24 h	TLM	Mortality (1)	14.30	53	24.49	Rehwold et al.	1971
	Carp	*Cyprinus carpio*	Adult	96 h	TLM	Mortality (1)	7.80	55	12.94	Rehwold et al.	1972
	Carp	*Cyprinus carpio*	Adult	48 h	TLM	Mortality (1)	9.20	55	15.27	Rehwold et al.	1972
	Carp	*Cyprinus carpio*	Adult	24 h	TLM	Mortality (1)	14.40	55	23.90	Rehwold et al.	1972
	banded killifish	*Fundulus diaphanus*	Adult	96 h	TLM	Mortality (1)	19.10	53	32.71	Rehwold et al.	1971
	banded killifish	*Fundulus diaphanus*	Adult	48 h	TLM	Mortality (1)	20.70	53	35.45	Rehwold et al.	1971
	banded killifish	*Fundulus diaphanus*	Adult	24 h	TLM	Mortality (1)	22.60	53	38.70	Rehwold et al.	1971
	banded killifish	*Fundulus diaphanus*	Adult	96 h	TLM	Mortality (1)	19.20	55	31.86	Rehwold et al.	1972
	banded killifish	*Fundulus diaphanus*	Adult	48 h	TLM	Mortality (1)	20.40	55	33.85	Rehwold et al.	1972
	banded killifish	*Fundulus diaphanus*	Adult	24 h	TLM	Mortality (1)	23.00	55	38.17	Rehwold et al.	1972
	Bonytail	*Gila elegans*	Larva	96 h	LC50	Mortality (1)	5.35	199	2.99	Buhl and Hamilton	1996
	Bonytail	*Gila elegans*	Juvenile	96 h	LC50	Mortality (1)	8.01	199	4.47	Buhl and Hamilton	1996
	Bonytail	*Gila elegans*	Swim-up fry	96 h	LC50	Mortality (1)	4.80	196	2.71	Hamilton	1995
	Bonytail	*Gila elegans*	Juvenile	96 h	LC50	Mortality (1)	5.80	196	3.28	Hamilton	1995
	Bonytail	*Gila elegans*	Juvenile	96 h	LC50	Mortality (1)	23.00	196	13.00	Hamilton	1995
	pumpkinseed	*Lepomis gibbosus*	Adult	96 h	TLM	Mortality (1)	20.00	53	34.25	Rehwold et al.	1971
	pumpkinseed	*Lepomis gibbosus*	Adult	48 h	TLM	Mortality (1)	21.80	53	37.33	Rehwold et al.	1971
	pumpkinseed	*Lepomis gibbosus*	Adult	24 h	TLM	Mortality (1)	25.20	53	43.15	Rehwold et al.	1971
	pumpkinseed	*Lepomis gibbosus*	Adult	96 h	TLM	Mortality (1)	20.10	55	33.36	Rehwold et al.	1972
	pumpkinseed	*Lepomis gibbosus*	Adult	48 h	TLM	Mortality (1)	21.90	55	36.34	Rehwold et al.	1972
	pumpkinseed	*Lepomis gibbosus*	Adult	24 h	TLM	Mortality (1)	25.10	55	41.65	Rehwold et al.	1972
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	MATC	Mortality (1)	7.48	68	10.38	Burton et al.	1972
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	NOEC	Mortality (1)	5.60	68	7.76	Burton et al.	1972
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	LOEC	Mortality (1)	10.00	68	13.86	Burton et al.	1972
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	LC50	Mortality (1)	3.05	45.4	5.95	Cairns and Scheier	1957
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	LC50	Mortality (1)	3.20	40.2	6.93	Thompson et al.	1980
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	LC50	malformation	11.21	218.1	5.79	Cairns and Scheier	1957
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	TLM	Mortality (1)	9.90	46	19.12	Cairns et al.	1971
	Bluegill	*Lepomis macrochirus*	Not reported	96 h	TLM	Mortality (1)	12.10	46	23.36	Cairns et al.	1971
	Bluegill	*Lepomis macrochirus*	Juvenile	24 h	LC50	Mortality (1)	19.10	36	45.39	Cairns et al.	1978
	Bluegill	*Lepomis macrochirus*	Juvenile	24 h	LC50	Mortality (1)	23.00	36	54.66	Cairns et al.	1978
	white perch	*Morone americana*	Adult	48 h	TLM	Mortality (1)	10.20	53	17.47	Rehwold et al.	1971
	white perch	*Morone americana*	Adult	24 h	TLM	Mortality (1)	13.60	53	23.29	Rehwold et al.	1971
	white perch	*Morone americana*	Adult	96 h	TLM	Mortality (1)	14.30	53	24.49	Rehwold et al.	1971
	white perch	*Morone americana*	Adult	48 h	TLM	Mortality (1)	10.10	55	16.76	Rehwold et al.	1972
	white perch	*Morone americana*	Adult	24 h	TLM	Mortality (1)	13.50	55	22.40	Rehwold et al.	1972
	white perch	*Morone americana*	Adult	96 h	TLM	Mortality (1)	14.40	55	23.90	Rehwold et al.	1972
	striped bass	*Morone saxatilis*	35-80 d old	96 h	LC50	Mortality (1)	0.43	455	0.12	Palawski et al.	1985
	striped bass	*Morone saxatilis*	35-80 d old	96 h	LC50	Mortality (1)	0.12	40	0.26	Palawski et al.	1985
	striped bass	*Morone saxatilis*	35-80 d old	96 h	LC50	Mortality (1)	0.43	285	0.18	Palawski et al.	1985
	striped bass	*Morone saxatilis*	Adult	96 h	TLM	Mortality (1)	6.70	53	11.47	Rehwold et al.	1971
	striped bass	*Morone saxatilis*	Adult	48 h	TLM	Mortality (1)	10.00	53	17.12	Rehwold et al.	1971
	striped bass	*Morone saxatilis*	Adult	24 h	TLM	Mortality (1)	11.20	53	19.18	Rehwold et al.	1971
	striped bass	*Morone saxatilis*	Adult	96 h	TLM	Mortality (1)	6.80	55	11.28	Rehwold et al.	1972
	striped bass	*Morone saxatilis*	Adult	48 h	TLM	Mortality (1)	10.00	55	16.60	Rehwold et al.	1972
	striped bass	*Morone saxatilis*	Adult	24 h	TLM	Mortality (1)	11.30	55	18.75	Rehwold et al.	1972
	golden shiner	*Notemigonus crysoleucas*	Juvenile	24 h	LC50	Mortality (1)	11.40	36	27.09	Cairns et al.	1978
	golden shiner	*Notemigonus crysoleucas*	Juvenile	24 h	LC50	Mortality (1)	7.76	36	18.44	Cairns et al.	1978
	Coho salmon	*Oncorhynchus kisutch*	Alevin	48 h	LC50	Mortality (1)	0.73	41.3	1.54	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Juvenile	96 h	LC50	Mortality (1)	0.82	41.3	1.73	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Juvenile	96 h	LC50	Mortality (1)	1.65	41.3	3.49	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Juvenile	96 h	LC50	Mortality (1)	1.81	41.3	3.83	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Juvenile	24 h	LC50	Mortality (1)	2.85	41.3	6.03	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Alevin	24 h	LC50	Mortality (1)	3.14	41.3	6.64	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Juvenile	24 h	LC50	Mortality (1)	5.16	41.3	10.92	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Juvenile	24 h	LC50	Mortality (1)	5.61	41.3	11.87	Buhl and Hamilton	1990
	Coho salmon	*Oncorhynchus kisutch*	Adult	96 h	LC50	Mortality (1)	0.91	25	2.93	Chapman and Stevens	1978
	Coho salmon	*Oncorhynchus kisutch*	Juvenile	96 h	LC50	Mortality (1)	4.60	94	4.85	Lorz and McPherson	1976
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.06	110	0.05	Alsop and Wood	1999
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.10	10	0.72	Alsop and Wood	1999
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.13	10	0.88	Alsop and Wood	1999
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	1.80	110	1.66	Alsop and Wood	1999
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.13	33	0.34	Anadu et al.	1989
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.17	33	0.43	Anadu et al.	1989
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.18	33	0.46	Anadu et al.	1989
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.21	33	0.54	Anadu et al.	1989
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.25	33	0.63	Anadu et al.	1989
	Rainbow trout	*Oncorhynchus mykiss*	Not reported	5 d	LC50	Mortality (1)	4.60	290	1.87	Ball	1967
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.18	103	0.17	Besser et al	2007
	Rainbow trout	*Oncorhynchus mykiss*	Swim-up fry	96 h	LC50	Mortality (1)	0.26	103	0.26	Besser et al	2007
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.17	41.3	0.36	Buhl and Hamilton	1990
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	24 h	LC50	Mortality (1)	0.22	41.3	0.45	Buhl and Hamilton	1990
	Rainbow trout	*Oncorhynchus mykiss*	Alevin	96 h	LC50	Mortality (1)	2.17	41.3	4.59	Buhl and Hamilton	1990
	Rainbow trout	*Oncorhynchus mykiss*	Alevin	24 h	LC50	Mortality (1)	3.12	41.3	6.60	Buhl and Hamilton	1990
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	24 h	LC50	Mortality (1)	1.56	36	3.71	Cairns et al.	1978

Table B.2: Detailed acute toxicity data for zinc. Lowest effect concentration for each species is highlighted.

Species Type	Species common name	Species latin name	Life stage	Duration	Endpoint	Observed effect	Effect concentration (mg/L)	Hardness	Effect Concentration (mg/L) at 100 mg/L Hardness [a]	Authors	Year
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	24 h	LC50	Mortality (1)	2.10	36	4.99	Cairns et al.	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	24 h	LC50	Mortality (1)	2.80	36	6.65	Cairns et al.	1978
	Rainbow trout	*Oncorhynchus mykiss*	parr	200 h	LC10	Mortality (1)	0.06	23	0.21	Chapman	1978
	Rainbow trout	*Oncorhynchus mykiss*	smolt	200 h	LC10	Mortality (1)	0.08	23	0.29	Chapman	1978
	Rainbow trout	*Oncorhynchus mykiss*	Swim-up fry	96 h	LC50	Mortality (1)	0.09	23	0.32	Chapman	1978
	Rainbow trout	*Oncorhynchus mykiss*	parr	200 h	LC50	Mortality (1)	0.12	23	0.42	Chapman	1978
	Rainbow trout	*Oncorhynchus mykiss*	parr	96 h	LC50	Mortality (1)	0.14	23	0.47	Chapman	1978
	Rainbow trout	*Oncorhynchus mykiss*	smolt	200 h	LC50	Mortality (1)	0.28	23	0.97	Chapman	1978
	Rainbow trout	*Oncorhynchus mykiss*	Alevin	96 h	LC50	Mortality (1)	0.82	23	2.83	Chapman	1978
	Rainbow trout	*Oncorhynchus mykiss*	Adult	96 h	LC50	Mortality (1)	1.76	83	2.06	Chapman and Stevens	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.07	9.2	0.50	Cusimano et al.	1986
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	7 d	LC50	Mortality (1)	0.07	9.2	0.50	Cusimano et al.	1986
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.10	9.2	0.73	Cusimano et al.	1986
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	7 d	LC50	Mortality (1)	0.10	9.2	0.73	Cusimano et al.	1986
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	7 d	LC50	Mortality (1)	0.50	9.2	3.78	Cusimano et al.	1986
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.67	9.2	5.07	Cusimano et al.	1986
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.13	29.1	0.37	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.17	30.23	0.47	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.19	29.1	0.55	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.21	29.6	0.59	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	1.47	190.35	0.85	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.55	29.1	1.56	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	1.17	105.49	1.12	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	2.56	398.56	0.79	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.61	29.1	1.74	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	1.51	29.1	4.30	De Schamphelaere and Janssen	2004
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.02	30.9	0.06	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.03	28.5	0.08	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.03	29.1	0.09	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.05	31.3	0.14	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.18	87.1	0.21	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.11	30.8	0.30	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.12	29.6	0.35	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	5 d	LC50	Mortality (1)	0.26	90	0.28	Hansen et al	2002
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.37	46.8	0.70	Holcombe and Andrew	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.52	47	0.98	Holcombe and Andrew	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.76	44.4	1.50	Holcombe and Andrew	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	1.91	169.7	1.22	Holcombe and Andrew	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	2.51	177.6	1.54	Holcombe and Andrew	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	2.96	179	1.81	Holcombe and Andrew	1978
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	Mortality (1)	0.28	5	3.54	McLeay	1976
	Rainbow trout	*Oncorhynchus mykiss*	Juvenile	24 h	LC50	Mortality (1)	1.24	5	15.70	McLeay	1976
	Rainbow trout	*Oncorhynchus mykiss*	Fry	96 h	LC50	Mortality (1)	0.13	24	0.44	Mebane et al	2008
	Rainbow trout	*Oncorhynchus mykiss*	Fry	96 h	LC50	Mortality (1)	0.12	16	0.55	Mebane et al	2008
	Rainbow trout	*Oncorhynchus mykiss*	Alevin	48 h	LC50	Mortality (1)	3.20	87.7	3.58	Shazili and Pascoe	1986
	Rainbow trout	*Oncorhynchus mykiss*	Alevin	48 h	LC50	Mortality (1)	3.40	87.7	3.80	Shazili and Pascoe	1986
	Rainbow trout	*Oncorhynchus mykiss*	Egg	48 h	LC50	Mortality (1)	4.30	87.7	4.81	Shazili and Pascoe	1986
	Rainbow trout	*Oncorhynchus mykiss*	Egg	48 h	LC50	Mortality (1)	7.00	87.7	7.82	Shazili and Pascoe	1986
	Rainbow trout	*Oncorhynchus mykiss*	Egg	48 h	LC50	Mortality (1)	9.10	87.7	10.17	Shazili and Pascoe	1986
	Rainbow trout	*Oncorhynchus mykiss*	Egg	48 h	LC50	Mortality (1)	9.20	87.7	10.28	Shazili and Pascoe	1986
	Rainbow trout	*Oncorhynchus mykiss*	Egg	48 h	LC50	Mortality (1)	24.00	87.7	26.82	Shazili and Pascoe	1986
	Rainbow trout	*Oncorhynchus mykiss*	Not reported	48 h	LC50	Mortality (1)	4.76	504	1.21	Solbé	1974
	Rainbow trout	*Oncorhynchus mykiss*	Not reported	101 h	LC50	Mortality (1)	4.76	504	1.21	Solbé	1974
	Rainbow trout	*Oncorhynchus mykiss*	Fingerling	96 h	LC50	Mortality (1)	0.56	14	2.96	Spry and Wood	1984
	Rainbow trout	*Oncorhynchus mykiss*	Fingerling	96 h	LC50	Mortality (1)	0.79	14	4.18	Spry and Wood	1984
	Sockeye salmon	*Oncorhynchus nerka*	Alevin	115 h	LC50	Mortality (1)	0.45	22	1.61	Chapman	1978
Fish	Sockeye salmon	*Oncorhynchus nerka*	parr	96 h	LC50	Mortality (1)	0.75	22	2.70	Chapman	1978
	Chinook salmon	*Oncorhynchus tshawytscha*	Juvenile	96 h	LC10	Mortality (1)	0.04	21	0.15	Finlayson and Verrue	1982
	Chinook salmon	*Oncorhynchus tshawytscha*	Juvenile	96 h	LC50	Mortality (1)	0.08	21	0.32	Finlayson and Verrue	1982
	Chinook salmon	*Oncorhynchus tshawytscha*	Fry	96 h	LC50	Mortality (1)	0.10	23	0.34	Chapman	1978
	Chinook salmon	*Oncorhynchus tshawytscha*	smolt	200 h	LC10	Mortality (1)	0.17	23	0.59	Chapman	1978
	Chinook salmon	*Oncorhynchus tshawytscha*	parr	200 h	LC10	Mortality (1)	0.30	23	1.04	Chapman	1978
	Chinook salmon	*Oncorhynchus tshawytscha*	smolt	200 h	LC50	Mortality (1)	0.36	23	1.26	Chapman	1978
	Chinook salmon	*Oncorhynchus tshawytscha*	parr	200 h	LC50	Mortality (1)	0.40	23	1.37	Chapman	1978
	Chinook salmon	*Oncorhynchus tshawytscha*	parr	96 h	LC50	Mortality (1)	0.46	23	1.61	Chapman	1978
	Chinook salmon	*Oncorhynchus tshawytscha*	smolt	96 h	LC50	Mortality (1)	0.70	23	2.44	Chapman	1978
	perch	*Perca fluviatilis*	Not reported	5 d	LC50	Mortality (1)	16.00	290	6.49	Ball	1967
	Fathead minnow	*Pimephales promelas*	Juvenile	96 h	LC50	Mortality (1)	2.61	220	1.34	Broderius and Smith	1979
	Fathead minnow	*Pimephales promelas*	Embryo	6 d	EC50	malformation	0.70	100	0.70	Dawson et al.	1988
	Fathead minnow	*Pimephales promelas*	Embryo	6 d	LOEC	Growth (1)	0.75	100	0.75	Dawson et al.	1988
	Fathead minnow	*Pimephales promelas*	Embryo	6 d	LC50	Mortality (1)	3.60	100	3.60	Dawson et al.	1988
	Fathead minnow	*Pimephales promelas*	Juvenile	96 h	LC50	Mortality (1)	3.10	45	6.10	Judy and Davies	1979
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	4.90	50	8.82	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	11.30	200	6.28	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	9.00	100	9.00	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	16.10	200	8.95	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	12.50	100	12.50	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	9.20	50	16.55	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	13.10	50	23.57	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	32.10	200	17.84	Mount	1966
	Fathead minnow	*Pimephales promelas*	Not reported	96 h	TLM	Mortality (1)	21.50	100	21.50	Mount	1966
	Fathead minnow	*Pimephales promelas*	Larva	96 h	LC50	Mortality (1)	0.25	47	0.48	Norberg-King	1989
	Fathead minnow	*Pimephales promelas*	Larva	96 h	LC50	Mortality (1)	0.31	47	0.59	Norberg-King	1989
	Fathead minnow	*Pimephales promelas*	Fry	96 h	TLM	Mortality (1)	0.87	186	0.51	Pickering and Vigor	1965
	Fathead minnow	*Pimephales promelas*	Fry	24 h	TLM	Mortality (1)	0.95	186	0.56	Pickering and Vigor	1965
	Fathead minnow	*Pimephales promelas*	Fry	48 h	TLM	Mortality (1)	0.95	186	0.56	Pickering and Vigor	1965
	Fathead minnow	*Pimephales promelas*	Egg	96 h	TLM	Mortality (1)	1.83	186	1.08	Pickering and Vigor	1965
	Fathead minnow	*Pimephales promelas*	Egg	48 h	TLM	Mortality (1)	2.44	186	1.44	Pickering and Vigor	1965
	Fathead minnow	*Pimephales promelas*	Less than 24hrs	96 h	LC50	Mortality (1)	0.33	290	0.13	Schubauer-Berigan et al.	1993
	Fathead minnow	*Pimephales promelas*	Less than 24hrs	96 h	LC50	Mortality (1)	0.50	390	0.16	Schubauer-Berigan et al.	1993
	Fathead minnow	*Pimephales promelas*	Less than 24hrs	96 h	LC50	Mortality (1)	0.78	290	0.32	Schubauer-Berigan et al.	1993
	Colorado Squawfish	*Ptychocheilus lucius*	Larva	96 h	LC50	Mortality (1)	3.34	199	1.86	Buhl and Hamilton	1996
	Colorado Squawfish	*Ptychocheilus lucius*	Juvenile	96 h	LC50	Mortality (1)	8.62	199	4.81	Buhl and Hamilton	1996
	Colorado Squawfish	*Ptychocheilus lucius*	Swim-up fry	96 h	LC50	Mortality (1)	1.70	196	0.96	Hamilton	1995
	Colorado Squawfish	*Ptychocheilus lucius*	Juvenile	96 h	LC50	Mortality (1)	4.30	196	2.43	Hamilton	1995
	Colorado Squawfish	*Ptychocheilus lucius*	Juvenile	96 h	LC50	Mortality (1)	12.00	196	6.79	Hamilton	1995
	Northern pikeminnow	*Ptychocheilus oregonensis*	Juvenile	168 h	LC50	Mortality (1)	2.95	25	9.54	Andros and Garton	1980
	Northern pikeminnow	*Ptychocheilus oregonensis*	Juvenile	168 h	LC50	Mortality (1)	3.65	25	11.81	Andros and Garton	1980
	Northern pikeminnow	*Ptychocheilus oregonensis*	Juvenile	96 h	LC50	Mortality (1)	3.69	25	11.95	Andros and Garton	1980
	Northern pikeminnow	*Ptychocheilus oregonensis*	Juvenile	96 h	LC50	Mortality (1)	3.70	25	11.97	Andros and Garton	1980
	longfin dace	*Rhinichthys chrysogaster*	Juvenile	96 h	LC50	Mortality (1)	0.79	217	0.41	Lewis	1978
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	0.46	205	0.25	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	0.64	205	0.35	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	0.22	21	0.83	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	1.00	205	0.54	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	2.02	205	1.10	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	2.69	205	1.46	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	3.20	205	1.74	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	0.60	11	3.89	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	1.41	21	5.29	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	1.07	11	6.94	Everall et al.	1989
	sea trout	*Salmo trutta*	Yearling	96 h	LC50	Mortality (1)	2.31	11	14.99	Everall et al.	1989
	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.03	29.1	0.09	Hansen et al	2002

Table B.2: Detailed acute toxicity data for zinc. Lowest effect concentration for each species is highlighted.

Species Type	Species common name	Species latin name	Life stage	Duration	Endpoint	Observed effect	Effect concentration (mg/L)	Hardness	Effect Concentration (mg/L) at 100 mg/L Hardness [a]	Authors	Year
Fish	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.04	28.5	0.10	Hansen et al	2002
	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.05	30.9	0.14	Hansen et al	2002
	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.08	31.3	0.21	Hansen et al	2002
	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.28	87.1	0.31	Hansen et al	2002
	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.17	30.8	0.45	Hansen et al	2002
	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.20	29.6	0.55	Hansen et al	2002
	Bull trout	*Salvelinus confluentus*	Juvenile	5 d	LC50	Mortality (1)	0.40	90	0.43	Hansen et al	2002
	Brook Trout	*Salvelinus fontinalis*	Juvenile	96 h	LC50	Mortality (1)	1.55	46.8	2.95	Holcombe and Andrew	1978
	Brook Trout	*Salvelinus fontinalis*	Juvenile	96 h	LC50	Mortality (1)	2.12	47	4.02	Holcombe and Andrew	1978
	Brook Trout	*Salvelinus fontinalis*	Juvenile	96 h	LC50	Mortality (1)	4.98	169.7	3.18	Holcombe and Andrew	1978
	Brook Trout	*Salvelinus fontinalis*	Juvenile	96 h	LC50	Mortality (1)	2.42	44.4	4.81	Holcombe and Andrew	1978
	Brook Trout	*Salvelinus fontinalis*	Juvenile	96 h	LC50	Mortality (1)	6.98	179	4.26	Holcombe and Andrew	1978
	Brook Trout	*Salvelinus fontinalis*	Embryo	6 h	NOEC	old) survival to	0.71	45.9	1.37	Holcombe et al.	1979
	Brook Trout	*Salvelinus fontinalis*	Embryo	6 h	LOEC	old) survival to	1.38	45.9	2.67	Holcombe et al.	1979
	Brook Trout	*Salvelinus fontinalis*	Embryo	6 h	LC50	old) survival to	2.94	45.9	5.68	Holcombe et al.	1979
	Arctic grayling	*Thymallus arcticus*	Juvenile	96 h	LC50	Mortality (1)	0.11	41.3	0.24	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	96 h	LC50	Mortality (1)	0.14	41.3	0.30	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	96 h	LC50	Mortality (1)	0.17	41.3	0.35	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	96 h	LC50	Mortality (1)	0.17	41.3	0.36	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	96 h	LC50	Mortality (1)	0.17	41.3	0.36	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	24 h	LC50	Mortality (1)	0.20	41.3	0.43	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	24 h	LC50	Mortality (1)	0.26	41.3	0.54	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Fry	96 h	LC50	Mortality (1)	0.32	41.3	0.67	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	24 h	LC50	Mortality (1)	0.41	41.3	0.88	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Alevin	96 h	LC50	Mortality (1)	1.58	41.3	3.34	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Fry	24 h	LC50	Mortality (1)	1.89	41.3	4.00	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Alevin	96 h	LC50	Mortality (1)	2.92	41.3	6.18	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Juvenile	24 h	LC50	Mortality (1)	4.70	41.3	9.94	Buhl and Hamilton	1990
	Arctic grayling	*Thymallus arcticus*	Alevin	24 h	LC50	Mortality (1)	5.14	41.3	10.87	Buhl and Hamilton	1990
	redbelly tilapia	*Tilapia zilli*	Juvenile	96 h	LC50	Mortality (1)	13.00	21	48.78	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	72 h	LC50	Mortality (1)	16.00	21	60.03	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	48 h	LC50	Mortality (1)	18.00	21	67.54	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	96 h	LC50	Mortality (1)	21.00	21	78.80	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	24 h	LC50	Mortality (1)	22.00	21	82.55	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	72 h	LC50	Mortality (1)	24.00	21	90.05	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	96 h	LC50	Mortality (1)	27.00	21	101.31	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	48 h	LC50	Mortality (1)	29.00	21	108.81	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	72 h	LC50	Mortality (1)	32.00	21	120.07	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	24 h	LC50	Mortality (1)	33.00	21	123.82	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	96 h	LC50	Mortality (1)	33.00	21	123.82	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	48 h	LC50	Mortality (1)	34.00	21	127.57	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	24 h	LC50	Mortality (1)	38.00	21	142.58	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	72 h	LC50	Mortality (1)	40.00	21	150.09	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	48 h	LC50	Mortality (1)	45.00	21	168.85	Hilmy et al.	1987
	redbelly tilapia	*Tilapia zilli*	Juvenile	24 h	LC50	Mortality (1)	49.00	21	183.86	Hilmy et al.	1987
	Razorback Sucker	*Xyrauchen texanus*	Juvenile	96 h	LC50	Mortality (1)	2.92	199	1.63	Buhl and Hamilton	1996
	Razorback Sucker	*Xyrauchen texanus*	Swim-up fry	96 h	LC50	Mortality (1)	4.10	196	2.32	Hamilton	1995
	Razorback Sucker	*Xyrauchen texanus*	Juvenile	96 h	LC50	Mortality (1)	6.50	196	3.68	Hamilton	1995
	Razorback Sucker	*Xyrauchen texanus*	Juvenile	96 h	LC50	Mortality (1)	16.00	196	9.05	Hamilton	1995
Invertebrate	Cladocerans	*Acroperus elongatus*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.61	250	0.74	Bossuyt et al	2005
	annelid	*Aeolosoma headleyi*	Not reported	48 h	LC50	Mortality (1)	13.50	45	26.56	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	24 h	LC50	Mortality (1)	14.20	45	27.93	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	48 h	LC50	Mortality (1)	15.00	45	29.51	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	24 h	LC50	Mortality (1)	15.60	45	30.69	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	48 h	LC50	Mortality (1)	15.60	45	30.69	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	24 h	LC50	Mortality (1)	16.00	45	31.47	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	48 h	LC50	Mortality (1)	17.60	45	34.62	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	48 h	LC50	Mortality (1)	18.10	45	35.61	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	24 h	LC50	Mortality (1)	18.30	45	36.00	Cairns et al.	1978
	annelid	*Aeolosoma headleyi*	Not reported	24 h	LC50	Mortality (1)	19.60	45	38.56	Cairns et al.	1978
	Rotifer	*Brachionus havanaensis*	Neonate	24 h	LC50	Mortality (1)	2.27	ND	-	Juarez-Franco et al	2007
	isopode	*Caecidotea bicrenata*	Not reported	96 h	LC50	Mortality (1)	20.22	220	10.37	Bosnak and Morgan	1981
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.07	113.6	0.06	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.11	182	0.06	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.07	97.6	0.07	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.12	182	0.07	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.15	182	0.09	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.10	97.6	0.10	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.12	113.6	0.11	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.11	97.6	0.11	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	LC50	Mortality (1)	0.13	113.6	0.12	Belanger et Cherry	1990
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.16	374	0.05	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.07	44	0.14	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.39	374	0.13	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.16	44	0.31	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.20	44	0.40	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.38	44	0.77	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.41	44	0.83	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.52	44	1.04	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.54	44	1.08	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.55	44	1.10	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.68	44	1.37	Hyne et al.	2005
	Cladocerans	*Ceriodaphnia dubia*	Not reported	48 h	LC50	Mortality (1)	0.50	190	0.29	Magliette et al.	1995
	Cladocerans	*Ceriodaphnia dubia*	Juvenile	48 h	EC50	Immobility (1 or 2)	0.67	280	0.28	Muyssen and Janssen	2002
	Cladocerans	*Ceriodaphnia dubia*	Less than 48h old	48 h	LC50	Mortality (1)	0.10	290	0.04	Schubauer-Berigan et al.	1993
	Cladocerans	*Ceriodaphnia dubia*	Less than 48h old	48 h	LC50	Mortality (1)	0.36	290	0.15	Schubauer-Berigan et al.	1993
	Cladocerans	*Ceriodaphnia dubia*	Neonate	48 h	LC50	Immobility (1 or 2)	0.26	ND	-	Shaw et al	2006
	Cladocerans	*Ceriodaphnia pulchella*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.26	250	0.58	Bossuyt et al	2005
	Cladocerans	*Ceriodaphnia pulchella*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	2.26	250	1.04	Bossuyt et al	2005
	Cladocerans	*Ceriodaphnia reticulata*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	0.94	250	0.43	Bossuyt et al	2005
	Cladocerans	*Ceriodaphnia reticulata*	Less than 4h	48 h	LC50	Mortality (1)	0.08	43	0.16	Mount and Norgberg	1984
	Cladocerans	*Chydorus ovalis*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.63	250	0.75	Bossuyt et al	2005
	Cladocerans	*Chydorus sphaericus*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.33	250	0.61	Bossuyt et al	2005
	Cladocerans	*Chydorus sphaericus*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	2.93	250	1.35	Bossuyt et al	2005
	Bivalve	*Corbicula fluminea*	Not reported	96 h	LC50	Mortality (1)	6.04	64	8.82	Rodgers et al.	1980
	Cladocerans	*Daphnia ambigua*	Neonate	48 h	LC50	Immobility (1 or 2)	0.30	ND	-	Shaw et al	2006
	Cladocerans	*Daphnia galeata*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.00	250	0.46	Bossuyt et al	2005
	Cladocerans	*Daphnia longispina*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.72	250	0.79	Bossuyt et al	2005
	Cladocerans	*Daphnia longispina*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	0.38	250	0.17	Bossuyt et al	2005
	Cladocerans	*Daphnia magna*	Juvenile	96 h	LC50	Mortality (1)	0.07	130	0.05	Attar and Maly	1982
	Cladocerans	*Daphnia magna*	Juvenile	72 h	LC50	Mortality (1)	0.13	130	0.10	Attar and Maly	1982
	Cladocerans	*Daphnia magna*	Juvenile	60 h	LC50	Mortality (1)	0.42	130	0.34	Attar and Maly	1982
	Cladocerans	*Daphnia magna*	Neonate	48 h	LC50	Immobility (1 or 2)	0.18	46.1	0.35	Barata et al.	1998
	Cladocerans	*Daphnia magna*	Neonate	48 h	LC50	Immobility (1 or 2)	0.71	179	0.43	Barata et al.	1998
	Cladocerans	*Daphnia magna*	Neonate	48 h	LC50	Immobility (1 or 2)	0.70	90.7	0.76	Barata et al.	1998
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	1.10	250	0.51	Berglind and Dave	1984
	Cladocerans	*Daphnia magna*	Less than 24hrs	24 h	EC50	Immobility (1 or 2)	3.00	250	1.38	Berglind and Dave	1984
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	LC50	Immobility (1 or 2)	0.10	49	0.18	Biesinger and Christensen	1972
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.65	250	1.22	Bossuyt et al	2005
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.91	250	1.34	Bossuyt et al	2005
	Cladocerans	*Daphnia magna*		48 h	LC50	Mortality (1)	0.28	45	0.55	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		48 h	LC50	Mortality (1)	0.56	45	1.10	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		24 h	LC50	Mortality (1)	0.79	45	1.55	Cairns et al.	1978

Table B.2: Detailed acute toxicity data for zinc. Lowest effect concentration for each species is highlighted.

Species Type	Species common name	Species latin name	Life stage	Duration	Endpoint	Observed effect	Effect concentration (mg/L)	Hardness	Effect Concentration (mg/L) at 100 mg/L Hardness [a]	Authors	Year
Invertebrate	Cladocerans	*Daphnia magna*		24 h	LC50	Mortality (1)	1.00	45	1.97	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		48 h	LC50	Mortality (1)	1.10	45	2.16	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		48 h	LC50	Mortality (1)	1.70	45	3.34	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		24 h	LC50	Mortality (1)	1.80	45	3.54	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		24 h	LC50	Mortality (1)	2.30	45	4.52	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		48 h	LC50	Mortality (1)	2.30	45	4.52	Cairns et al.	1978
	Cladocerans	*Daphnia magna*		24 h	LC50	Mortality (1)	2.80	45	5.51	Cairns et al.	1978
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	1.86	19.6	7.40	De Schamphelaere et al.	2004
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	1.99	19.6	7.92	De Schamphelaere et al.	2004
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.12	19.6	8.43	De Schamphelaere et al.	2004
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.18	19.6	8.67	De Schamphelaere et al.	2004
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.53	19.6	10.06	De Schamphelaere et al.	2004
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.69	19.6	10.70	De Schamphelaere et al.	2004
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.35	26.5	1.09	De Schamphelaere et al.	2005
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.14	250.5	0.98	De Schamphelaere et al.	2005
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	1.67	121.7	1.41	De Schamphelaere et al.	2005
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	0.36	13.8	1.91	De Schamphelaere et al.	2005
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.58	196.4	1.46	De Schamphelaere et al.	2005
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	2.26	122.4	1.90	De Schamphelaere et al.	2005
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	EC50	Immobility (1 or 2)	3.29	189.3	1.92	De Schamphelaere et al.	2005
	Cladocerans	*Daphnia magna*	4-6 d old	48 h	LC50	Mortality (1)	0.92	120	0.79	Hall et al.	1986
	Cladocerans	*Daphnia magna*	Juvenile	48 h	EC50	Immobility (1 or 2)	0.55	50	0.99	Heijerick et al.	2002
	Cladocerans	*Daphnia magna*	Juvenile	48 h	EC50	Immobility (1 or 2)	0.72	50	1.29	Heijerick et al.	2002
	Cladocerans	*Daphnia magna*	Juvenile	48 h	EC50	Immobility (1 or 2)	0.75	50	1.34	Heijerick et al.	2002
	Cladocerans	*Daphnia magna*	Juvenile	48 h	EC50	Immobility (1 or 2)	1.49	50	2.67	Heijerick et al.	2002
	Cladocerans	*Daphnia magna*	Not reported	48 h	LC50	Mortality (1)	1.22	190	0.71	Magliette et al.	1995
	Cladocerans	*Daphnia magna*	Less than 24hrs	48 h	LC50	Mortality (1)	0.15	50	0.27	Oikari et al.	1992
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.21	101.8	0.21	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.35	197	0.20	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.14	51.9	0.25	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.38	197	0.21	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.24	101.8	0.24	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.41	197	0.23	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.24	101.8	0.24	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.41	197	0.23	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.27	101.8	0.27	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.17	51.9	0.30	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Less than 24hrs	72 h	LC50	Mortality (1)	0.21	51.9	0.36	Paulauskis and Winner	1988
	Cladocerans	*Daphnia magna*	Neonate	48 h	LC50	Immobility (1 or 2)	0.82	ND	-	Shaw et al	2006
	Cladocerans	*Daphnia pulex*	Less than 24hrs	48 h	LC50	Mortality (1)	0.11	43	0.22	Mount and Norgberg	1984
	Cladocerans	*Daphnia pulex*		48 h	LC50	Mortality (1)	0.28	45	0.55	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		24 h	LC50	Mortality (1)	0.46	45	0.90	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		48 h	LC50	Mortality (1)	0.50	45	0.98	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		24 h	LC50	Mortality (1)	0.56	45	1.10	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		48 h	LC50	Mortality (1)	0.94	45	1.85	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		24 h	LC50	Mortality (1)	1.10	45	2.16	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		48 h	LC50	Mortality (1)	1.20	45	2.36	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		48 h	LC50	Mortality (1)	1.50	45	2.95	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		24 h	LC50	Mortality (1)	1.80	45	3.54	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*		24 h	LC50	Mortality (1)	2.16	45	4.25	Cairns et al.	1978
	Cladocerans	*Daphnia pulex*	Neonate	48 h	LC50	Immobility (1 or 2)	0.27	ND	-	Shaw et al	2006
	zebra mussel	*Dreissena polymorpha*	Adult	48 h	NOEC	Filtration rate	0.19	268	0.08	Kraak et al.	1994
	zebra mussel	*Dreissena polymorpha*	Adult	48 h	EC50	Filtration rate	0.56	268	0.24	Kraak et al.	1994
	zebra mussel	*Dreissena polymorpha*	Adult	48 h	EC50	Filtration rate	1.35	268	0.59	Kraak et al.	1994
	Scud	*Hyalella azteca*	7- to 14-d old	96 h	LC50	Mortality (1)	0.29	290	0.12	Schubauer-Berigan et al.	1993
	Scud	*Hyalella azteca*	7- to 14-d old	96 h	LC50	Mortality (1)	1.20	290	0.49	Schubauer-Berigan et al.	1993
	Scud	*Hyalella azteca*	7- to 14-d old	96 h	LC50	Mortality (1)	1.50	290	0.61	Schubauer-Berigan et al.	1993
	coelenterate	*Hydra oligactis*	Not reported	72 h	LC50	Mortality (1)	20.00	209.76	10.68	Karntanut and Pascoe	2002
	coelenterate	*Hydra oligactis*	Not reported	48 h	LC50	Mortality (1)	33.00	209.76	17.62	Karntanut and Pascoe	2002
	coelenterate	*Hydra viridissima*	Not reported	96 h	LC50	Mortality (1)	0.94	20	3.66	Holdway et al	2001
	coelenterate	*Hydra viridissima*	Not reported	96 h	LC50	Mortality (1)	11.00	209.76	5.87	Karntanut and Pascoe	2002
	coelenterate	*Hydra viridissima*	Not reported	72 h	LC50	Mortality (1)	16.00	209.76	8.54	Karntanut and Pascoe	2002
	coelenterate	*Hydra viridissima*	Not reported	48 h	LC50	Mortality (1)	28.00	209.76	14.95	Karntanut and Pascoe	2002
	coelenterate	*Hydra vulgaris*	Not reported	96 h	LC50	Mortality (1)	2.30	20	8.99	Holdway et al	2001
	coelenterate	*Hydra vulgaris*	Not reported	72 h	LC50	Mortality (1)	20.00	209.76	10.68	Karntanut and Pascoe	2002
	coelenterate	*Hydra vulgaris*	Not reported	48 h	LC50	Mortality (1)	25.00	209.76	13.35	Karntanut and Pascoe	2002
	coelenterate	*Hydra vulgaris*	Not reported	48 h	LC50	Mortality (1)	35.00	209.76	18.68	Karntanut and Pascoe	2002
	coelenterate	*Hydra vulgaris*	Not reported	24 h	LC50	Mortality (1)	49.00	209.76	26.16	Karntanut and Pascoe	2002
	isopode	*Lirceus alabamae*	Not reported	96 h	LC50	Mortality (1)	8.30	152	5.82	Bosnak and Morgan	1981
	Oligochaete	*Lumbriculus variegatus*	Not reported	96 h	LC50	Mortality (1)	6.30	30	17.47	Bailey and Liu	1980
	Oligochaete	*Lumbriculus variegatus*	Not reported	48 h	LC50	Mortality (1)	8.10	30	22.47	Bailey and Liu	1980
	Oligochaete	*Lumbriculus variegatus*	Not reported	24 h	LC50	Mortality (1)	9.10	30	25.24	Bailey and Liu	1980
	Snail	*Lymnaea luteola*	Adult	96 h	LC50	Mortality (1)	5.00	200	2.78	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	72 h	LC50	Mortality (1)	6.65	200	3.70	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	48 h	LC50	Mortality (1)	6.75	200	3.75	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	72 h	LC50	Mortality (1)	8.01	200	4.45	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	96 h	LC50	Mortality (1)	8.01	200	4.45	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	24 h	LC50	Mortality (1)	9.14	200	5.08	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	96 h	LC50	Mortality (1)	11.00	200	6.11	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	72 h	LC50	Mortality (1)	11.40	200	6.34	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	48 h	LC50	Mortality (1)	11.58	200	6.44	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	48 h	LC50	Mortality (1)	15.40	200	8.56	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	24 h	LC50	Mortality (1)	16.29	200	9.05	Khangarot and Ray	1987
	Snail	*Lymnaea luteola*	Adult	24 h	LC50	Mortality (1)	21.81	200	12.12	Khangarot and Ray	1987
	Cladocerans	*Moina macrocopa*	Neonate	24 h	LC50	Mortality (1)	2.04	ND	-	Wong	1992
	Cladocerans	*Moina macrocopa*	Neonate	48 h	LC50	Mortality (1)	1.17	ND	-	Wong	1992
	Snail	*Physa gyrina*	Adult	96 h	LC50	Mortality (1)	1.27	36	3.03	Nebeker et al.	1986
	Snail	*Physa heterostropha*	Not reported	96 h	LC50	Mortality (1)	3.46	165.2	2.26	Cairns and Scheier	1958
	Snail	*Physa heterostropha*	Not reported	96 h	LC50	Mortality (1)	0.82	50	1.48	Cairns and Scheier	1958
	Mayfly	*Rhithrogena hageni*	nymph	96 h	LC50	Mortality (1)	50.50	44.4	100.48	Brinkman and Johnston	2008
	Cladocerans	*Simocephalus exspinosus*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.50	250	0.69	Bossuyt et al	2005
	Cladocerans	*Simocephalus exspinosus*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	0.91	250	0.42	Bossuyt et al	2005
	Cladocerans	*Simocephalus vetulus*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	0.85	250	0.39	Bossuyt et al	2005
	Cladocerans	*Simocephalus vetulus*	Less than 48h old	48 h	EC50	Immobility (1 or 2)	1.04	250	0.48	Bossuyt et al	2005
	worm	*Tubifex tubifex*	Not reported	96 h	LC50	Immobility (1 or 2)	5.65	237	2.72	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	96 h	LC50	Mortality (1)	0.76	12	4.56	Rathore and Khangarot	2003
	worm	*Tubifex tubifex*	Not reported	72 h	LC50	Immobility (1 or 2)	9.16	237	4.41	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	96 h	LC50	Mortality (1)	7.95	173	5.00	Rathore and Khangarot	2003
	worm	*Tubifex tubifex*	Not reported	96 h	LC50	Immobility (1 or 2)	10.99	237	5.29	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	48 h	LC50	Immobility (1 or 2)	12.40	237	5.97	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	72 h	LC50	Immobility (1 or 2)	12.40	237	5.97	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	24 h	LC50	Immobility (1 or 2)	13.38	237	6.44	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	96 h	LC50	Immobility (1 or 2)	14.74	237	7.10	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	96 h	LC50	Mortality (1)	17.89	305	6.95	Rathore and Khangarot	2003
	worm	*Tubifex tubifex*	Not reported	72 h	LC50	Immobility (1 or 2)	17.15	237	8.26	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	48 h	LC50	Immobility (1 or 2)	17.83	237	8.58	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	96 h	LC50	Mortality (1)	5.72	45	11.26	Rathore and Khangarot	2003
	worm	*Tubifex tubifex*	Not reported	24 h	LC50	Immobility (1 or 2)	20.81	237	10.02	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	48 h	LC50	Immobility (1 or 2)	20.81	237	10.02	Rathore and Khangarot	2002
	worm	*Tubifex tubifex*	Not reported	24 h	LC50	Immobility (1 or 2)	23.67	237	11.39	Rathore and Khangarot	2002

[a] Values adjusted based on hardness using an acute hardness:toxicity slope factor of 0.8473 from USEPA (1987) and the equation: EXP(LN(EFFECT conc)-(0.8473)*(LN(measured water hardness)-LN(desired water hardness))).

Table B.3: Lowest effect endpoint reported for each freshwater species after a long-term exposure to zinc. See Table B.4 for test details and sources.

					Test Reported		Hardness-Adjusted Effect Concentration			
Species Common Name	**Scientific Name**	**Duration**	**Endpoint**	**Observed Effect**	**Hardness (mg/L)**	**Effect Concentration (mg/L)**	**Effect Concentration (mg/L) at 50 mg/L Hardness [a]**	**Effect Concentration (mg/L) at 100 mg/L Hardness [a]**	**Effect Concentration (mg/L) at 200 mg/L Hardness [a]**	**Effect Concentration (mg/L) at 300 mg/L Hardness [a]**
Green algae	*Pseudokirchneriella subcapitata*	7 d	EC10	Growth	NR	0.0011	0.0011	0.0011	0.0011	0.0011
Mayfly	*Epeorus latifolium*	4 weeks	IC10	emergence	83	0.0144	0.0094	0.0169	0.0303	0.0427
Water flea	*Ceriodaphnia dubia*	4 weeks	LOEC	Reproduction - Number of young per adult	97.6	0.025	0.014	0.026	0.046	0.065
Green alga	*Chlorella vulgaris*	72 h	EC50	biomass	NR	0.034	0.034	0.034	0.034	0.034
Water flea	*Daphnia magna*	50 d	MATC	Reproduction - Brood size	51.9	0.0217	0.0210	0.0378	0.0679	0.0957
Eurasian minnow	*Phoxinus phoxinus*	150 d	MATC	Growth	71	0.032	0.024	0.043	0.077	0.108
Zebra mussel	*Dreissena polymorpha*	10 weeks	EC50	Filtration rate	268	0.131	0.032	0.057	0.102	0.144
Mottled sculpin	*Cottus bairdi*	30 d	LC50	Mortality	48.6	0.032	0.033	0.059	0.106	0.149
Snail	*Potamopyrgus jenkinsi*	12 weeks	MATC	Growth	159	0.091	0.034	0.061	0.110	0.156
Chironomids	*Tanytarsus dissimilis*	10 d	LC50	Mortality	46.8	0.0368	0.0389	0.0700	0.1257	0.1772
Rotifer	*Brachionus havanaensis*	18 d	EC10	Population growth inhibition	NR	0.0782	0.0782	0.0782	0.0782	0.0782
Green alga	*Chlorella pyrenoidosa*	24 h	MATC	Cell density	25.51	0.0283	0.0500	0.0898	0.1615	0.2275
Fathead minnow	*Pimephales promelas*	NR	EC10	Eggs adhesiveness	46	0.0469	0.0503	0.0905	0.1626	0.2292
Rainbow trout	*Oncorhynchus mykiss*	30 d	LC10	Mortality	31.72	0.0345	0.0507	0.0911	0.1638	0.2309
Green algae	*Scenedesmus quadricauda*	15 d	IC10	Growth	NR	0.0961	0.0961	0.0961	0.0961	0.0961
Chironomids	*Chironomus riparius*	11 weeks	LOEC	Development	NR	0.100	0.100	0.100	0.100	0.100
Green hydra	*Hydra viridissima*	7 d	EC10	Population growth inhibition	20	0.0522	0.1134	0.2038	0.3664	0.5163
Chinook salmon	*Oncorhynchus tshawytscha*	200 h	LC10	Mortality	23	0.068	0.131	0.236	0.424	0.597
Amphipod	*Hyalella azteca*	7 d	LC50	Mortality	18	0.056	0.133	0.239	0.429	0.605
Duckweed	*Lemna minor*	7 d	IC10	Growth	NR	0.318	0.318	0.318	0.318	0.318
Brook Trout	*Salvelinus fontinalis*	24 w	MATC	egg fragility	45.9	0.174	0.187	0.336	0.604	0.852
Pink hydra	*Hydra vulgaris*	7 d	EC10	Population growth inhibition	20	0.1779	0.3863	0.6943	1.2481	1.7588
Common duckmeat	*Spirodela polyrrhiza*	4 d	IC50	Growth	NR	0.935	0.935	0.935	0.935	0.935
Cutthroat trout	*Oncorhynchus clarkii*	14 d	LC10	Mortality	40	0.453	0.547	0.983	1.768	2.491
Sea trout	*Salmo trutta*	14 d	LC10	Mortality	39	0.504	0.622	1.118	2.009	2.832
Bryozoan	*Pectinatella magnifica*	96 h	LC10	Mortality	205	2.286	0.693	1.245	2.239	3.155
Star duckweed	*Lemna trisulca*	14 d	EC50	final yield (oven dry weight)	20.37	0.327	0.699	1.256	2.258	3.183
Atlantic salmon	*Salmo salar*	14 d	LC50	Mortality	351	3.640	0.700	1.258	2.262	3.187
Snail	*Physa gyrina*	30 d	LC50	Mortality	36	0.771	1.018	1.830	3.289	4.635
Bryozoan	*Plumatella emarginata*	96 h	LC10	Mortality	205	3.474	1.053	1.893	3.402	4.794
Bryozoan	*Lophopodella carteri*	96 h	LC50	Mortality	205	4.093	1.241	2.230	4.008	5.649
Diatom	*Cyclotella meneghiniana*	5 d	LC10	Growth rate	121	2.803	1.327	2.386	4.288	6.043
Bluegill	*Lepomis macrochirus*	20 d	TLM	Mortality	370	11.300	2.078	3.736	6.715	9.463
Mayfly	*Rhithrogena hageni*	10 d	EC10	Mortality	44.4	2.069	2.288	4.113	7.392	10.417
Green alga	*Chlamydomonas sp.*	10 d	LC10	Growth rate	121	8.381	3.968	7.133	12.821	18.068
Crayfish	*Orconectes virilis*	14 d	LC10	Mortality	26	9.920	17.249	31.006	55.733	78.540

[a] If adjusted from another hardness, value was calculated using the following equation: EXP(LN(EFFECT conc)-(0.846)*(LN(measured water hardness)-LN(desired water hardness))) (Minnow 2010)

NR - not reported

Species not relevant at Faro

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Amphipod	*Hyalella azteca*	1 week	10 weeks	LOEC	Mortality	180	130	144	7.9-8.6	Borgmann et al	1993
Amphipod	*Hyalella azteca*	1 week	10 weeks	MATC	Mortality	134.16	130	107	7.9-8.6	Borgmann et al	1993
Amphipod	*Hyalella azteca*	1 week	10 weeks	NOEC	Mortality	100	130	80	7.9-8.6	Borgmann et al	1993
Amphipod	*Hyalella azteca*	1- 11 days	7 d	LC50	Mortality	56	18	239	6.44-8.68	Borgmann et al	2005
Amphipod	*Hyalella azteca*	1- 11 days	7 d	LC50	Mortality	70	18	299	6.44-8.68	Borgmann et al	2005
Amphipod	*Hyalella azteca*	1- 11 days	7 d	LC50	Mortality	222	124	185	7.23-8.98	Borgmann et al	2005
Atlantic salmon	*Salmo salar*	parr	14 d	LC50	Mortality	3640	351	1258	7.6	Hodson and Sprague	1975
Atlantic salmon	*Salmo salar*	parr	14 d	LC50	Mortality	5046	351	1744	7.6	Hodson and Sprague	1975
Atlantic salmon	*Salmo salar*	parr	14 d	LC50	Mortality	5198	351	1797	7.6	Hodson and Sprague	1975
Bluegill	*Lepomis macrochirus*	Not reported	20 d	TLM	Mortality	11300	370	3736	7.8 (7.7-8.0)	Pickering	1968
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	EC10	Hatching success	418	45.9	808	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	IC10	egg fragility	200	45.9	386	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	8 weeks	LC10	Embryo (6 hours old) survival to hatch	1114	45.9	2153	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	LC10	Mortality	1215	45.9	2348	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	LOEC	egg fragility	266	45.9	514	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	LOEC	Hatching success	534	45.9	1032	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	LOEC	Mortality	1382	45.9	2671	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	LOEC	Mortality	2099	45.9	4056	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	LOEC	Mortality	1382	45.9	2671	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	MATC	egg fragility	174	45.9	336	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	8 weeks	MATC	Embryo (6 hours old) survival to hatch	990	45.9	1913	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	MATC	Hatching success	377	45.9	729	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	MATC	Mortality	990	45.9	1913	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	MATC	Mortality	1000	45.9	1932	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	MATC	Mortality	1685	45.9	3256	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	NOEC	egg fragility	114	45.9	220	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	NOEC	Hatching success	266	45.9	514	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	NOEC	Mortality	709	45.9	1370	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	NOEC	Mortality	1353	45.9	2615	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	NOEC	Mortality	724	45.9	1399	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	IC25	Growth	486.61		487		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	LC50	survival	798.91		799		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	LOEC	Growth	500		500		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	LOEC	survival	594.6		595		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	MATC	survival	443		443		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	NOEC	Growth	287.17		287		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	NOEC	survival	329.87		330		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	Juvenile	14 d	LC10	Mortality	445		445	7.3	Nehring and Goettl	1974
Brook Trout	*Salvelinus fontinalis*	Juvenile	14 d	LC50	Mortality	960		960	7.3	Nehring and Goettl	1974
Bryozoan	*Lophopodella carteri*	2-3 days	96 h	LC50	Mortality	4093	205	2230	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Lophopodella carteri*	2-3 days	96 h	LC50	Mortality	5630	205	3067	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Pectinatella magnifica*	2-3 days	96 h	LC10	Mortality	2286	205	1245	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Pectinatella magnifica*	2-3 days	96 h	LC50	Mortality	4310	205	2348	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Plumatella emarginata*	2-3 days	96 h	LC10	Mortality	3474	205	1893	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Plumatella emarginata*	2-3 days	96 h	LC50	Mortality	5300	205	2888	6.7-7.0	Pardue and Wood	1980
Chinook salmon	*Oncorhynchus tshawytscha*	Alevin	200 h	LC10	Mortality	364-661	23	1262-2292	7.1	Chapman	1978
Chinook salmon	*Oncorhynchus tshawytscha*	Fry	200 h	LC10	Mortality	68	23	236	7.1	Chapman	1978
Chinook salmon	*Oncorhynchus tshawytscha*	Fry	200 h	LC50	Mortality	97	23	336	7.1	Chapman	1978
Chironomid	*Chironomus riparius*	1st instar	11 weeks	LOEC	Development	100		100	7.3-7.7	Timmermans et al.	1992
Chironomid	*Tanytarsus dissimilis*	Larva	10 d	LC50	Mortality	36.8	46.8	70	7.3- 7.7	Anderson et al	1980
Common duckmeat	*Spirodela polyrrhiza*	Adult	4 d	IC50	Growth	935	ND	935		Gaur et al.	1994
crayfish	*Orconectes virilis*	Adult	14 d	LC10	Mortality	9920	26	31006	7.1	Mirenda	1986

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
crayfish	*Orconectes virilis*	Adult	14 d	LC50	Mortality	84000	26	262550	7.1	Mirenda	1986
Cutthroat trout	*Oncorhynchus clarkii*	Juvenile	14 d	LC10	Mortality	453	40	983	7.2	Nehring and Goettl	1974
Cutthroat trout	*Oncorhynchus clarkii*	Juvenile	14 d	LC50	Mortality	670	40	1455	7.2	Nehring and Goettl	1974
Diatom	*Cyclotella meneghiniana*	Population	5 d	LC10	Growth rate	10689	121	9097	6.8	Cairns et al.	1978
Diatom	*Cyclotella meneghiniana*	Population	5 d	LC10	Growth rate	2803	121	2386	6.8	Cairns et al.	1978
Diatom	*Cyclotella meneghiniana*	Population	5 d	LC10	Growth rate	5716	121	4865	6.8	Cairns et al.	1978
Duckweed	*Lemna minor*	Adult	7 d	IC10	Growth	318		318	6.30-6.40	Dirilgen and Inel	1994
Duckweed	*Lemna minor*	Not reported	7 d	EC50	Growth	3014.48		3014	5.5 +/- 0.2	Drost et al	2007
Duckweed	*Lemna minor*	Not reported	7 d	EC10	Growth	1379.05		1379	6	Ince et al	1999
Duckweed	*Lemna minor*	Not reported	7 d	EC50	Growth	9600		9600	6	Ince et al	1999
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	LC10	Mortality	102	71	136	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	30 d	LOEC	Growth	200	71	267	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	150 d	LOEC	Growth	200	71	267	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	30 d	LOEC	Growth	130	71	174	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	LOEC	Growth	50	71	67	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	30 d	MATC	Growth	161	71	215	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	150 d	MATC	Growth	161	71	215	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	30 d	MATC	Growth	81	71	108	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	MATC	Growth	32	71	43	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	30 d	NOEC	Growth	130	71	174	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	150 d	NOEC	Growth	130	71	174	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	30 d	NOEC	Growth	50	71	67	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	NOEC	Growth	20	71	27	7.1-8.2	Bengtsson	1974
Fathead minnow	*Pimephales promelas*	Egg	NR	EC10	Eggs adhesiveness	46.9	46	90	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	LOEC/L	Eggs adhesiveness	145	46	280	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	LOEC/L	Hatching success	295	46	569	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	LOEC/L	Mortality	295	46	569	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	MATC	Eggs adhesiveness	106	46	204	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	MATC	Hatching success	207	46	399	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	MATC	Mortality	207	46	399	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	NOEC/L	Eggs adhesiveness	78	46	150	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	NOEC/L	Hatching success	145	46	280	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	NOEC/L	Mortality	145	46	280	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Larva	7 d	ChV	Growth	430	190	250	8.3-8.7	Magliette et al.	1995
Fathead minnow	*Pimephales promelas*	Larva	7 d	LC50	Mortality	780	190	453	8.3-8.7	Magliette et al.	1995
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC/L	Growth	630	190	366	8.3-8.7	Magliette et al.	1995
Fathead minnow	*Pimephales promelas*	Larva	7 d	IC10	Growth	83.9	48	156		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Growth	374	48	696		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Mortality	184	48	342		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	MATC	Growth	262	48	487		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	MATC	Mortality	125	48	233		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Growth	184	48	342		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Mortality	84.6	48	157		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	ChV	Growth	184	47	349	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	ChV	Growth	315	47	597	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	32 d	ChV	Mortality	188	47	356	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LC50	Mortality	250	47	474	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LC50	Mortality	283	47	536	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Growth	278	47	527	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Growth	454	47	860	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	32 d	LOEC	Mortality	275	47	521	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Growth	122	47	231	7.4-8.2	Norberg-King	1989

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Growth	218	47	413	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	32 d	NOEC	Mortality	129	47	244	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Egg	12 d	NOEC	Mortality	1050	186	621	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Fry	7 d	NOEC	Mortality	560	186	331	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Egg	7 d	TLM	Mortality	1690	186	1000	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Egg	12 d	TLM	Mortality	1630	186	964	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Fry	7 d	TLM	Mortality	870	186	515	7.5-7.6	Pickering and Vigor	1965
Green alga	*Chlamydomonas sp.*	Population	10 d	LC10	Growth rate	8381	121	7133	6.8	Cairns et al.	1978
Green alga	*Chlamydomonas sp.*	Population	10 d	LC10	Growth rate	9398	121	7998	6.8	Cairns et al.	1978
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	EC50	Growth	57	25.51	181		Lin et al	2007
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	LOEC	Cell density	40	25.51	127		Lin et al	2007
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	MATC	Cell density	28.28	25.51	90		Lin et al	2007
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	NOEC	Cell density	20	25.51	64		Lin et al	2007
Green alga	*Chlorella vulgaris*	exponential growth phase	72 h	EC50	biomass	34		34		Muyssen and Janssen	2001
Green alga	*Chlorella vulgaris*	exponential growth phase	72 h	EC50	Growth	153		153		Muyssen and Janssen	2001
Green alga	*Pseudokirchneriella subcapitata*	Not reported	24 h	EC50	Growth	15		15		Chen et al	1997
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC50	Growth	178		178		Chen et al	1997
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC10	Growth	1.05		1.1	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC10	Growth	1.32		1.3	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC10	Growth	11.74		12	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC10	Growth	13.48		13	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC50	Growth	4.1		4.1	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC10	Growth	13.48		13	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC50	Growth	4.1		4.1	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC50	Growth	4.4		4.4	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC50	Growth	27		27	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC50	Growth	32		32	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	58.1	19.6	231	8	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	62.3	19.6	247	8	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	71.2	19.6	283	8	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	85	19.6	337	7	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	131	19.6	520	7	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	142	19.6	564	6	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	142	19.6	564	7	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	191	19.6	758	6	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	215	19.6	853	6	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	biomass	4.12	40	8.9	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	biomass	32.7	40	71	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	biomass	39.24	40	85	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	Growth rate	11.12	40	24	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	Growth rate	45.13	40	98	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	Growth rate	68.68	40	149	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	10.5	24.4	35	7.8	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	15.8	24.4	52	7.7	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	21.1	24.4	70	7.65	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	26.4	24.4	87	7.3	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	26.4	24.4	87	7.4	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	29	24.4	96	7.6	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	47.5	24.4	157	7.1	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	94.8	24.4	313	6.8	Heijerick et al.	2002

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	119	24.4	392	6.2	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	224	24.4	739	5.6	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	8.44	37.2	19	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	10.5	37.2	24	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	10.9	62.3	16	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	11.1	62.3	17	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	14.9	112.3	14	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	27.9	112.3	25	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	15.4	162.3	10	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	33.2	162.3	22	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	17.5	212.4	9	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	34.4	212.4	18	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	54.9	262.6	24	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	exponential growth phase	72 h	EC50	biomass	39		39		Muyssen and Janssen	2001
Green alga	*Pseudokirchneriella subcapitata*	exponential growth phase	72 h	EC50	Growth	138		138		Muyssen and Janssen	2001
Green alga	*Pseudokirchneriella subcapitata*	Not reported	48 h	EC50	Growth	96	130	77	7.8-8.8	Pardos et al	1998
Green alga	*Scenedesmus quadricauda*	Population	5 d	LC10	Growth rate	10451	121	8894	6.8	Cairns et al.	1978
Green alga	*Scenedesmus quadricauda*	Population	5 d	LC10	Growth rate	9559	121	8135	6.8	Cairns et al.	1978
Green alga	*Scenedesmus quadricauda*	Population	15 d	IC10	Growth	96.1		96	4.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	LOEC	Growth	225		225	6.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	LOEC	Growth	500		500	8.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	15 d	LOEC	Growth	100		100	4.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	MATC	Growth	150		150	6.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	MATC	Growth	335		335	8.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	NOEC	Growth	100		100	6.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	NOEC	Growth	225		225	8.5	Starodub et al.	1987
Green hydra	*Hydra viridissima*	Not reported	7 d	EC10	Population growth inhibition	52.23	20	204	7.25-7.53	Holdway et al	2001
Green hydra	*Hydra viridissima*	Not reported	7 d	LOEC	Population growth inhibition	75	20	293	7.25-7.53	Holdway et al	2001
Green hydra	*Hydra viridissima*	Not reported	7 d	MATC	Population growth inhibition	53.4	20	208	7.25-7.53	Holdway et al	2001
Green hydra	*Hydra viridissima*	Not reported	7 d	NOEC	Population growth inhibition	38	20	148	7.25-7.53	Holdway et al	2001
Mayfly	*Epeorus latifolium*	Larva	4 weeks	IC10	emergence	14.4	83	17	7.9-8.0	Hatakeyama	1989
Mayfly	*Epeorus latifolium*	Larva	4 weeks	LC10	Mortality	15	83	18	7.9-8.0	Hatakeyama	1989
Mayfly	*Rhithrogena hageni*	nymph	10 d	EC10	Mortality	2069.2	44.4	4113	7.77	Brinkman and Johnston	2008
Mayfly	*Rhithrogena hageni*	nymph	10 d	LOEC	Mortality	10800	44.4	21465	7.77	Brinkman and Johnston	2008
Mayfly	*Rhithrogena hageni*	nymph	10 d	MATC	Mortality	7565.71	44.4	15037	7.77	Brinkman and Johnston	2008
Mayfly	*Rhithrogena hageni*	nymph	10 d	NOEC	Mortality	5300	44.4	10534	7.77	Brinkman and Johnston	2008
Mixed invertebrates	N/A	Population	14 d	LOEC	Community similarity	17.1	135	13		Marshall et al.	1983
Mixed invertebrates	N/A	Population	14 d	LOEC	Primary productivity	17.1	135	13		Marshall et al.	1983
Mixed invertebrates	N/A	Population	14 d	LOEC	Specific zooplanton populations	17.1	135	13		Marshall et al.	1983
Mixed invertebrates	N/A	Population	14 d	LOEC	Zooplanction species diversity	17.1	135	13		Marshall et al.	1983
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	EC10	Mortality	155.7	154	108	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	LOEC	Mortality	379	154	263	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	MATC	Mortality	255	154	177	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	NOEC	Mortality	172	154	119	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	newly emerged	30 d	LC50	Mortality	32	48.6	59	7.38 (7.2-7.6)	Woodling et al	2002
Pink hydra	*Hydra vulgaris*	Not reported	7 d	EC10	Population growth inhibition	177.93	20	694	7.25-7.53	Holdway et al	2001
Pink hydra	*Hydra vulgaris*	Not reported	7 d	LOEC	Population growth inhibition	250	20	976	7.25-7.53	Holdway et al	2001
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	LC10	Mortality	458	25	1480	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	LOEC	Mortality	819	25	2646	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	MATC	Mortality	603	25	1948	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	NOEC	Mortality	444	25	1435	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Alevin	186 h	LC10	Mortality	256	23	888	7.1	Chapman	1978

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Rainbow trout	*Oncorhynchus mykiss*	Swim-up fry	200 h	LC10	Mortality	54	23	187	7.1	Chapman	1978
Rainbow trout	*Oncorhynchus mykiss*	Alevin	186 h	LC50	Mortality	555	23	1924	7.1	Chapman	1978
Rainbow trout	*Oncorhynchus mykiss*	Swim-up fry	200 h	LC50	Mortality	93	23	322	7.1	Chapman	1978
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	312	29.1	887	5.68	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	46.1	29.1	131	7.65	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	73.6	29.1	209	7.58	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	99.1	29.1	282	6.78	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	38.4	29.6	108	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	34.5	31.72	91	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	171	104.99	164	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	290	190.35	168	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	337	398.68	105	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>1280	29.1	>3637	6.7	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>1280	29.1	>3637	7.74	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>1740	29.1	>4944	7.58	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>800	29.1	>2273	5.68	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	345	29.1	980	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>375	29.6	>1050	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	2310	29.6	6470	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	162	29.1	460	7.65	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	166	29.1	472	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	117	29.6	328	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	2310	29.6	6470	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Growth	166	29.1	472	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Growth	974	29.6	2728	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	45.4	29.1	129	7.73	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	78.9	29.1	224	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	31.5	29.6	88	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	974	29.6	2728	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	259	23.4	885	6.15	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	185	28.2	540	6.8	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	219	31.5	582	7.08	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	902	103.7	875	7.76	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	578	176.3	358	8.13	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	582	23.4	1989	6.15	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	406	28.2	1185	6.8	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	337	31.5	895	7.08	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	1970	103.7	1910	7.76	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	1850	176.3	1145	8.13	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	370	23.4	1264	6.15	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	324	28.2	945	6.8	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	199	31.5	529	7.08	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	771	103.7	748	7.76	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	696	176.3	431	8.13	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	IC25	Growth	148.03		148		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	LC50	survival	195.38		195		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	LOEC	Growth	250		250		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	LOEC	survival	250		250		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	MATC	survival	177		177		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	NOEC	Growth	114.63		115		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	NOEC	survival	125		125		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC10	Length	300	19.7	1186	6.75 +/- 0.4	Mebane et al	2008

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Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC10	Mortality	88	19.7	348	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC10	Weight	199	19.7	787	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC20	Mortality	147	19.7	581	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC20	Weight	387	19.7	1530	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	LOEC	Length	365	19.7	1443	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	LOEC	Mortality	117	19.7	462	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	LOEC	Weight	365	19.7	1443	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	MATC	Length	279	19.7	1103	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	MATC	Weight	279	19.7	1103	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	NOEC	Length	214	19.7	846	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	NOEC	Weight	214	19.7	846	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	14 d	LC10	Mortality	318	37	737	7.3	Nehring and Goettl	1974
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	14 d	LC50	Mortality	410	37	951	7.3	Nehring and Goettl	1974
Rainbow trout	*Oncorhynchus mykiss*	Fingerling	22 months	LOEC/L	Mortality	640	333	231	7.81	Sinley et al.	1974
Rainbow trout	*Oncorhynchus mykiss*	Fingerling	22 months	MATC	Mortality	453	333	164	7.81	Sinley et al.	1974
Rainbow trout	*Oncorhynchus mykiss*	Fingerling	22 months	NOEC/L	Mortality	320	333	116	7.81	Sinley et al.	1974
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	EC10	Population growth inhibition	78.2		78	7.1-7.3	Juarez-Franco et al	2007
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	LOEC	Population growth inhibition	141.94		142	7.1-7.3	Juarez-Franco et al	2007
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	MATC	Population growth inhibition	100.36		100	7.1-7.3	Juarez-Franco et al	2007
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	NOEC	Population growth inhibition	70.96		71	7.1-7.3	Juarez-Franco et al	2007
Sea trout	*Salmo trutta*	Juvenile	14 d	LC10	Mortality	504	39	1118	7.2	Nehring and Goettl	1974
Sea trout	*Salmo trutta*	Juvenile	14 d	LC50	Mortality	640	39	1420	7.2	Nehring and Goettl	1974
Snail	*Physa gyrina*	Adult	30 d	LC50	Mortality	771	36	1830	6.9	Nebeker et al.	1986
Snail	*Physa gyrina*	Adult	30 d	NOEC/L	Mortality	570	36	1353	6.9	Nebeker et al.	1986
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	EC50	Growth	103	159	70	7.8-8.2	Dorgelo et al.	1995
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	LOEC	Growth	115	159	78	7.8-8.2	Dorgelo et al.	1995
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	MATC	Growth	91	159	61	7.8-8.2	Dorgelo et al.	1995
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	NOEC	Growth	72	159	49	7.8-8.2	Dorgelo et al.	1995
Star duckweed	*Lemna trisulca*	Not reported	14 d	EC50	final yield (oven dry weight)	327	20.37	1256	7.8-8.3 +/- 0.3	Huebert and Shay	1992
Star duckweed	*Lemna trisulca*	Not reported	14 d	EC50	multiplication rate (number of fronds)	915.6	20.37	3518	7.8-8.3 +/- 0.3	Huebert and Shay	1992
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	25	97.6	26	6	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	25	97.6	26	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	50	97.6	51	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	100	113.6	90	6, 8, 9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	100	182	60	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	50	182	30	6	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	MATC	Reproduction - Number of young per adult	35	97.6	36	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	MATC	Reproduction - Number of young per adult	71	113.6	64	6, 8, 9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	MATC	Reproduction - Number of young per adult	71	182	43	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	25	97.6	26	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	50	113.6	45	6, 8, 9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	100	182	60	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	50	182	30	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	60-84 h	96 h	ChV	Mortality	70	169	45	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	7 d	ChV	Mortality	90	169	58	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	60-84 h	96 h	ChV	Reproduction - Brood size	45	169	29	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	7 d	ChV	Reproduction - Brood size	105	169	67	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	Juvenile	9 d	EC50	Immobility	354	280	148	7.8	Muyssen and Janssen	2002
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC16	Repro - Number of young per survivor	70	49	128	7.4-8.2	Biesinger and Christensen	1972
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Repro - Number of young per survivor	102	49	187	7.4-8.2	Biesinger and Christensen	1972
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LC50	Immobility	158	49	289	7.4-8.2	Biesinger and Christensen	1972
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	92.1	26.5	283	7.3	De Schamphelaere et al.	2005

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	378	122.4	319	6.8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	59.2	124.7	49	8.4	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	265	183.2	159	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	171	189.3	100	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	126	196.4	71	8.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	196	250.5	90	7.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	112	26.5	344	7.3	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	536	122.4	452	6.8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	171	124.7	142	8.4	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	473	183	284	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	313	189	183	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	242	196.4	137	8.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	299	250.5	137	7.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	62.6	13.8	334	6	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	94.5	26.5	291	7.3	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	491	122.4	414	6.8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	72.7	124.7	60	8.4	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	251	183	151	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	244	189.3	142	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	143	196.4	81	8.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	155	250.5	71	7.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Population	21 d	EC10	Population growth inhibition	420	225	211	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Population	21 d	EC50	Population growth inhibition	570	225	287	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LC50	Mortality	840	225	423	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LOEC	Length	120	225	60	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LOEC	Mortality	1000	225	504	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LOEC	Repro - Number of young per survivor	1000	225	504	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	328	35	797	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	233	110	215	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	277	110	256	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	313	110	289	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	557	110	514	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	179	240	85	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	308	240	147	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	331	240	158	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	394	240	188	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	502	240	239	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	634	240	302	8.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	911	240	434	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	423	240	202	6	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	114	370	38	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	341	370	113	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	600	370	198	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	90	370	30	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	445	35	1082	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	209	110	193	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	110	295	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	445	110	411	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	110	581	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	1000	240	477	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	209	240	100	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	240	153	7.25	Heijerick et al.	2003

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	575	240	274	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	575	240	274	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	240	300	8.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	425	240	203	6	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	370	106	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	370	106	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	370	208	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	370	208	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	196	50	352	7	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	202	50	363	6.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	218	50	392	6	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	233	50	419	7.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	239	50	430	5.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	262	50	471	8	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	117	50	210	8	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	133	50	239	7.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	154	50	277	7	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	161	50	289	5.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	162	50	291	6.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	168	50	302	6	Heijerick et al.	2005
Water flea	*Daphnia magna*	Less than 48h old	21 d	IC10	Reproduction - Number of young per adult	67.6	64.9	97	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	LOEC	Mortality	150	64.9	216	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	LOEC	Reproduction - Number of young per adult	150	64.9	216	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	MATC	Mortality	122	64.9	176	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	MATC	Reproduction - Number of young per adult	122	64.9	176	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	NOEC	Mortality	100	64.9	144	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	NOEC	Reproduction - Number of young per adult	100	64.9	144	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	29.8	51.9	52	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	32.8	51.9	57	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	55.7	51.9	97	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	65.8	101.8	65	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	158	197	89	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	214	197	121	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	111.8	51.9	195	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	120.2	51.9	209	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	86.6	51.9	151	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	124.4	101.8	123	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	178.7	197	101	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	237.2	197	134	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	21.7	51.9	38	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	99.2	51.9	173	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	86.6	101.8	85	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	174.6	197	98	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	224.7	197	127	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	112.5	51.9	196	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	120.8	51.9	210	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	87.5	51.9	152	8.39	Paulauskis and Winner	1988

Table B.4: Detailed long-term effects of zinc on a variety of aquatic organisms (Minnow 2010).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [a]	pH	Authors (as cited in Minnow 2010)	Year
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	125	101.8	123	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	179.2	197	101	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	237.5	197	134	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	100	51.9	174	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	25	51.9	44	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	87.5	101.8	86	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	175	197	99	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	225	197	127	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	134 d	LOEC	Growth	100	145	73	8.2-9.5	Winner	1981
Water flea	*Daphnia magna*	Less than 24hrs	134 d	LOEC	Reproduction - Brood size	300	145	219	8.2-9.5	Winner	1981
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	EC50	Filtration rate	131	268	57	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	LC10	Mortality	517	268	225	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	LC50	Mortality	1065	268	463	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	LOEC	Filtration rate	382	268	166	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	MATC	Filtration rate	196	268	85	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	NOEC	Filtration rate	101	268	44	7.9	Kraak et al.	1994

[a] If adjusted from another hardness, value was calculated using the following equation: EXP(LN(EFFECT conc)-(0.846)*(LN(measured water hardness)-LN(desired water hardness))) (Minnow 2010)

most sensitive effect end-point

Table B.5: Data used to develop hardness-zinc toxicity relationships for long-term exposures to zinc (Minnow 2010).

Family	Species Common Name	Scientific Name	Duration	Endpoint	Life Stage	Observed Effect	Test Hardness (mg/L)	Effect Concentration (µg/L)	Mean Effect Concentration if Applicable (ug/L)	pH	Author(s)	Year
Algae	Green Algae	*Pseudokirchneriella subcapitata*	72 h	EC50	Population	biomass	212.4	17.5	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	212.4	34.4	←	7.5	Heijerick et al.	2002
				Mean EC50					24.5			
			72 h	EC50	Population	biomass	162.3	15.4	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	162.3	33.2	←	7.5	Heijerick et al.	2002
				Mean EC50					22.6			
			72 h	EC50	Population	biomass	112.3	14.9	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	112.3	27.9	←	7.5	Heijerick et al.	2002
				Mean EC50					20.4			
			72 h	EC50	Population	biomass	62.3	10.9	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	62.3	11.1	←	7.5	Heijerick et al.	2002
				Mean EC50					11.0			
			72 h	EC50	Population	biomass	37.2	8.44	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	37.2	10.5	←	7.5	Heijerick et al.	2002
				Mean EC50					9.41			
			72 h	EC50	Population	biomass	262.6	54.9		7.5	Heijerick et al.	2002
Invertebrates	Water Flea	*Daphnia magna*	21 d	EC10	< 24 hrs	Reproduction - # young / adult	196.4	126		8.2	De Schamphelaere et al.	2005
			21 d	EC10	< 24 hrs	Reproduction - # young / adult	189.3	171		8	De Schamphelaere et al.	2005
			21 d	EC10	< 24 hrs	Reproduction - # young / adult	183.2	265		8	De Schamphelaere et al.	2005
			21 d	EC10	< 24 hrs	Reproduction - # young / adult	124.7	59.2		8.4	De Schamphelaere et al.	2005
			21 d	EC10	Not reported	Reproduction (1)	110	233	←	8	Heijerick et al.	2003
			21 d	EC10	Not reported	Reproduction (1)	110	557	←	8	Heijerick et al.	2003
				Mean EC10					360			
			21 d	EC10	Not reported	Reproduction (1)	240	634		8.5	Heijerick et al.	2003
			21 d	EC10	Not reported	Reproduction (1)	370	600	←	8	Heijerick et al.	2003
			21 d	EC10	Not reported	Reproduction (1)	370	90	←	8	Heijerick et al.	2003
				Mean EC10					232			
			50 d	IC10	< 24 hrs	Reproduction - Brood size	51.9	29.8	←	8.39	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	51.9	32.8	←	8.39	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	51.9	55.7	←	8.39	Paulauskis and Winner	1988
				Mean IC10					37.9			
			50 d	IC10	< 24 hrs	Reproduction - Brood size	101.8	65.8		8.32	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	197	158	←	8.29	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	197	214	←	8.29	Paulauskis and Winner	1988
				Mean IC10					184			
			21 d	EC10	Population	Population growth inhibition	225	420		8.1	Enserink et al.	1991
			21 d	EC16	< 24 hrs	Reproduction - Number of young per survivor	49	70		7.4-8.2	Biesinger and Christensen	1972
				IC10	< 48 hrs	Reproduction - Number of young per adult	64.9	67.6		7.6-7.8	Münzinger and Monicelli	1991
		Ceriodaphnia dubia	7 d	ChV	24hrs	Reproduction - Brood size	169	105		7.8-8.2	Masters et al.	1991
			4 weeks	MATC	< 24 hrs	Reproduction - Number of young per adult	97.6	35	←	9	Belanger et Cherry	1990
			4 weeks	MATC	< 24 hrs	Reproduction - Number of young per adult	113.6	71	←	6, 8, 9	Belanger et Cherry	1990
			4 weeks	Mean MATC	24hrs	Reproduction- Number of young per adult	106		50			
			4 weeks	MATC	24hrs	Reproduction - Number of young per adult	182	71		8	Belanger et Cherry	1990
	Amphipod	*Hyalella azteca*	7 d	LC50	1- 11 days	Mortality (1)	18	56	←	6.44-8.68	Borgmann et al	2005
			7 d	LC50	1- 11 days	Mortality (1)	18	70	←	6.44-8.68	Borgmann et al	2005
			7 d	Mean LC50	1- 11 days	Mortality (1)			63			
			7 d	LC50	1- 11 days	Mortality (1)	124	222		7.23-8.98	Borgmann et al	2005
Fish	Rainbow Trout	*Oncorhynchus mykiss*	30 d	LC10	Juvenile	Mortality (1)	31.72	34.5		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	104.99	171		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	190.35	290		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	398.68	337		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	29.6	38.4	←	7.45	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	29.1	46.1	←	7.65	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	29.1	73.6	←	7.58	De Schamphelaere and Janssen	2004
				Mean LC10			29.3		50.7			
			30 d	LC10	Juvenile	Mortality (1)	29.1	99.1	←	6.78	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	28.2	185	←	6.8	De Schamphelaere et al.	2005
				Mean LC10					135			
			30 d	LC10	Juvenile	Mortality (1)	31.5	219		7.08	De Schamphelaere et al.	2005
			30 d	LC10	Juvenile	Mortality (1)	176.3	578		8.13	De Schamphelaere et al.	2005
			30 d	LC10	Juvenile	Mortality (1)	103.7	902		7.76	De Schamphelaere et al.	2005
	Fathead Minnow	*Pimephales promelas*	32 d	ChV	Larva	Mortality	47	188		7.4-8.2	Norberg-King	1989
			7 d	LC50	Larva	Mortality	190	780		8.3-8.7	Magliette et al.	1995
			NR	MATC	Egg	Mortality	46	207		7-8	Benoit and Holcombe	1978
			7 d	MATC	Larva	Mortality	48	125			Norberg and Mount	1985
			7 d	TLM	Fry	Mortality	186	870		7.5-7.6	Pickering and Vigor	1965

"← " values included in mean

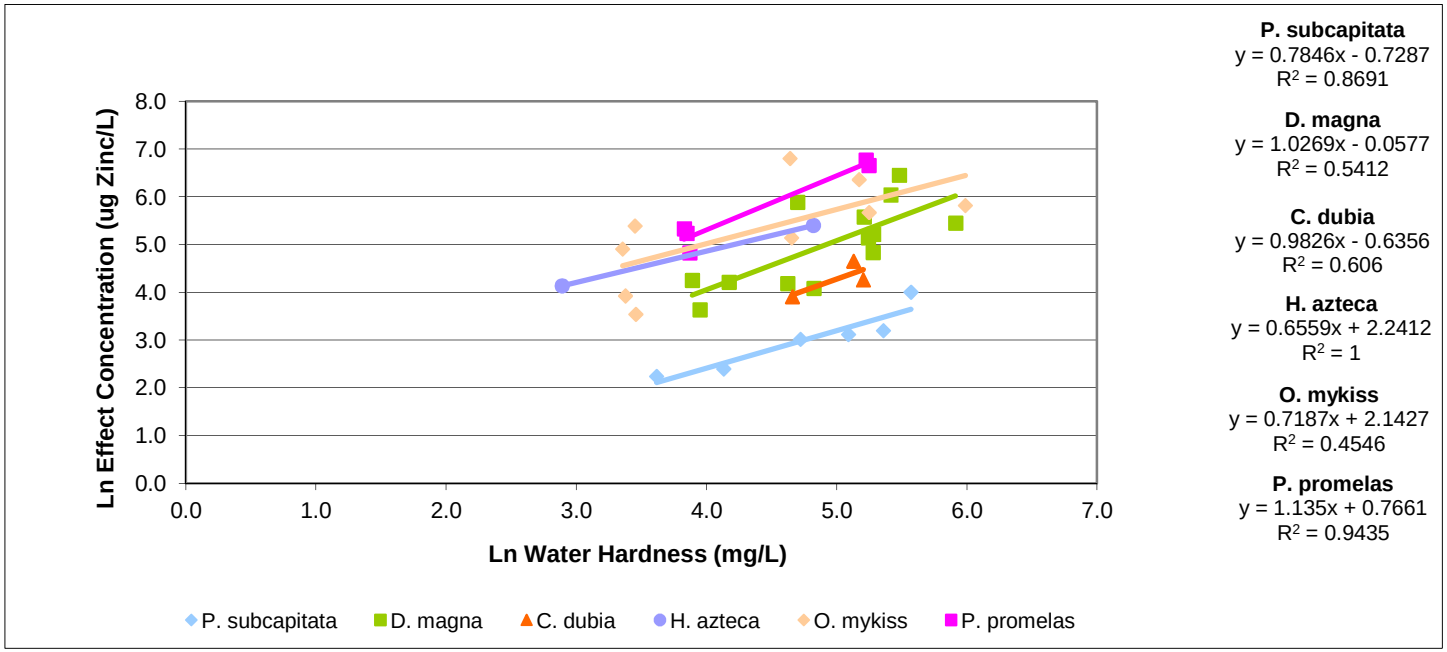

Figure B.1: Comparison of zinc hardness-toxicity relationships for various aquatic species in long-term exposures. Data in Appendix Table B.5. Combined slope equals 0.846. (Minnow 2010)

ATTACHMENT C

CADMIUM TOXICITY DATA

Table C.1: Lowest effect endpoint reported for freshwater species after acute exposure to cadmium (CCME 2014b).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Effect concentration (mg/L)	Hardness (mg/L)	Effect Concentration (mg/L) at 50 mg/L Hardness [a]	Effect Concentration (mg/L) at 100 mg/L Hardness [a]	Effect Concentration (mg/L) at 200 mg/L Hardness [a]	Effect Concentration (mg/L) at 300 mg/L Hardness [a]
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	96 h	LC50	0.00115	120	0.00047	0.00096	0.0019	0.0029
Amphipod	*Hyalella azteca*	4-14 d	96 h	LC50	0.005	290	0.00084	0.0017	0.0034	0.0052
Cladoceran	*Daphnia magna*	Adult	72 h	LC50	0.00334	179	0.00091	0.0018	0.0037	0.0056
Brown trout	*Salmo trutta*	Juvenile	96 h	LC50	0.0014	43.5	0.0016	0.0033	0.0066	0.0100
Striped bass	*Morone saxatilis*	35-80 days old	96 h	LC50	0.01	285	0.0017	0.0035	0.0070	0.011
Mottled sculpin	*Cottus bairdi*	Swim-up fry	96 h	LC50	0.0036	102	0.0017	0.0035	0.0071	0.011
Chinook Salmon	*Oncorhynchus tshawytscha*	Swim-up fry	96 h	LC50	0.0018	23	0.0040	0.0080	0.016	0.024
Coho salmon	*Oncorhynchus kisutch*	Juvenile	96 h	LC50	0.0034	41	0.0042	0.0084	0.017	0.026
Arctic grayling	*Thymallus arcticus*	Juvenile	96 h	LC50	0.004	41	0.0049	0.0099	0.020	0.030
Mountain whitefish	*Prosopium williamsoni*	Embryo	96 h	LC50	0.0047	47.8	0.0049	0.0099	0.020	0.030
Green hydra	*Hydra viridissima*	Not reported	96 h	LC50	0.003	19.5	0.0078	0.016	0.032	0.048
Fathead minnow	*Pimephales promelas*	< 24 h	96 h	LC50	0.06	290	0.010	0.020	0.041	0.062
Neosho mucket	*Lampsilis rafinesqueana*	Juvenile	96 h	EC50	0.02	44	0.023	0.046	0.093	0.14
Cladoceran	*Simocephalus serrulatus*	Neonate	48 h	LC50	0.0245	43.5	0.028	0.057	0.12	0.17
Cladoceran	*Daphnia pulex*	< 24 h	96 h	LC50	0.0324	53.5	0.030	0.061	0.12	0.19
Cladoceran	*Ceriodaphnia reticulata*	< 24 h	48 h	LC50	0.184	240	0.037	0.076	0.15	0.23
Amphipod	*Gammarus pseudolimnaeus*	< 24 h	96 h	LC50	0.0544	67	0.040	0.082	0.17	0.25
Pink hydra	*Hydra vulgaris*	Juvenile	96 h	LC50	0.12	108	0.055	0.11	0.22	0.34
Cladoceran	*Simocephalus vetulus*	< 24 h	48 h	LC50	0.0893	67	0.066	0.13	0.27	0.41
Moss bladder snail	*Aplexa hypnorum*	Adult	96 h	LC50	0.093	44.4	0.10	0.21	0.43	0.65
Oligochaete	*Lumbriculus variegates*	Adult	96 h	LC50	0.78	290	0.13	0.26	0.53	0.81
Mayfly	*Paraleptophlebia praepedita*	Juvenile	96 h	LC50	0.449	67	0.33	0.67	1.4	2.1
White River crayfish	*Procambarus acutus*	Adult	96 h	LC50	0.368	44.5	0.41	0.84	1.7	2.6
Northwestern salamander	*Ambystoma gracile*	Larva	96 h	LC50	0.4684	45	0.52	1.1	2.1	3.2
Placid crayfish	*Orconectes placidus*	Adult	96 h	LC50	0.487	44.1	0.55	1.1	2.3	3.4
Red swamp crayfish	*Procambarus clarkii*	Juvenile	96 h	LC50	0.624	52.9	0.59	1.2	2.4	3.6
Zebrafish	*Danio rerio*	Larva	96 h	LC50	1.73	141	0.60	1.2	2.5	3.7
Midge	*Chironomus tentans*	Second instar	96 h	LC50	1.68	114	0.73	1.5	3.0	4.5
Midge	*Chironomus riparius*	Second instar	96 h	LC50	1.76	114	0.76	1.5	3.1	4.7
Goldfish	*Carassius auratus*	Adult	96 h	LC50	0.748	44.4	0.84	1.7	3.5	5.2
Argentine toad	*Bufo arenarum*	Stage 26	96 h	LC50	2.19	80	1.4	2.7	5.6	8.4
Oligochaete	*Limnodrilus hoffmeisteri*	Adult	96 h	LC50	0.17	5.3	1.7	3.4	6.8	10
Oligochaete	*Brachiura sowerbyi*	Adult	96 h	LC50	0.24	5.3	2.3	4.7	9.6	14
Kentucky River crayfish	*Orconectes juvenilis*	Adult	96 h	LC50	2.44	44.1	2.8	5.6	11	17
Oligochaete	*Quistadrilus multisetosus*	Adult	96 h	LC50	0.32	5.3	3.1	6.3	13	19
White sucker	*Catostomus commersoni*	Juvenile	96 h	LC50	1.11	18	3.1	6.3	13	19
Guppy	*Lebistes reticulatus*	1-2 g	96 h	LC50	1.27	20	3.2	6.5	13	20
Yellow perch	*Perca flavescens*	Juvenile	96 h	LC50	8.14	120	3.3	6.8	14	21
Electric blue dragon crayfish	*Procambarus alleni*	Adult	96 h	LC50	3.07	45.8	3.4	6.8	14	21
Oligochaete	*Spirosperma ferox*	Adult	96 h	LC50	0.35	5.3	3.4	6.9	14	21
Oligochaete	*Varichaeta pacifica*	Adult	96 h	LC50	0.38	5.3	3.7	7.5	15	23
Northern crayfish	*Orconectes virilis*	Adult	96 h	LC50	3.3	42.5	3.9	7.9	16	24
Oligochaete	*Spirosperma nikolskyi*	Adult	96 h	LC50	0.45	5.3	4.4	8.9	18	27
Bluegill	*Lepomis macrochirus*	1-2 g	96 h	LC50	1.94	20	4.9	10.0	20	30
Channel catfish	*Ictalurus punctatus*	Juvenile	96 h	LC50	4.48	44.4	5.1	10	21	31
Oligochaete	*Stylpdrilus heringianus*	Adult	96 h	LC50	0.55	5.3	5.4	11	22	33
Oligochaete	*Rhyacodrilus montana*	Adult	96 h	LC50	0.63	5.3	6.2	12	25	38
Green sunfish	*Lepomis cyanellus*	1-2 g	96 h	LC50	2.84	20	7.2	15	29	44
Mayfly	*Rhithrogena hageni*	Nymph	96 h	LC50	10.5	48	11	22	45	68

[a] Values adjusted based on hardness using an acute hardness:toxicity slope factor of 1.016 from CCME (2014b).

Species not relevant at Faro

Table C.2: Lowest effect endpoint reported for freshwater species after long-term exposure to cadmium (CCME 2014b).

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	ObservedEffect	Effect Concentration (mg/L)	Hardness (mg/L)	Effect Concentration (mg/L) at 50 mg/L Hardness [a]	Effect Concentration (mg/L) at 100 mg/L Hardness [a]	Effect Concentration (mg/L) at 200 mg/L Hardness [a]	Effect Concentration (mg/L) at 300 mg/L Hardness [a]
Cladoceran	*Daphnia magna*	Adult	7 days	EC10	Feeding inhibition	0.00013	179	0.00005	0.00008	0.00014	0.00020
Cladoceran	*Ceriodaphnia reticulata*	Adult	7 days	MATC	Reproduction - Number of young per adult	0.00043	240	0.00012	0.00021	0.00037	0.00052
Amphipod	*Hyalella azteca*	7-8 days	28 days	IC25	Biomass, decrease	0.00051	280	0.00012	0.00022	0.00039	0.00054
Rainbow trout	*Oncorhynchus mykiss*	Early life stage	62 days	EC10	Weight	0.00015	29.4	0.00023	0.00041	0.00074	0.0010
Bull trout	*Salvelinus confluentus*	Juvenile	55 days	MATC	Growth	0.000549	30.6	0.00083	0.0015	0.0026	0.0037
Green hydra	*Hydra viridissima*	Not reported	7 days	NOEC /L	Population growth inhibition	0.0004	19.5	0.00087	0.0016	0.0028	0.0039
Midge	*Chironomus tentans*	< 24 h	60 days	IC25	Hatching success	0.004	280	0.00096	0.0017	0.0030	0.0042
Mottled sculpin	*Cottus bairdi*	Fry	21 days	EC50	Biomass, decrease	0.00177	104	0.00096	0.0017	0.0030	0.0043
Atlantic salmon	*Salmo salar*	Egg	496 days	MATC	Biomass, decrease	0.00061	28	0.00099	0.0018	0.0031	0.0044
Sturgeon	*Acipenser transmontanus*	Fry	58 days	LC20	Mortality	0.0015	70	0.0011	0.0020	0.0036	0.0050
Mountain Whitefish	*Prosopium williamsoni*	Embryo and fry	90 days	IC10	Weight, biomass	0.0012	47.8	0.0012	0.0022	0.0039	0.0055
Amphipod	*Echinogammarus meridionalis*	Adult	6 days	MATC	Feeding inhibition	0.00516	263	0.0013	0.0023	0.0041	0.0058
European shrimp	*Atyaephyra desmarestii*	Adult	6 days	MATC	Feeding inhibition	0.00524	263	0.0013	0.0023	0.0042	0.0058
Brown trout	*Salmo trutta*	Fry	30 days	IC20	Biomass, decrease	0.00087	29.2	0.0014	0.0024	0.0043	0.0060
Amphipod	*Gammarus pulex*	Adult	7 days	NOEL /L	Feeding inhibition	0.0075	269	0.0019	0.0033	0.0059	0.0082
Cladoceran	*Daphnia pulex*	<24 h	42 days	MATC	Reproduction – Brood size	0.00735	230	0.0021	0.0037	0.0065	0.0092
Brook trout	*Salvelinus fontinalis*	Larva	126 days	MATC	Biomass, decrease	0.002	45	0.0022	0.0039	0.0069	0.0097
Chinook salmon	*Oncorhynchus tshawytscha*	Fry	8 days	LC10	Mortality	0.0012	23	0.0023	0.0041	0.0072	0.010
Fathead minnow	*Pimephales promelas*	Larva	7 days	MATC	Mortality	0.0098	278	0.0024	0.0042	0.0075	0.010
Cladoceran	*Ceriodaphnia dubia*	Not reported	14 days	MATC	Reproduction	0.002	17	0.0049	0.0087	0.015	0.022
Alga	*Ankistrodesmus falcatus*	Population	96 h	NOEC /L	Growth	0.01	118	0.0049	0.0087	0.015	0.022
Fatmucket	*Lampsilis siliquoidea*	Juvenile	28 days	IC10	Length	0.0046	44	0.0051	0.0091	0.016	0.023
White sucker	*Catostomus commersoni*	Embryo	40 h	MATC	Biomass, decrease	0.0071	45	0.0077	0.014	0.024	0.034
Coho salmon	*Oncorhynchus kisutch*	Larva	62 days	MATC	Biomass, decrease	0.0072	45	0.0079	0.014	0.025	0.035
Lake trout	*Salvelinus namaycush*	Larva	64 days	MATC	Biomass, decrease	0.0074	45	0.0081	0.014	0.026	0.036
Northern pike	*Esox lucius*	Embryo	35 days	MATC	Biomass, decrease	0.0074	45	0.0081	0.014	0.026	0.036
Olgiochaete	*Aeolosoma headleyi*	Young worms	14 days	MATC	Population growth	0.0401	168	0.015	0.026	0.046	0.065
Great marsh snail	*Lymnaea stagnalis*	Adult	4 week s	NOEC /L	Growth	0.08	284	0.019	0.034	0.060	0.084
Midge	*Chironomus riparius*	First instar	17 days	MATC	Mortality	0.0474	98	0.027	0.048	0.086	0.12
Marsh snail	*Lymnaea palustris*	Adult	4 week s	EC50	Growth	0.0582	58.2	0.051	0.091	0.16	0.23
Duckweed	*Lemna minor*	Not reported	7 days	EC50	Growth rate	0.214	166	0.079	0.14	0.25	0.35
Northwestern salamander	*Ambystoma gracile*	Larva	24 days	MATC	Weight	0.0972	45	0.11	0.19	0.34	0.47
Mayfly	*Rhithrogena hageni*	Nymph	10 days	EC10	Mortality	2.571	48	2.7	4.7	8.4	12
Dragonfly	*Erythemis simplicicollis*	Larva	7 days	NOEC /L	Survival	100	120	48	86	153	214
Dragonfly	*Pachydiplax longipennis*	Larva	7 days	MATC	Survival	160	120	77	138	244	342

[a] Values adjusted based on hardness using an chronic hardness:toxicity slope factor of 0.83 from CCME (2014b).

Species not relevant at Faro

ATTACHMENT D

COBALT TOXICITY DATA

Table D.1: Lowest effect endpoint reported for each freshwater species after acute exposure to cobalt (Nagpal 2004).

Species	Life stage	Duration	Endpoint	Effect Concentration (µg/L)	Confidence Interval	Hardness (mg/L $CaCO_3$)	Author
Green alga (*Chlorella vulgaris*)		3– 4 mo.	LOEC	8.2 µg at/L			den Dooren 1965 as cited in Nagpal 2004
Water flea (*Ceriodaphnia dubia*)			FAV	336		57	Diamond et al. 1992 as cited in Nagpal 2004
Chlamydomonas eugametos		10-14 d	LOEC (growth)	500			Hutchinson 1973 as cited in Nagpal 2004
Rainbow trout (*Oncorhynchus mykiss*)		96 hr	LC20	533	237-1201	24.9	Marr et al. 1998 as cited in Nagpal 2004
Daphnia magna	<24 hr	48 hr	LC50	1,110		45.3	Biesinger & Christensen 1972 as cited in Nagpal 2004
Fathead minnow (*Pimephales promelas*)		48 hr	NOEC	1245		57	Diamond et al. 1992 as cited in Nagpal 2004
Clawed frog (*Xenopus laevis*)	Embryo	101 hr	EC50	1,473		-	Sunderman 1992 as cited in Nagpal 2004
Alga (*Pediastrum tetras*)			LOEC	1,550			Coleman et al. 1971 as cited in Nagpal 2004
Alga (*Euglena viridis*)		21 d	LOEC	1,550			Coleman et al. 1971 as cited in Nagpal 2004
Planarian (*Dugesia tigrina*)		240 hr	LC50	3490	3010-4050		Solski and Piontek 1987 as cited in Nagpal 2004
Insect (*Eudiaptomus padamus*)	Adult	48 hr	LC50	4,000	8,000-2,000	33	Baudouin & Scoppa 1974 as cited in Nagpal 2004
Blue-green alga (*Spirulina platensis*)		261 hr	TLM	4,000			Sharma et al. 1987 as cited in Nagpal 2004
Haematococcus capensis		10-14 d	Growth reduction 75%	5,000			Hutchinson 1973 as cited in Nagpal 2004
Crayfish (*Austropotamobuis pallipes pallipes*)	19-32 mm	96 hr	LC50	8,800		-	Boutet & Chaisemartin 1973 as cited in Nagpal 2004
Tubificid worm		5 d	Nuclear expansion	10,000			Fischer et al. 1980 as cited in Nagpal 2004
Crayfish (*Orconectes limosus*)	19-32 mm	96 hr	EC50	10,200		-	Boutet & Chaisemartin 1973 as cited in Nagpal 2004
Cyanobacterium (*Anacystis nidulans*)		10-14 d	Reduced growth	15,000			Lee et al. 1992 as cited in Nagpal 2004
Cyclops abyssorun	Adult	48 hr	LC50	15,500	18,800-12,800	33	Baudouin & Scoppa 1974 as cited in Nagpal 2004
Mayfly (*E. subvaria*)	-	4 day	LC50	16,000		44.0	Warwich and Bell 1969 as cited in Nagpal 2004
Flatworm (*Dugesia tigrina*)	Juvenile	96 hr	LC50	25,000		130	Ewell et al. 1986 as cited in Nagpal 2004
Rotifer (*Philodina acuticornis*)		24 hr	EC50	27,800		25	Buikema et al. 1984 as cited in Nagpal 2004
Stonefly (*Acroneuria lycorias*)		8 d	50% survival	32,000		44.0	Warwich & Bell 1969 as cited in Nagpal 2004
Caddisfly (*Hydropsyche betteni*)		7 d	50% survival	32,000		44.0	Warwich & Bell 1969 as cited in Nagpal 2004
Amphipod (*Crangonyx pseudogracilis*)		96 hr	LC50	39,200	35,300- 43,300	50	Martin & Holdich 1986 as cited in Nagpal 2004
Giant gouramis (*Colisa fasciatus*)	Adult female	96 hr	LC50	225,000		120	Srivastava & Agrawal 1979 as cited in Nagpal 2004
Tubificid worm (*Tubifex tubifex*)		24 hr	EC50	447,710	358,990-561,200	245	Khangarot 1991 as cited in Nagpal 2004

Species not relevant at Faro

Table D.2: Detailed short-term effects of cobalt on a variety of aquatic organisms (Nagpal 2004).

Species Type	Species	Life stage	Duration	Endpoint	Effect Concentration (µg/L)	Confidence Interval	Hardness (mg/L $CaCO_3$)	Author
Invertebrates	Mayfly (*E. subvaria*)	-	4 day	LC50	16,000		44.0	Warwich and Bell 1969 as cited in Nagpal 2004
	Mayfly (*E. subvaria*)		96 hr	TLM	16,000		44.0	Warwich & Bell 1969 as cited in Nagpal 2004
	Daphnia magna	Neo-nate	48 hr	EC50	7,370		-	Kimball 1978 as cited in Nagpal 2004
	Daphnia magna	Neo-nate	48 hr	EC50	5,990		-	Kimball 1978 as cited in Nagpal 2004
	Daphnia magna	Neo-nate	96 hr	EC50	1,860		-	Kimball 1978 as cited in Nagpal 2004
	Daphnia magna	<24 hr	48 hr	LC50	1,620		45.3	Biesinger & Christensen 1972 as cited in Nagpal 2004
	Daphnia magna	<24 hr	48 hr	LC50	1,110		45.3	Biesinger & Christensen 1972 as cited in Nagpal 2004
	Daphnia magna	Various	24 hr	EC50	2,110		245	Khangarot et al. 1987 as cited in Nagpal 2004
	Daphnia magna	Various	48 hr	EC50	1,490		245	Khangarot et al. 1987 as cited in Nagpal 2004
	Daphnia magna	Juvenile	96 hr	LC50	3,200		130	Ewell et al. 1986 as cited in Nagpal 2004
	Daphnia magna		24 hr	EC50	2,610	1,450-5,890	240	Khangarot & Ray 1989 as cited in Nagpal 2004
	Daphnia magna		48 hr	EC50	1,490	1,270- 2,480	240	Khangarot & Ray 1989 as cited in Nagpal 2004
	Daphnia Hyalina	Adult	48 hr	EC50	1,320	1,630-1,070	33	Baudouin & Scoppa 1974 as cited in Nagpal 2004
	Cyclops abyssorun	Adult	48 hr	LC50	15,500	18,800-12,800	33	Baudouin & Scoppa 1974 as cited in Nagpal 2004
	Insect (*Eudiaptomus padamus*)	Adult	48 hr	LC50	4,000	8,000-2,000	33	Baudouin & Scoppa 1974 as cited in Nagpal 2004
	Water flea (*Ceriodaphnia dubia*)	<24 hr old	24 hr	LC50	2347		57	Diamond et al. 1992 as cited in Nagpal 2004
	Water flea (*Ceriodaphnia dubia*)	<24 hr old	24 hr		4596		256	Diamond et al. 1992 as cited in Nagpal 2004
	Water flea (*Ceriodaphnia dubia*)	<24 hr old	24 hr		4196		476	Diamond et al. 1992 as cited in Nagpal 2004
	Water flea (*Ceriodaphnia dubia*)	<24 hr old	24 hr		>5300		882	Diamond et al. 1992 as cited in Nagpal 2004
	Water flea (*Ceriodaphnia dubia*)			FAV	336		57	Diamond et al. 1992 as cited in Nagpal 2004
	Crayfish (*Austropotamobuis pallipes pallipes*)	19-32 mm	96 hr	LC50	8,800		-	Boutet & Chaisemartin 1973 as cited in Nagpal 2004
	Crayfish (*Orconectes limosus*)	19-32 mm	96 hr	EC50	10,200		-	Boutet & Chaisemartin 1973 as cited in Nagpal 2004
	Rotifer (*Philodina acuticornis*)		24 hr	EC50	27,800		25	Buikema et al. 1984 as cited in Nagpal 2004
	Rotifer (*Philodina acuticornis*)		48 hr	EC50	183,000		25	Buikema et al. 1984 as cited in Nagpal 2004
	Rotifer (*Philodina acuticornis*)		96 hr	EC50	59,000		25	Buikema et al. 1984 as cited in Nagpal 2004
	Planarian (*Dugesia tigrina*)		240 hr	LC50	3490	3010-4050		Solski and Piontek 1987 as cited in Nagpal 2004
	Tubificid worm (*Tubifex tubifex*)		24 hr	EC50	447,710	358,990-561,200	245	Khangarot 1991 as cited in Nagpal 2004
	Tubificid worm (*Tubifex tubifex*)		48 hr	EC50	447,710	358,990- 561,200	245	Khangarot 1991 as cited in Nagpal 2004
	Tubificid worm		96 hr	EC50	139,320	113,140-148,790	245	Khangarot 1991 as cited in Nagpal 2004
	Tubificid worm		5 d	Nuclear expansion	10,000			Fischer et al. 1980 as cited in Nagpal 2004
	Flatworm (*Dugesia tigrina*)	Juvenile	96 hr	LC50	25,000		130	Ewell et al. 1986 as cited in Nagpal 2004
	Stonefly (*Acroneuria lycorias*)		8 d	50% survival	32,000		44.0	Warwich & Bell 1969 as cited in Nagpal 2004
	Caddisfly (*Hydropsyche betteni*)		7 d	50% survival	32,000		44.0	Warwich & Bell 1969 as cited in Nagpal 2004
	Amphipod (*Crangonyx pseudogracilis*)		48 hr	LC50	167,000	148,000-199,000	50	Martin & Holdich 1986 as cited in Nagpal 2004
	Amphipod (*Crangonyx pseudogracilis*)		96 hr	LC50	39,200	35,300- 43,300	50	Martin & Holdich 1986 as cited in Nagpal 2004
Fish	Rainbow trout (*Oncorhynchus mykiss*)		96 hr	LC50	1406	569-3474	24.9	Marr et al. 1998 as cited in Nagpal 2004
	Rainbow trout (*Oncorhynchus mykiss*)		96 hr	LC20	533	237-1201	24.9	Marr et al. 1998 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)	Juvenile (8 wk old)	96 hr	LC50	3,610		-	Kimball 1978 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)	5-15 day	48 hr	LC50	>5830		57	Diamond et al. 1992 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)		48 hr	NOEC	1245		57	Diamond et al. 1992 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)		48 hr		7280		256	Diamond et al. 1992 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)		48 hr		13733		476	Diamond et al. 1992 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)		48 hr		6200		882	Diamond et al. 1992 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)	Juvenile	96 hr	LC50	48,000		130	Ewell et al. 1986 as cited in Nagpal 2004
	Fathead minnow (*Pimephales promelas*)		96 hr	LC50	91,900	56,300-132,900	44	Curtis & Ward 1981 as cited in Nagpal 2004
	Giant gouramis (*Colisa fasciatus*)	Adult female	96 hr	LC50	225,000		120	Srivastava & Agrawal 1979 as cited in Nagpal 2004
Amphibian	Clawed frog (*Xenopus laevis*)	Embryo	101 hr	EC50	1,473		-	Sunderman 1992 as cited in Nagpal 2004
	Clawed frog (*Xenopus laevis*)		101 hr	LC50	612,905			Sunderman 1992 as cited in Nagpal 2004
	Clawed frog (*Xenopus laevis*)	Embryo	101 hr	LOEC	2,475		-	Sunderman 1992 as cited in Nagpal 2004

Table D.2: Detailed short-term effects of cobalt on a variety of aquatic organisms (Nagpal 2004).

Species Type	Species	Life stage	Duration	Endpoint	Effect Concentration (µg/L)	Confidence Interval	Hardness (mg/L $CaCO_3$)	Author
Plants and Algae	Blue-green alga (*Anabaene variabilis*)		96 hr	Reduced growth	5,000–20,000			Ahluwalia & Kaur 1988 as cited in Nagpal 2004
	Blue-green alga (*Anabaene variabilis*)		96 hr	No growth	50,000			Ahluwalia & Kaur 1988 as cited in Nagpal 2004
	Green alga (*Chlorella vulgaris*)		96 hr	Reduced growth	50,000-100,000			Ahluwalia & Kaur 1988 as cited in Nagpal 2004
	Green alga (*Chlorella vulgaris*)		21 d	NOEC	550			Coleman et al. 1971 as cited in Nagpal 2004
	Green alga (*Chlorella vulgaris*)		21 d	LOEC	1,550			Coleman et al. 1971 as cited in Nagpal 2004
	Green alga (*Chlorella vulgaris*)		10-14 d	100% growth reduction	1,000			Hutchinson 1973 as cited in Nagpal 2004
	Green alga (*Chlorella vulgaris*)		96 hr	EC50 (growth)	522			Rachlin & Grosso 1993 as cited in Nagpal 2004
	Green alga (*Chlorella vulgaris*)		3–4 mo.	NOEC	4.2 µg at/L			den Dooren 1965 as cited in Nagpal 2004
	Green alga (*Chlorella vulgaris*)		3– 4 mo.	LOEC	8.2 µg at/L			den Dooren 1965 as cited in Nagpal 2004
	Alga (*Pediastrum tetras*)			LOEC	1,550			Coleman et al. 1971 as cited in Nagpal 2004
	Alga (*Euglena viridis*)		21 d	LOEC	1,550			Coleman et al. 1971 as cited in Nagpal 2004
	Cyanobacterium (*Anacystis nidulans*)		10-14 d	Reduced growth	15,000			Lee et al. 1992 as cited in Nagpal 2004
	Cyanobacterium (*Anacystis nidulans*)		10-14 d	No growth	30,000			Lee et al. 1992 as cited in Nagpal 2004
	Blue-green alga (*Spirulina platensis*)		96 hr	EC50 (growth)	23,800 (+/-6,400)			Sharma et al. 1987 as cited in Nagpal 2004
	Blue-green alga (*Spirulina platensis*)		120 hr	EC50 (growth)	14,400 (+/-2,100)			Sharma et al. 1987 as cited in Nagpal 2004
	Blue-green alga (*Spirulina platensis*)		144 hr	EC50 (growth)	10,900 (+/-1,500)			Sharma et al. 1987 as cited in Nagpal 2004
	Blue-green alga (*Spirulina platensis*)		168 hr	EC50 (growth)	8,130 (+/-930)			Sharma et al. 1987 as cited in Nagpal 2004
	Blue-green alga (*Spirulina platensis*)		131 hr	TLM	12,000			Sharma et al. 1987 as cited in Nagpal 2004
	Blue-green alga (*Spirulina platensis*)		261 hr	TLM	4,000			Sharma et al. 1987 as cited in Nagpal 2004
	Haematococcus capensis		10-14 d	Growth reduction 75%	5,000			Hutchinson 1973 as cited in Nagpal 2004
	Chlamydomonas eugametos		10-14 d	LOEC (growth)	500			Hutchinson 1973 as cited in Nagpal 2004

Table D.3: Long-term toxicity data used for developing the Federal Water Quality Guideline for cobalt (EC 2013).

Group	Species	Endpoint	Concentration (µg/L)	Reference
invertebrates	Amphipod (*Hyalella azteca*)	28d IC_{25} (growth)	2.9	Norwood et al. 2007 as cited in EC 2013
	Water flea (*Daphnia magna*)	28d LOEC (reproduction)	4.4	Kimball (unpublished) as cited in EC 2013
	Water flea (*Ceriodaphnia dubia*)	21d EC_{10} (reproduction)	7.9	CDI 2009 as cited in EC 2013
	Snail (*Lymnea stagnalis*)	28d EC_{10} (growth)	22	De Schamphelaere et al. 2008 as cited in EC 2013
	Midge (*Chironomus tentans*)	20d EC_{10} (growth)	123	CDI 2009 as cited in EC 2013
	Oligochaete (*Aeolosoma*)	14d EC_{10} (reproduction)	155	CDI 2009 as cited in EC 2013
	Rotifer (*Philodina acuticornis*)	4d EC_{50} (reproduction)	59000	Buikema et al. 1974 as cited in EC 2013
fish	Zebrafish (*Brachydanio rerio*)	16d MATC (survival)	340	Dave and Xiu 1991 as cited in EC 2013
	Fathead minnow (*Pimephales promelas*)	35d EC_{10} (survival)	351	CDI 2009 as cited in EC 2013
	Rainbow trout (*Oncorhynchus mykiss*)	81d EC_{10} (biomass)	2171	CDI 2009 as cited in EC 2013
plant	Duckweed (*Lemna minor*)	7d EC_{10} (growth)	4.9	CDI 2009 as cited in EC 2013
	Green alga (*Pseudokirchneriella subcapitata*)	4d EC_{10} (growth)	23	CDI 2009 as cited in EC 2013
	Giant duckweed (*Spirodela polyrhiza*)	4d EC_{50} (growth)	140	Gaur et al. 1994 as cited in EC 2013
	Green alga (*Chlamydomonas reinhardtii*)	5d EC_{30} (growth)	1120	Macfie et al. 1994 as cited in EC 2013
	Green alga (*Chlamydomonas acidophila*)	4d EC_{50} (growth)	4100	Nishikawa and Tominaga 2001 as cited in EC 2013

ATTACHMENT E

MANGANESE TOXICITY DATA

Table E.1: Lowest effect endpoint reported for each freshwater species after acute and chronic exposure to manganese. See Tables E.2 and E.3 for test details and sources.

	Species Common Name	Species Scientific Name	Organism Age/Size	Duration	Endpoint	Effect	Reported Effect Concentration (µg Mn/L)	Reported Water Hardness (as $CaCO_3$)	LC50 (ug/L) at 50 mg/L Hardness [a]	LC50 (ug/L) at 100 mg/L Hardness [a]	LC50 (ug/L) at 200 mg/L Hardness [a]	LC50 (ug/L) at 300 mg/L Hardness [a]
Acute	Rainbow trout	*Oncorhynchus mykiss*	embryo-larval	- [c]	LC50	mortality	2,910	100	1,738	2,910	4,871	6,584
	Water flea	*Daphnia magna*	<24 hr	48 hr	LC50	mortality	4,700	170	1,893	3,168	5,303	7,168
	Brook trout	*Salvelinus fontinalis*	26 mm, 0.168 g, 87 d	- [c]	LC50	mortality	3,606	48	3,717	6,222	10,415	14,077
	Amphipod	*Hyalella azteca*	2-3 mm	- [c]	LC50	mortality	6,630	96	4,083	6,834	11,440	15,463
	Brown trout	*Salmo trutta*	138 mm	- [c]	LC50	mortality	3,770	37.5	4,669	7,815	13,081	17,681
	Fathead minnow	*Pimehales promelas*	<7 d	- [c]	LC50	mortality	9,346	100	5,583	9,346	15,644	21,146
	Water flea	*Ceriodaphnia dubia*	<24 hr	- [c]	LC50	mortality	25,480	200	9,094	15,222	25,480	34,441
	Mussel	*Lampsilis siliquoidea*	<5d	96 hr	LC50	mortality	43,300	157	18,500	30,967	51,835	70,063
	Mussel	*Megalonaias nervosa*	<5d	96 hr	LC50	mortality	31,500	101	18,680	31,268	52,339	70,745
	Mussel	*Anodonta imbecillus*	6-8 d	- [b]	LC50	mortality	36,200	80	25,527	42,730	71,525	96,678
	Northern squawfish	*Ptychocheilus oregonensis*	Juvenile	- [c]	LC50	mortality	130,465	347	30,917	51,751	86,626	117,089
	Longfin dace	*Agosia chrysogaster*	43 mm	- [c]	LC50	mortality	130,000	224	42,649	71,390	119,499	161,523
	Midge	*Chironomus tentans*	11 d	- [c]	LC50	mortality	327,832	96	201,884	337,930	565,657	764,582
	Western toad	*Bufo boreus*	tadpole	- [c]	LC50	mortality	339,842	95	210,915	353,047	590,960	798,784

	Species Common Name	Species Scientific Name	Test Type	Duration	Endpoint	Effect	Reported Effect Concentration (µg Mn/L)	Reported Water Hardness (as $CaCO_3$)	Effect Concentration (ug/L) at 50 mg/L Hardness [b]	Effect Concentration (ug/L) at 100 mg/L Hardness [b]	Effect Concentration (ug/L) at 200 mg/L Hardness [b]	Effect Concentration (ug/L) at 300 mg/L Hardness [b]
Chronic	Rainbow trout	*Oncorhynchus mykiss*	33d	- [c]	MATC	biomass	1,085	34	1,234	1,555	1,959	2,242
	Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC10	biomass	1,152	26	1,432	1,804	2,273	2,602
	Brook trout	*Salvelinus fontinalis*	Early-life-stage	- [c]	EC10	biomass	2,826	156	1,935	2,437	3,070	3,514
	Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC10	survival and reproduction	2,731	46	2,808	3,537	4,456	5,100
	Brown Trout	*Salmo trutta*	Early-life-stage	30 d	EC10	mortality	4,133	152	2,854	3,595	4,529	5,183
	Water flea	*Daphnia magna*	3 wk	3 wk	16% reproductive impairment	reproductive impairment	4,100	45	4,246	5,349	6,739	7,713

[a] Values adjusted to a hardness of 100 mg/L (as $CaCO_3$) using an acute hardness:toxicity slope factor of 0.7432 from GEI (2009).

[b] Values adjusted to a hardness of 100 mg/L (as CaCO3) using a chronic hardness:toxicity slope factor of 0.3331 from GEI (2009).

[c] Not provided by GEI (2009).

Table E.2: Detailed acute toxicity data for manganese. Lowest effect concentration for each species is highlighted.

Species Common Name	Species Scientific Name	Organism Age/Size	Duration	LC50 (ug/L)	Confidence Interval (ug/L)	Water Hardness (as $CaCO_3$)	LC50 (ug/L) at 100 mg/L Hardness [a]	Citation
Rainbow trout	*Oncorhynchus mykiss*	embryo-larval	- [b]	2,910	(2,600-3,230)[c]	100	2,910	Birge et al. (1979) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	62 mm	- [b]	14,500	(8,500-24,800)	36	30,983	Davies (1980) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	201 mm	- [b]	116,000	(90,600-148,500)	304	50,768	Davies (1980) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	121 mm	- [b]	30,000	(19,000-47,300)	36	64,103	Davies (1980) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	41 mm, 0.601 g, 70 d	- [b]	3,170	(2,900 - 3,470)	27.6	8,252	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	42 mm	- [b]	4,830	(4,180-5,580)	37.5	10,012	Davies and Brinkman (1994) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	41 mm, 0.590 g, 70 d	- [b]	16,200	(1,400 - 18,700)	147.8	12,117	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	33d	- [b]	2,008	(1,697-2,377)	44	3,696	ENSR (1990) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	24.5 mm, 0.123 g, 50 d	- [b]	2,490	(2,070-3,008)	48	4,296	ENSR (1994) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	23.4 mm, 0.094 g, 50 d	- [b]	5,320	(3,110-5,970)	90	5,753	ENSR (1994) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	23.5 mm, 0.097 g, 50 d	- [b]	11,149	(10,038-12,464)	170	7,516	ENSR (1994) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	37 mm, 0.405 g, 70 d	- [b]	5,120	(4,600-5,700)	31.3	12,139	Davies and Brinkman (1998) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	74 mm, 5.2 g, 150 d	- [b]	73,300	(48,250-111,340)	28	188,789	ENSR (1996a) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	26 mm, 0.168 g, 87 d	- [b]	3,606	(2,320-4,400)	48	6,222	ENSR (1994) as cited in GEI (2009)
Brown trout	*Salmo trutta*	138 mm	- [b]	3,770		37.5	7,815	Davies and Brinkman (1994) as cited in GEI (2009)
Brown trout	*Salmo trutta*	116 mm	- [b]	49,900	(43,600-57,400)	454	16,210	Davies and Brinkman (1995) as cited in GEI (2009)
Brown trout	*Salmo trutta*	23.3 mm, 0.103 g, 115 d	- [b]	15,973	(7,464-36,484)	48	27,561	ENSR (1994) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	9,346	(8,029-10,879)	100	9,346	ENSR (1992a) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	15,826	(12,311-20,344)	200	9,455	ENSR (1992a) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	3,542	(2,967-4,228)	26	9,639	ENSR (1992a) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	6,232	(5,680-6,830)	50	10,432	ENSR (1992a) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	10,302	(9,182-11,621)	48	17,776	ENSR (1990) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	27,440	(24,742-31,269)	176	18,027	ENSR (1990) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	17,279	(15,232-19,408)	92	18,384	ENSR (1990) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	8,557	(7,188-10,187)	28	22,039	ENSR (1996) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	0.4 g, 101 d	- [b]	197,315	(99,951-389,522)	28	508,197	ENSR (1996) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	<7 d	- [b]	45,000		396	16,181	ENSR (1990) as cited in GEI (2009)
Longfin dace	*Agosia chrysogaster*	43 mm	- [b]	130,000	(100,000-169,000)	224	71,390	Lewis (1978) as cited in GEI (2009)
Northern squawfish	*Ptychocheilus oregonensis*	Juvenile	- [b]	130,465	(36,063- --)	347	51,751	Beleau and Bartosz (1982) as cited in GEI (2009)
Northern squawfish	*Ptychocheilus oregonensis*	Post-larval	- [b]	189,482	(145,410-330,001)	316	80,575	Beleau and Bartosz (1982) as cited in GEI (2009)
Amphipod	*Hyalella azteca*	2-3 mm	- [b]	6,630	(4,893-9,018)	96	6,834	ENSR (1996) as cited in GEI (2009)
Amphipod	*Hyalella azteca*	2-3 mm	- [b]	10,169	(8,548-11,717)	94	10,648	ENSR (1996b) as cited in GEI (2009)
Water flea	*Daphnia magna*	12 h		9,800		45	17,740	Biesinger and Christensen (1972) as cited in GEI (2009)
Water flea	*Daphnia magna*	<24 hr	48 hr	4,700		170[d]	3,168	Baird et al. (1991)
Water flea	*Daphnia magna*	<24 hr	48 hr	20,000		170[d]	13,482	Baird et al. (1991)
Water flea	*Daphnia magna*	<24 hr	48 hr	32,300		170[d]	21,774	Baird et al. (1991)
Water flea	*Daphnia magna*	<24 hr	48 hr	56,100		170[d]	37,818	Baird et al. (1991)
Water flea	*Daphnia magna*	<24 hr	48 hr	34,500		170[d]	23,257	Baird et al. (1991)
Water flea	*Daphnia magna*	<24 hr	48 hr	22,800		170[d]	15,370	Baird et al. (1991)

Table E.2: Detailed acute toxicity data for manganese. Lowest effect concentration for each species is highlighted.

Species Common Name	Species Scientific Name	Organism Age/Size	Duration	LC50 (ug/L)	Confidence Interval (ug/L)	Water Hardness (as $CaCO_3$)	LC50 (ug/L) at 100 mg/L Hardness [a]	Citation
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	25,480	(22,600-28,730)	200	15,222	ENSR (1992b) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	20,495	(17,865-23,513)	100	20,495	ENSR (1992b) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	12,513	(11,480-13,630)	50	20,945	ENSR (1992b) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	8,757	(7,330-10,470)	26	23,831	ENSR (1992b) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	45,000		396	16,181	ENSR (1990) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	28,849	(25,108-34,419)	176	18,952	ENSR (1990) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	23,456	(20,734-26,552)	92	24,956	ENSR (1990) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	<24 hr	- [b]	15,641	(14,073-17,437)	48	26,988	ENSR (1990) as cited in GEI (2009)
Mussel	*Anodonta imbecillus*	6-8 d	- [b]	36,200		80	42,730	Wade, Hudson, and McKinney (1989) as cited in GEI (2009)
Mussel	*Lampsilis siliquoidea*	<5d	96 hr	43,300		157 [d]	30,967	US EPA (2010)
Mussel	*Megalonaias nervosa*	<5d	96 hr	31,500		101 [d]	31,268	US EPA (2010)
Midge	*Chironomus tentans*	11 d	- [b]	327,832	(218,452-611,066)	96	337,930	ENSR (1996) as cited in GEI (2009)
Western toad	*Bufo boreus*	tadpole	- [b]	339,842	(312,300-369,820)	95	353,047	ENSR (1996) as cited in GEI (2009)

[a] Values adjusted to a hardness of 100 mg/L (as $CaCO_3$) using a hardness:toxicity slope factor of 0.7432 from GEI (2009).

[b] Not provided by GEI (2009).

[c] Data reported as suspect by GEI (2009).

[d] mean hardness of range presented in report.

Table E.3: Detailed chronic toxicity data for manganese. Lowest effect concentration for each species is highlighted (GEI 2009).

Species Common Name	Species Scientific Name	Test Type	Duration	Endpoint	Effect[a]	Effect Concentration (µg Mn/L)	Confidence Interval (ug/L)	Water Hardness (mg/L as $CaCO_3$)	Concentration (ug/L) at 100 mg/L Hardness [b]	Citation
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	EC10	biomass	1,201	(765-1,887)	29	1,814	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	EC20	biomass	1,398	(967-2,022)	29	2,111	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	EC10	biomass	3,477	(2,961-4,082)	151	3,031	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	EC20	biomass	4,259	(3,703-4,898)	151	3,713	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	NOEC	biomass	760		29	1,148	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	NOEC	biomass	3,390		151	2,955	Davies and Brinkman (1998) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	33d	- [c]	MATC	biomass	1,085		34	1,555	MATC calculated as geomean of NOEC and LOEC concentrations
Rainbow trout	*Oncorhynchus mykiss*	33d	- [c]	LOEC	biomass	1,530		34	2,192	Goettl and Davies (1978) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	33d	- [c]	NOEC	biomass	770		34	1,103	Goettl and Davies (1978) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	LOEC	biomass	1,000		5	2,713	Lewis (1978) as cited in GEI (2009)
Rainbow trout	*Oncorhynchus mykiss*	Early-life-stage	- [c]	NOEC	biomass	<1,000		5	<2,713	Lewis (1978) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	Early-life-stage	- [c]	EC10	biomass	2,826	(2,060-3,875)	156	2,437	Davies and Brinkman (1998) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	Early-life-stage	- [c]	EC10	biomass	1,699	(1,033-2,795)	32	2,483	Davies and Brinkman (1998) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	Early-life-stage	- [c]	EC20	biomass	2,104	(1,379-3,209)	32	3,075	Davies and Brinkman (1998) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	Early-life-stage	- [c]	EC20	biomass	3,695	(2,846-4,796)	156	3,186	Davies and Brinkman (1998) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	Early-life-stage	- [c]	NOEC	biomass	550		32	804	Davies and Brinkman (1998) as cited in GEI (2009)
Brook trout	*Salvelinus fontinalis*	Early-life-stage	- [c]	NOEC	biomass	3,530		156	3,044	Davies and Brinkman (1998) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	EC10	biomass	4,133	(3,249-5,257)	152	3,595	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	EC10	biomass	7,365	(6,227-8,710)	450	4,463	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	EC20	biomass	5,148	(4,179-6,342)	152	4,478	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	EC20	biomass	8,209	(7,110-9,478)	450	4,974	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	EC10	biomass	4,330		31	6,396	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	EC20	biomass	4,705		31	6,950	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	NOEC	biomass	3,940		31	5,820	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	NOEC	biomass	2,780		152	2,418	Stubblefield et al. (1997) as cited in GEI (2009)
Brown Trout	*Salmo trutta*	Early-life-stage	30 d	NOEC	biomass	4,550		450	2,757	Stubblefield et al. (1997) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC10	biomass	1,152	(932-2,696)	26	1,804	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC20	biomass	1,338	(641-2,792)	26	2,096	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Early-life-stage	35 d	EC10	biomass	2,289	(1,806-2,902)	30	3,418	ENSR (1996e) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Early-life-stage	35 d	EC20	biomass	2,550	(2,074-3,135)	30	3,808	ENSR (1996e) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC10	biomass	3,164	(2,818-3,552)	46	4,098	ENSR (1989b) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC10	biomass	4,397	(3,022-6,399)	100	4,397	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC20	biomass	3,417	(3,091-3,777)	46	4,426	ENSR (1989b) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC20	biomass	5,120	(3,758-6,974)	100	5,120	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC10	biomass	5,183		50	6,529	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC20	biomass	5,490		50	6,916	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC10	biomass	11,614	(8570-15,776)	200	9,220	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	EC20	biomass	13,152	(10,093-17,140)	200	10,440	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	NOEC	biomass	980		26	1,535	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	NOEC	biomass	5,040		50	6,349	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	NOEC	biomass	4,560		100	4,560	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	NOEC	biomass	7,860		200	6,239	ENSR (1992d) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Short-term chronic	7 d	NOEC	biomass	4,700		46	6,087	ENSR (1989b) as cited in GEI (2009)
Fathead minnow	*Pimehales promelas*	Early-life-stage	35 d	NOEC [based on survival]	biomass	1,410		30	2,106	ENSR (1996e) as cited in GEI (2009)

Table E.3: Detailed chronic toxicity data for manganese. Lowest effect concentration for each species is highlighted (GEI 2009).

Species Common Name	Species Scientific Name	Test Type	Duration	Endpoint	Effect[a]	Effect Concentration (µg Mn/L)	Confidence Interval (ug/L)	Water Hardness (mg/L as $CaCO_3$)	Concentration (ug/L) at 100 mg/L Hardness [b]	Citation
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC10	survival and reproduction	2,731	(2,105-3,544)	46	3,537	ENSR (1989a) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC20	survival and reproduction	3,317	(2,692-4,089)	46	4,296	ENSR (1989a) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC10	survival and reproduction	2,922	(2,237-3,819)	26	4,577	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC20	survival and reproduction	3,314	(2,630-4,175)	26	5,191	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC10	survival and reproduction	5,281	(3,607-7,732)	100	5,281	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC10	survival and reproduction	6,910	(5,430-8,792)	200	5,485	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC10	survival and reproduction	4,370	(3,698-5,165)	50	5,505	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC20	survival and reproduction	6,052	(4,349-8,422)	100	6,052	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC20	survival and reproduction	4,885	(4,225-5,649)	50	6,154	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	EC20	survival and reproduction	7,809	(6,317-9,654)	200	6,199	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	NOEC	survival and reproduction	1,980		26	3,101	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	NOEC	survival and reproduction	2,010		50	2,532	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	NOEC	survival and reproduction	4,460		100	4,460	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	NOEC	survival and reproduction	7,540		200	5,985	ENSR (1992c) as cited in GEI (2009)
Water flea	*Ceriodaphnia dubia*	7-d chronic	7 d	NOEC	survival and reproduction	2,900		46	3,756	ENSR (1989a) as cited in GEI (2009)
Water flea	*Daphnia magna*	3 wk	3 wk	16% reproductive impairment	reproductive impairment	4,100		45	5,349	Biesinger and Christensen (1972) as cited in GEI (2009)

[a] As stated by GEI (2009)

[b] Values adjusted to a hardness of 100 mg/L (as CaCO3) using a hardness:toxicity slope factor of 0.3331 from GEI (2009).

[c] Not provided by (GEI 2009).