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Report

Faro Project Management Team

Faro Mine Complex Closure and Reclamation – Project Proposal

Current Environmental Conditions Supporting Document

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Current Environmental Conditions Supporting Document

Prepared by:

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Project Number:

107403

Date:

March 31, 2009

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March 31, 2009 Project Number: 107403

Deborah Pitt
Faro Project Management Team
Assessment and Abandoned Mines
Government of Yukon
Box 2703
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Dear Ms. Pitt:

Re: 107403 –Environmental Conditions, Assessment of the Closure and Reclamation Plan for the Faro Mine Complex

Please find enclosed our report titled "*Current Environmental Conditions Supporting Document",* an Appendix for the "Project Proposal - Faro Mine Complex Closure and Reclamation Project Proposal."

We thank you for the opportunity to conduct this work. Please contact the undersigned if you have any questions regarding the information included in this report.

Sincerely,
AECOM Canada Ltd.

For: Kathleen Wood, B.A.
Project Manager
Kathleen.Wood@aecom.com

Encl.

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      B2.2-2. Vangorda Creek Drainage Mine Run-off, Mine Effluent and Internal Sites
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1. Climate and Atmospheric Environment

1.1 Climate (Meteorology)

1.1.1 Climate Overview

The Faro Mining Complex is located in the Anvil Range Mountains within the Macmillan Highlands of the Yukon Plateau-North ecoregion, (Janowicz *et al.*, 2005) contained within the Boreal Cordillera Ecozone. The climate of the Boreal Cordillera Ecozone is marked by long cold winters and short warm summers and ranges from subhumid to semi arid with the coldest mean temperatures occurring in the Yukon Plateau Region (Environment Canada, 2005). The Yukon North-Plateau terrain is made up if rolling uplands, small mountain groups and nearly level table lands dissected by deeply cut, generally broad, U-shaped valleys (www.ec.g.ca).

The climate is characterized as sub-arctic continental with 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 ten degrees lower in valley bottoms as compared to uplands, due to 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.*, 2005)

1.1.2 Meteorological Data Sources

Regional data from a meteorological station operated by Environment Canada in Faro and site specific data from two meteorology stations established at the Faro Mine Complex will be used throughout this section to provide an overall picture of the regional and site specific climate.

From their online climate data service, (www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html, accessed March 2009), Environment Canada has published meteorological data at Faro starting in 1966, however a consistent, generally intact dataset is available from 1972 to present coming from three different stations. This is the dataset used in this baseline report. A summary of the environment Canada Stations can be seen below in Table 1.1-1. Any reference to the Environment Canada Faro station, refer to the station in operation from 1971 – 1977. Another station, Anvil, was also operated by Environment Canada at the Faro Mine Complex with data published online between 1967 and 1991. As this station is no longer in operation, the focus of this baseline compilation has been relating the Environment Canada stations at Faro to those at the mine complex. It is the hope that the Faro A and Faro Aut stations will be a long term stations and the comparisons and correlations made between with the Faro Mine Complex site can continue to be refined as more data becomes available and that this will be a useful tool for future analysis.

The location of the Environment Canada Stations can be seen on Figure 1.1-1. As per the location and elevation information available online climate data service from Environment Canada, Faro and Faro Aut stations are at the same location, while the Faro A is approximately 2.5 km away. Faro A and Faro Aut are at an elevation of 716.6 masl and Faro is at 694.3 masl. This information has not been verified with

Environment Canada, although it would appear there is an error in elevation or location of the Faro Aut station. These three stations are considered to be consistent and have been combined into a single data set for this report. Environment Canada has published the climate normals and extremes between 1971 and 2000 for the Faro A site. These normals and extremes have been used throughout the baseline report to compare and correlate annual data for both the Environment Canada data as well as data from the site stations discussed below.

Two meteorological stations were established at the Faro Mine Complex on the Faro and Grum waste rock dump sites in December of 2003. The station at the Grum waste rock dump is considered representational of the Grum and Vangorda and as such is referred to as the VanGrum Station (Janowicz *et al.,* 2005). The station on the Faro waste rock dump is simply referred to as the Faro site station. The mean elevation of the Grum waste rock dump is 1,250 masl and mean elevation of the Faro waste rock dump is 1,200 masl (Janowicz *et al.,* 2005). Making the waste rock dumps and the site meteorological stations approximately 500 m higher in elevation that the Faro A station. These stations measure air temperature, relative humidity, incoming, outgoing and net radiation, windspeed and direction, rainfall, snowfall, snowdepth, soil moisture and temperature and soil heat flux. These stations are generally performing well with the exception of the collection of winter precipitation readings. The resulting precipitation data is sparse during the winter months (Janowicz *et al.,* 2005). A total precipitation gauge was installed in February of 2008. Data from the instrument has not been used in the baseline report given its short period of record.

1.1.3 Temperature

1.1.3.1 Methods and Data Considerations

The three Environment Canada stations have been used interchangeably to develop the dataset for temperature. A comparison between Faro A and Faro Aut shows the temperatures at the two stations are generally consistent. The normals shown on Figure 1.1-2 for Faro A are from the Normals and Extremes published by Environment Canada (Environment Canada, 2008a) for the period between 1971 and 2000.

The annual averages and extremes shown in Figure 1.1-3 are also from Faro A between 1978 – 2007 and from Faro from 1972-1974 and 1976. The data is taken from the monthly reporting available from Environment Canada's online climate data service. Nine months throughout the Faro A record were missing, and the calculated normal was used in its place to calculate the annual average. Data for 1975, 1977 and 2002 were not complete enough to include in the dataset.

Temperature data from the two mine-site data stations were plotted and compared with Faro Aut data between December 2003 and December 2008. The Faro Aut station was chosen for this comparison as the daily records are more complete than the Faro A records.

1.1.3.2 Regional Temperature Normals and Extremes

The temperature normals and extremes published for the Faro A site (seen on Figure 1.1-2) illustrate the cold winters and warm summers typically seen in this region. The daily average temperature is lowest in

January at -21.5°C and highest in July at 15°C. This gap is further illustrated by an average daily minimum temperature in January of -26°C and an average daily maximum in July of 20.9°C.

The average variation of temperature throughout the day can also be seen by looking at the normal daily minimum and maximum. The change in temperature throughout the day is slightly more pronounced in the summer with an 11.9°C difference between the minimum and maximum in July and less in the winter with an 8.7°C difference in January.

1.1.3.3 Regional Long Term Temperature Trends

The annual average temperatures from 1972 to 2006 can be seen on Figure 1.1-3. This figure shows the mean daily, mean daily minimum and mean daily maximum as well as the extreme minimum and maximum seen each year. A slight warming trend can be seen in these annual means with 1.2°C, 1.5°C and 1.8°C change in the mean daily maximum, mean daily and mean daily minimum respectively. A warming trend is also apparent in the extreme maximum and minimum of 0.5°C and 2.3°C respectively.

1.1.3.4 Local Site Temperature Data

As seen in Figure 1.1-4, temperatures at the each of the Faro Mine site meteorological stations are generally the same with the Faro Site station being slightly warmer than the VanGrum Site station in winter and slightly cooler in the summer. A comparison of the daily average temperatures at the mine sites with those at the Faro Aut station (seen on Figure 1.1-5) 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 mine sites, due to temperature inversions (Janowicz *et al.,* 2005).

1.1.3.5 Expected Temperature Conditions at the Faro Mine Site

While a long-term, complete dataset at the Faro Mine Complex site does not exist, a strong correlation exists between the temperatures seen at Faro A and those seen at the site stations. Plots of the temperatures at the two sites with those at the Faro A Station and the resulting regression analysis and equations can be seen on Figures 1.1-6 and 1.1-7. With this correlation, the normals published for the Environment Canada Faro A station can be adapted to the Mine sites using these equations.

1.1.4 Precipitation

Please see Section 3.1.3.1 – Climate Water Balance, in the Hydrology Baseline Study (Section 3.1).

1.1.5 Wind

1.1.5.1 Data Sources and Considerations

Environment Canada's meteorological station in the town of Faro (Faro AUT) and Project specific meteorological stations, as described above were used to assess surface winds for the five year period between 2004 and 2008. Wind speed, wind class frequency data, and wind direction were assessed and are

presented below in a series of windroses. The description of winds have been presented according to season, with a summary of total wind speed, wind direction and wind class frequency for the Faro AUT, Faro Site and VanGrum Site stations presented on Figure 1.1-8, followed by wind speed and direction for the same three stations for summer and winter on Figures 1.1-9 and 1.1-10 respectively.

1.1.5.2 Summary of Wind Speed, Wind Direction and Wind Class Frequency

Wind speeds average 2.378 m/s for Faro AUT, 1.979 m/s for the Faro site station and 3.0 m/s for the VanGrum site station. Across data sets, calm winds occur at lower frequencies (Faro AUT >1%, Faro site >10%, VanGrum on site >2%). Figure 1.1-8 also suggests that the data has a higher percentage of wind class frequencies across calmer wind classes (0.5-5.7 m/s).

At Faro AUT, winds predominately flow from the southwest and northeasterly quadrants. Wind direction at the Faro site station is predominantly from the southern quadrants. Figure 1.1-8 shows that at the VanGrum site station, wind direction is predominately from the northwest and southeast quadrants.

1.1.5.3 Seasonal Wind Speed and Wind Direction

The seasonal analysis of the wind data is defined as:

- Summer: May, June, July, August, September; and
- Winter: October, November, December, January, February, March, April.

Summaries for the wind speed and direction can be seen on Figures 1.1-9 and 1.1-10 for summer and winter respectively.

Summer wind speeds average 2.3 m/s for Faro AUT, 2.0 m/s for the Faro site station and 2.0 m/s for the VanGrum site station. At Faro AUT, prevailing wind direction in the summer is from the northwest and southeast quadrants. Wind direction at the Faro site station flows from the following divided quadrants: between NNE(~11%), NE(~7%), SSE (~9%), S (~8%), SW(~10%), W(~11%), and WNW(~7%). At the Vangrum on site station, wind direction is predominately from the northwest and southeast quadrants.

Winter wind speeds average 2.4 m/s for Faro AUT, 2.0 m/s for the Faro site station and 3.0 m/s for the VanGrum site station. At Faro AUT, prevailing wind direction occurs from the southeast quadrant. Wind direction at the Faro site station is variable but occurs predominately from the eastern quadrants. At the VanGrum site station, wind direction is predominately from the Northwest and Southeast quadrants.

Based on this seasonal analysis, there is seasonal wind variation. In general, the region appears to experience elevated frequency of higher wind speeds during the winter months.

1.1.6 Solar Radiation

1.1.6.1 Data Sources and Considerations

A record of solar radiation is not published for the Environment Canada Faro stations. The meteorological stations at the mine complex measure solar radiation and the average daily solar radiation for each month is seen on Figure 1.1-11 Although this data set is for only five years, a strong correlation exists for the average daily solar radiation for each month at both and an average value can be easily expressed. Table 1.1-2 below shows the monthly data (as was plotted on Figure 1.1-14) with the calculated monthly average and the correlation between the monthly averages for each year.

1.1.7 Evaporation and Evapotranspiration

Please see Section 3.1.3.1 – Climatic Water Balance, in the Hydrology Baseline Study (Section 3.1) – Assuming there will be mention of humidity in this section. Will check when hydrology section received.

Legend

- Meteorological Station

N
W E
S

Kilometers
0 1 2

1:100,000

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro

Climate Station Locations

March 2009

AECOM

Figure 1.1-1

Map Document: (S:\GIS_Pdata\Faro\107403_80649_FaroGIS\MXD\107403_DFIG1.1-1_Climate Stations_ml_09-Mar31.mxd)
31/03/2009 -- 4:39:00 PM

Figure 1.1-2. Monthly Temperature Normals and Extremes (1971-2000) - Faro A

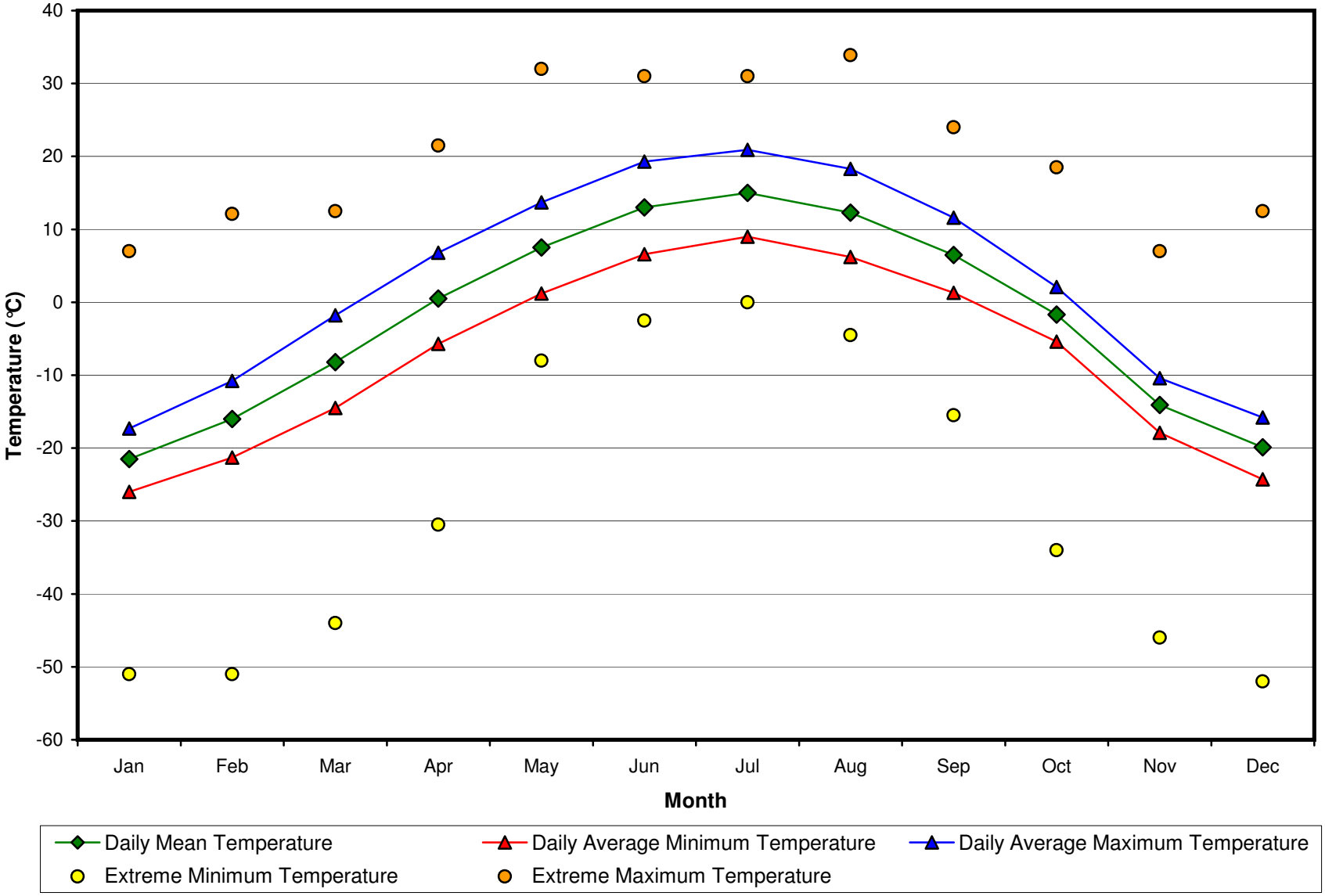

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Figure 1.1-3. Mean Annual Temperature - Faro A

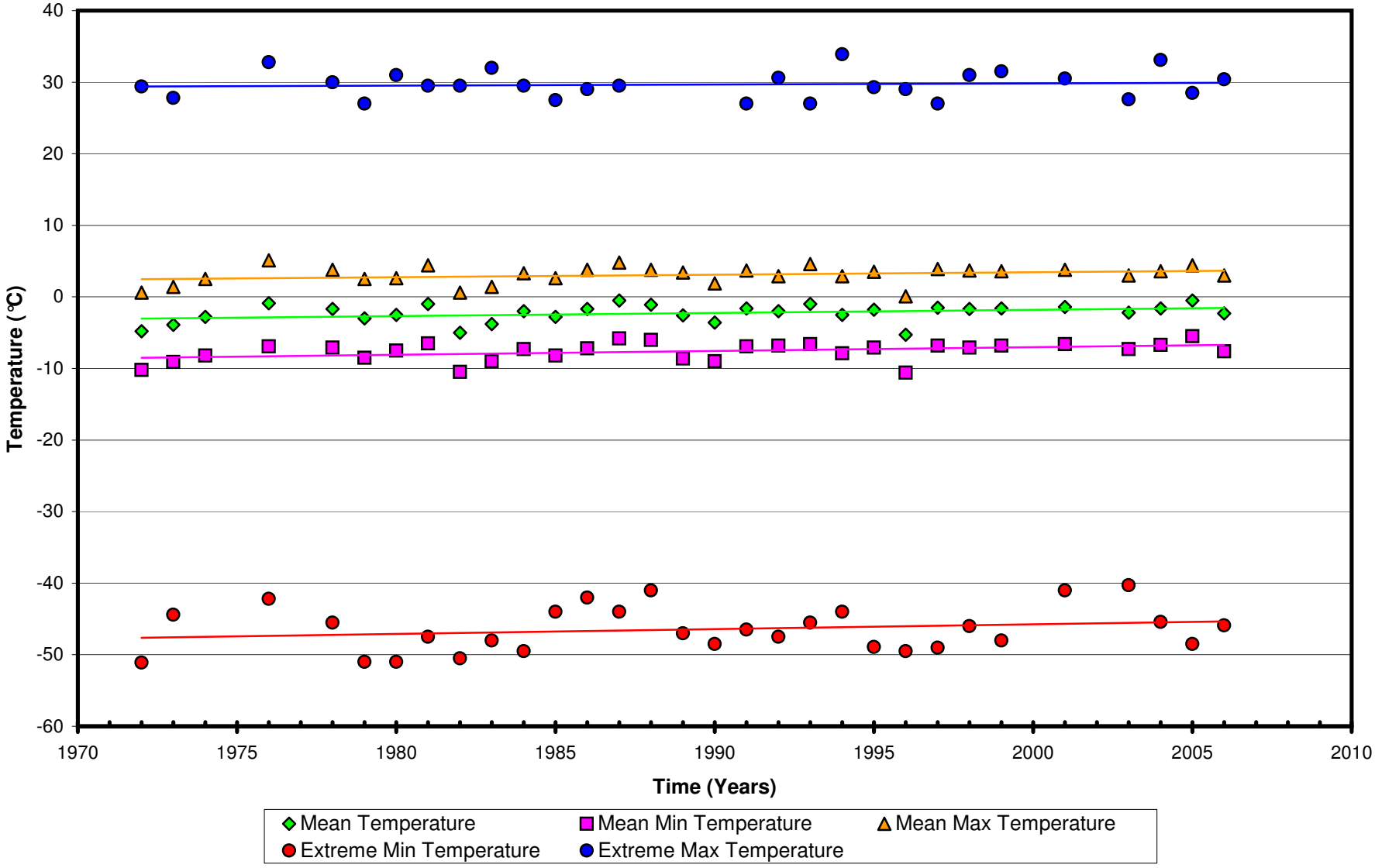

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Figure 1.1-4. Daily Average Temperature

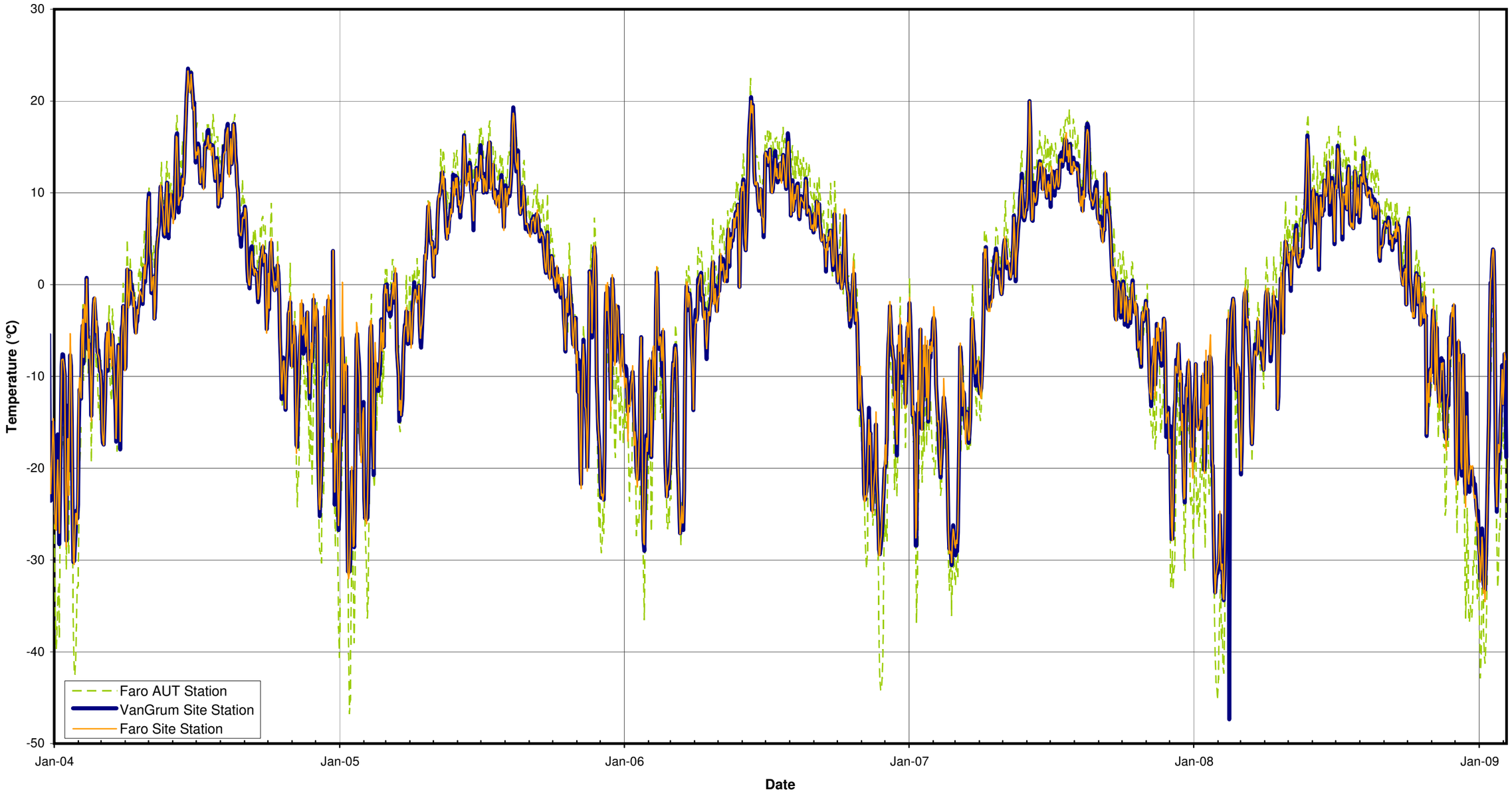

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Figure 1.1-5. Comparison of Monthly Average Temperature with Faro A Normal

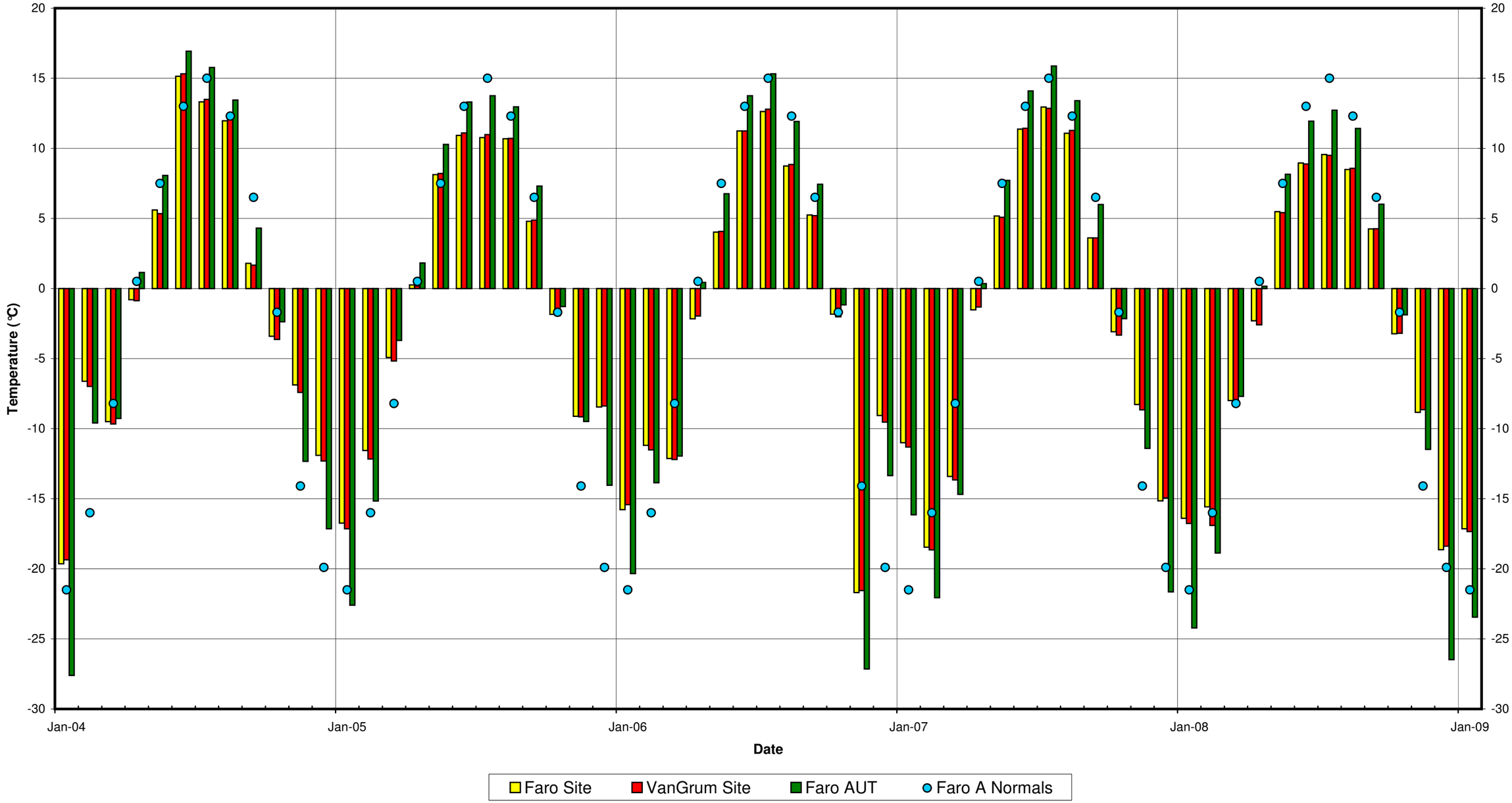

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Figure 1.1-6. Correlation Between Daily Temperature at Faro Site and Faro AUT

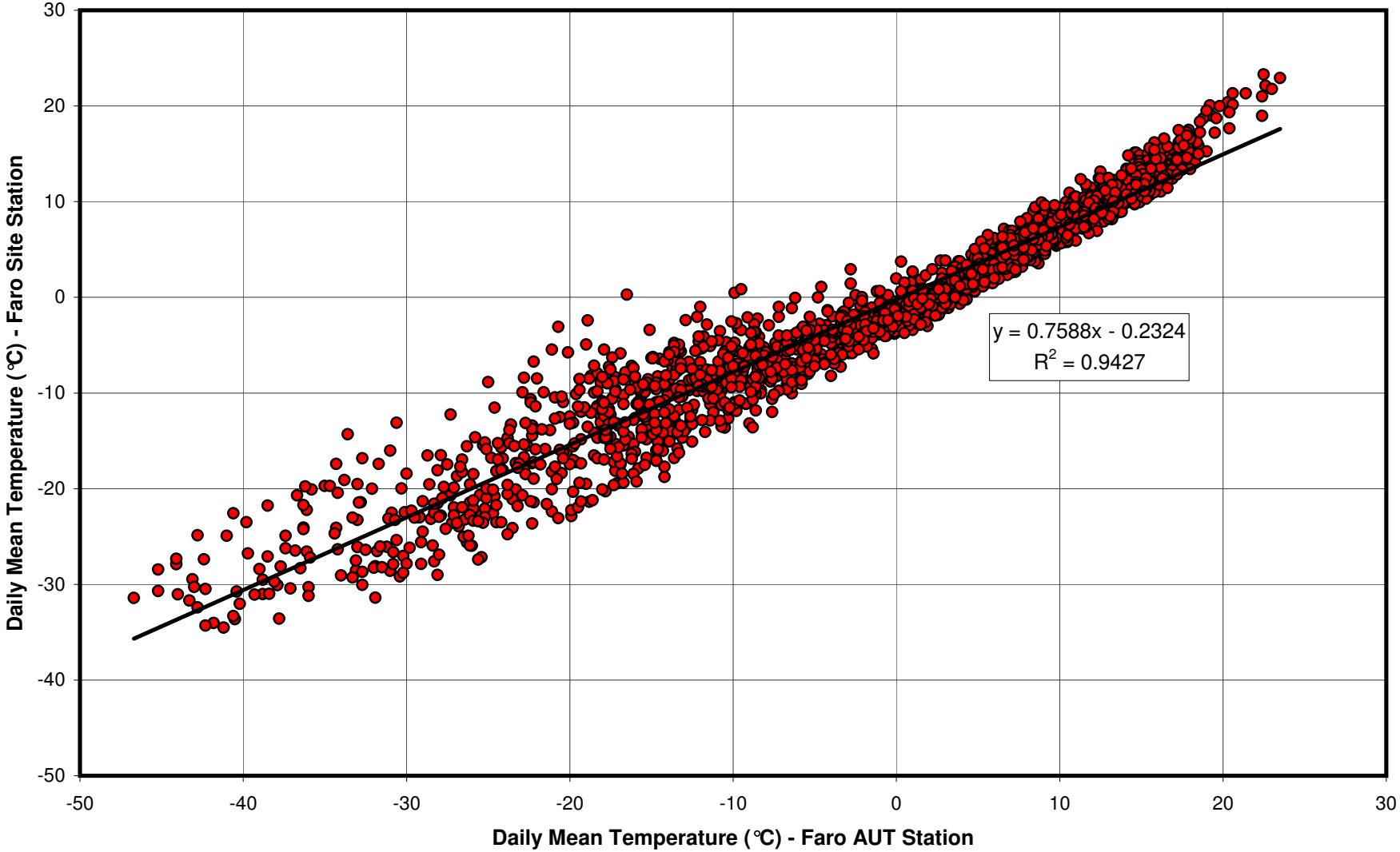

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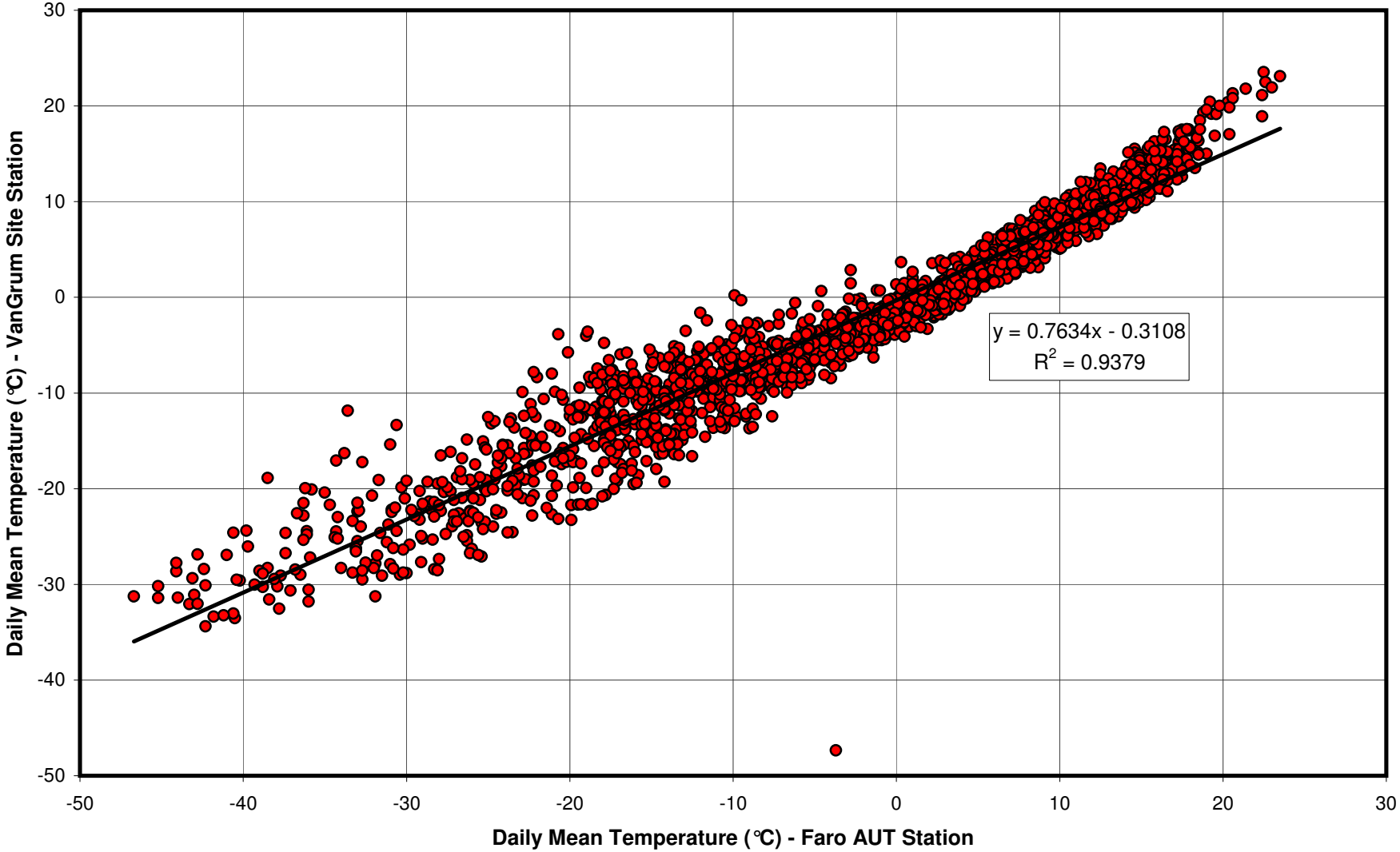
Figure 1.1-7. Correlation Between Daily Temperature at VanGrum Site and Faro AUT



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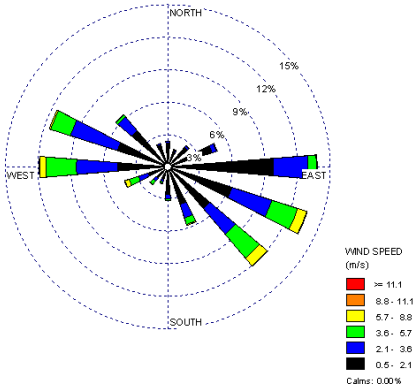
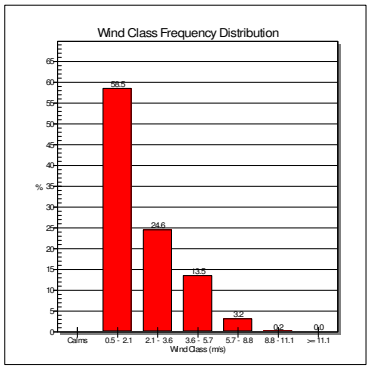
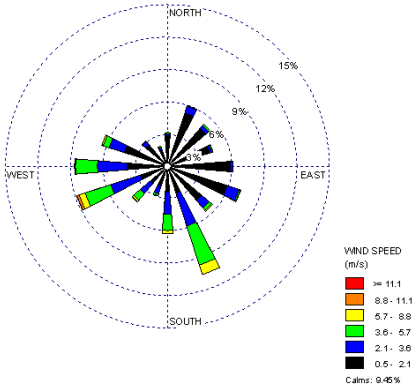
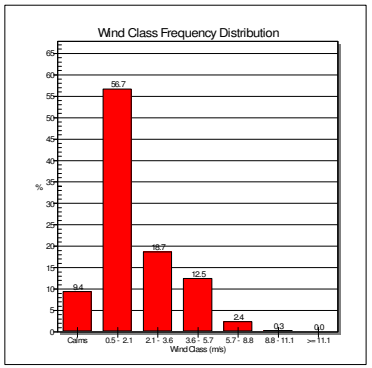
Faro AUT (2004-2008)



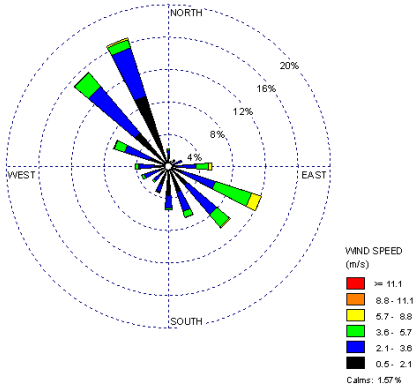


Faro Site (2004- 2008)





VanGrum Site (2004-2008)



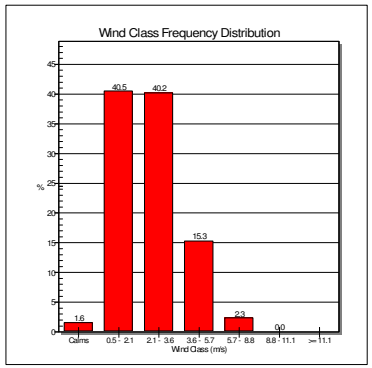


Figure 1.1-8. Summary of Total Wind Speed, Wind Direction, and Wind Class Frequency

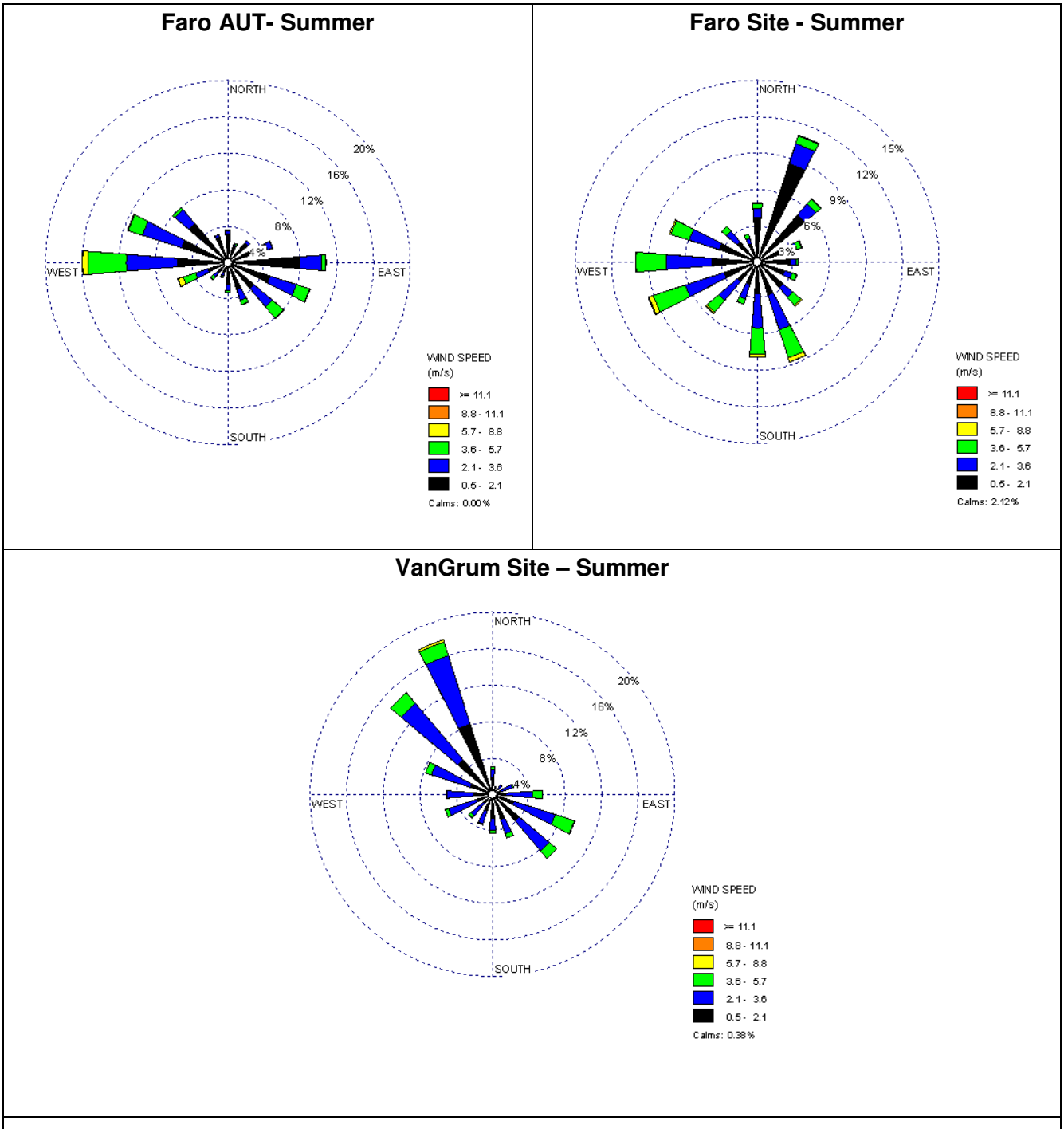


Figure 1.1-9. Summary of Summer Wind Speed and Wind Direction

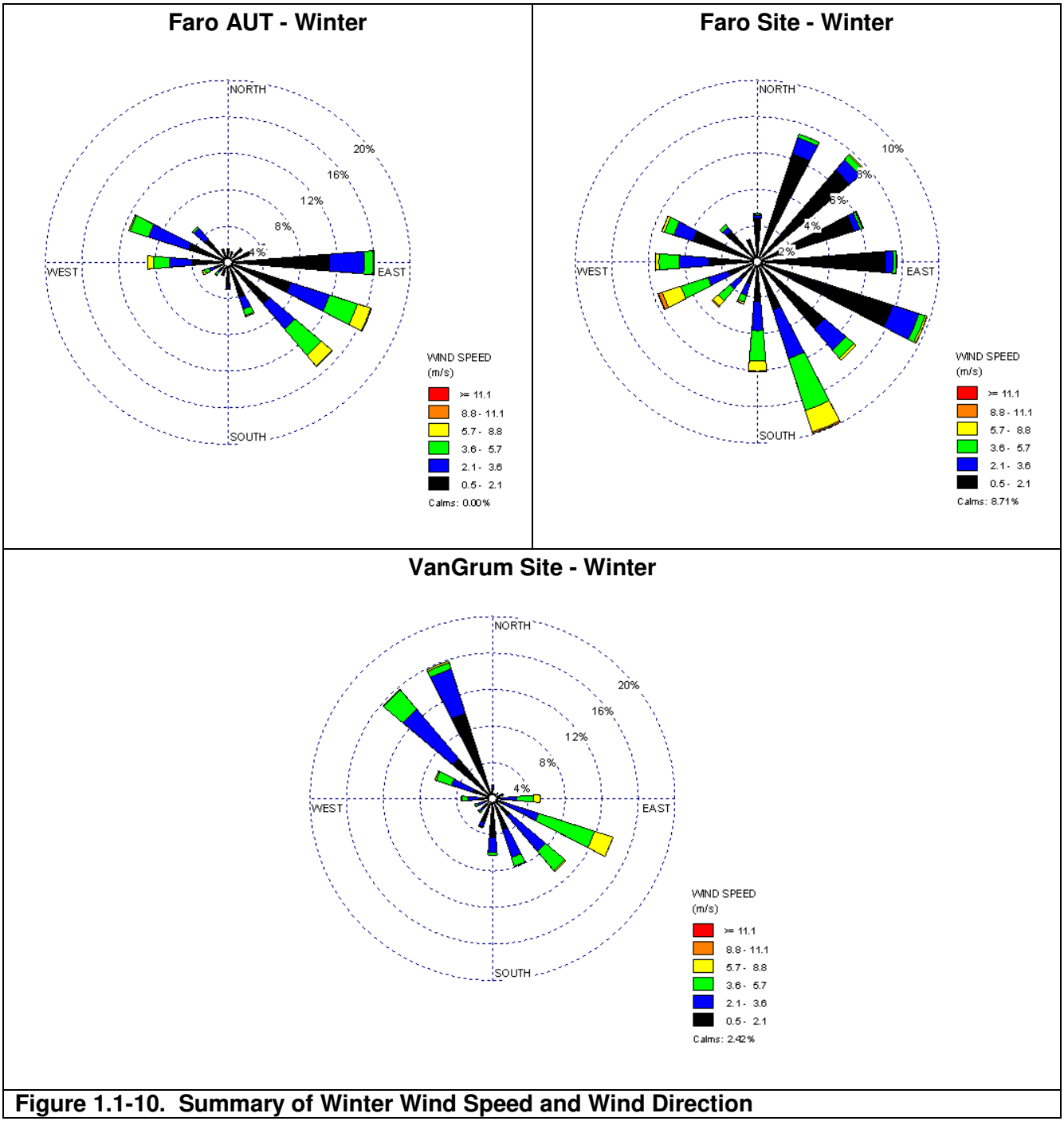


Figure 1.1-10. Summary of Winter Wind Speed and Wind Direction

Figure 1.1-11. Average Daily Solar Radiation (KW)

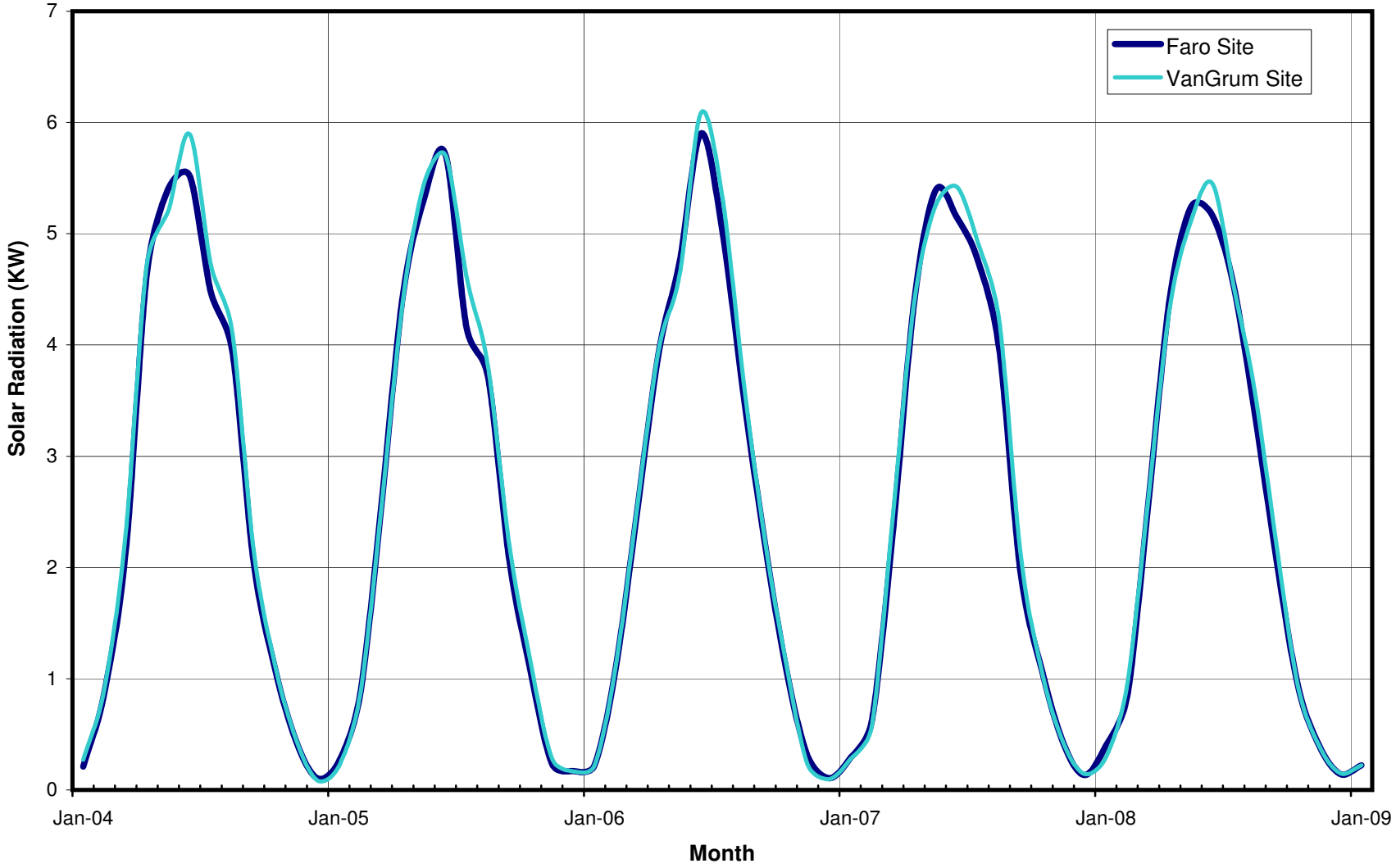


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Table 1.1-1. Environment Canada Meteorological Stations around Faro

Environment Canada Station	Period of Monthly Reporting	Parameters Measured	In Baseline Dataset
Faro	1966 - 1968	Temperature[1], Total Precipitation[2]	No
Faro	1971 - 1977	Temperature[1], Total Precipitation[2], snow on ground	Yes
Faro A	1978 - present	Temperature[1], Total Precipitation[2], snow on ground	Yes
Faro Aut	2002 - present	Temperature[1]	Yes
Anvil	1967 - 1991	Temperature[1], Total Precipitation[2], snow on ground	No

1. Temperature includes mean maximum, mean, mean minimum, extreme maximum, extreme minimum..
2. Total precipitation includes total rainfall and total snowfall, reported separately.

Table 1.1-2. Average Daily Solar Radiation

	Station	Average Daily Solar Radiation (KW)					Average	Correlation
		2004	2005	2006	2007	2008		
January	Van Grum	0.27	0.21	0.22	0.28	0.30	**0.26**	0.61
	Faro	0.21	0.25	0.22	0.28	0.40		
February	Van Grum	0.91	0.86	1.11	0.56	0.95	**0.87**	0.97
	Faro	0.88	0.87	1.09	0.61	0.84		
March	Van Grum	2.31	2.55	2.54	2.44	2.63	**2.46**	0.98
	Faro	2.15	2.57	2.51	2.31	2.59		
April	Van Grum	4.73	4.38	3.95	4.39	4.33	**4.36**	0.97
	Faro	4.65	4.43	3.92	4.38	4.41		
May	Van Grum	5.21	5.45	4.64	5.25	5.12	**5.18**	0.90
	Faro	5.41	5.31	4.75	5.39	5.24		
June	Van Grum	5.89	5.70	6.09	5.42	5.45	**5.60**	0.90
	Faro	5.52	5.71	5.90	5.15	5.16		
July	Van Grum	4.72	4.61	5.32	4.92	4.53	**4.70**	0.86
	Faro	4.47	4.15	5.02	4.76	4.53		
August	Van Grum	4.12	3.81	3.66	4.22	3.57	**3.79**	0.98
	Faro	3.95	3.72	3.54	3.97	3.38		
September	Van Grum	2.17	2.21	2.25	2.12	2.22	**2.14**	0.93
	Faro	2.06	2.08	2.21	1.95	2.09		
October	Van Grum	1.13	1.16	1.13	1.06	0.94	**1.07**	0.91
	Faro	1.09	1.07	1.09	1.08	0.95		
November	Van Grum	0.45	0.28	0.23	0.43	0.40	**0.36**	0.89
	Faro	0.44	0.24	0.31	0.42	0.40		
December	Van Grum	0.08	0.17	0.10	0.14	0.15	**0.13**	0.96
	Faro	0.10	0.17	0.11	0.13	0.14		

1.2 Atmospheric Environment

1.2.1 Introduction

For the purposes of this assessment, atmospheric environment refers to the conditions of the atmosphere in the vicinity of the project. These conditions will be described by the following valued components (VCs):

- Air quality; and
- Greenhouse gases (GHGs).

Air quality has been selected as a VC because of its intrinsic importance to the health and well-being of humans, wildlife, and vegetation. Several epidemiological studies published over the last few decades have demonstrated the link between poor air quality and negative human health outcomes.

Similarly, GHGs have been selected as a VC because of their intrinsic importance to climate change as a regional and international issue. The Government of Canada has recognized that climate change is a major concern to all Canadians. They have prepared an action plan to fight climate change that will reduce emissions of greenhouse gases (GHGs) and help Canadians across the country to adapt to a changing climate. They also recognize that achievement of their goals to reduce GHG emissions requires working together with public, industry, provinces and territories.

It is important, therefore, to develop an appreciation of the current state of the regional atmospheric environment, including the relative influence of mine-related and other air contaminant emission sources. A review of the existing concentrations and releases of air contaminants and GHGs will serve as a benchmark for comparing the emissions related to the proposed Project.

1.2.2 Local Study Area

The local study area (LSA) for the assessment of air quality and GHGs is the zone of influence of the project air emissions, including the sensitive receptors nearest to the mine site. As such, the LSA will include the town of Faro.

Within the spatial domain of the assessment, the Project effects on air quality and GHG emissions are manifest most strongly in the region of the pits, tailings areas and roads associated with the Faro Mine Complex and the Vangorda and Grum pit areas.

1.2.3 Potential Issues

1.2.3.1 Air Quality

The proposed project has the potential to impact the local air quality primarily through construction activities related to the proposed remediation activities. The long-term operational phase of the remediated mine site also has the potential to impact the local air quality through the mitigation of fugitive releases of mine-associated tailings and dust.

The potential effects during the construction phase will be related to the airborne dust and diesel emissions generated by construction activities. Following construction, there is a potential for positive effects on air quality due to the re-sloping and covering of exposed tailings and waste rock.

1.2.3.2 GHGs

The mine closure has the potential to affect existing GHG levels during its construction phase. The main component of the mine closure activities that may affect GHG levels is the increased diesel emissions during the construction phase due to increased vehicles and construction equipment on the Project site.

The following table summarizes the potential issues/effects, the relevant VC and the important measureable parameters for the VC.

Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless gas resulting from the incomplete combustion of hydrocarbon fuels. For this Project, CO emissions may result from the use of mobile equipment and stationary combustion sources such as diesel generators, particularly during the construction phase.

Fine Particulate Matter

The overall, post-closure impact of the Project is expected to reduce emissions of particulates from fugitive dust sources, such as tailing piles and roads. Construction activities may result in emissions of fine particulate matter from various sources including mobile transportation, auxiliary power units, and combustion-powered equipment. Fine particulate matter is composed of a wide range of materials arising from dust emissions and combustion of fuels. The material components of fine particulate matter in the ambient air in the project region may include elemental metals and non-metals from exposed by the mining operations.

Fine particulate matter is typically assessed as a mass size fraction because the effectiveness of the human body's defences against particles is dependent on particle size. Mass size fractions PM_{10} and $PM_{2.5}$ are of concern due to their characteristic ability to penetrate the human respiratory system. PM_{10} expresses particulate concentrations as the total mass size fraction at or below an aerodynamic diameter of 10 µm. $PM_{2.5}$ is defined as particulate matter with a diameter of less than 2.5 µm. This fraction is often described as the fine fraction of PM_{10}.

Metals and Non-metals

The environmental and human health effects of metals and non-metals depend on the pathways by which these parameters reach humans and the environment. The degree of concern regarding environmental and human health effects varies with each metal and non-metal. Construction activities for the remediation of the Project site has the potential to emit metals and non-metals as fugitive emissions.

Nitrogen Dioxide (NO_2)

The oxides of nitrogen (NO_X) comprise of nitric oxide (NO) and nitrogen dioxide (NO_2). The majority of ambient atmospheric NO_X is emitted in the form of NO, which is oxidised in air to produce NO_2. The conversion of NO to NO_2 takes place via reactions with chemically active species, such as ozone. NO_X is emitted from most combustion sources, including motor vehicles, auxiliary power units and combustion-powered equipment.

Sulphur Dioxide (SO_2)

SO_2 is a corrosive acid gas which combines with water vapour in the atmosphere to produce acid rain. Both wet and dry deposition may cause damage and destruction of vegetation. SO_2 may also lead to the degradation of soils, building materials and watercourses. SO_2 in ambient air is also associated with asthma and chronic bronchitis.

Dust as Total Suspended Particulates (TSP)

Dust is defined as all particulate matter up to 75 µm in diameter and comprises both suspended and deposited dust. The negative effects associated with dust include irritation of the eye, nose and throat, and the nuisance caused by deposition on cars, windows, property, and the natural environment. Dust emissions may arise from both construction activities and emissions from vehicles associated with the Project. Dust from construction and industrial activities is typically assessed as total suspended particulates (TSP). TSP is a measure of the total amount of particulates of all size fractions in ambient air and is generally used to represent the potential for nuisance dust effects such as soiling.

Volatile Organic Compounds (VOCs)

Many VOCs are known are suspected of having direct toxic effects to humans. Once in the atmosphere, some reactive VOCs can also combine with NOx through photochemical reactions to form ozone, which is a major component of smog. VOC emissions may arise from the use of mobile equipment and stationary combustion sources such as diesel generators during the construction phase of the Project.

1.2.4 Baseline Ambient Air Quality Assessment

Baseline ambient air quality data were obtained from federal emission inventory reports, and an ambient air quality monitoring campaign conducted in 2008 by Senes Consultants Limited. Information is presented based on past air monitoring completed at the Project Site, the National Pollutant Inventory Report 2006 (Environment Canada, 2008) and Canada's Greenhouse Gas Inventory (Environment Canada, 2007).

1.2.4.1 Ambient Air Quality Monitoring

Ambient Air Quality Criteria

The evaluation of air monitoring data typically relies on regulatory standards or objectives with respect to atmospheric concentrations. Although, the Yukon government has the primary responsibility for various

aspects of air pollution control, federal actions are also commonly integrated into air quality assessments. The Canadian Environmental Protection Act (CEPA) allows for the federal regulation and control of air emissions and concentrations. The two important federal tools used to help control air quality pollutants are:

- National Ambient Air Quality Objectives (NAAQOs); and
- Canada-Wide Standards (CWS).

NAAQOs help guide the federal and Yukon governments in making decisions regarding air quality management. The NAAQOs are primarily effects-based but are also reflective of technological, economic and societal information. These objectives are national goals for outdoor air quality for the protection of public health, the environment and aesthetic properties of the environment.

The NAAQOs from the federal government are based on a three-tier structure and are defined as follows:

- **The Maximum Desirable Level (MDL)** is the long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted parts of the country and for the continuing development of pollution control technology.
- **The Maximum Acceptable Level (MAL)** is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort, and well-being.
- **The Maximum Tolerable Level (MTL)** denotes time-based concentrations of air contaminants beyond which, because of a diminishing margin of safety, appropriate action is required to protect the health of the general population.

Under CEPA 1999, CWS are considered environmental quality objectives. Yukon has endorsed the CWS for $PM_{2.5}$ through the Canadian Council of Minister of the Environment (CCME).

The limits or objectives set by the federal or Yukon governments were used to assess the existing ambient air quality surrounding the Faro mine site. Through the remainder of this report, limits or objectives for air quality will be termed as air criteria. Air criteria from the federal and Yukon governments were used for compounds for which they were available. For contaminants that did not have criteria outlined by the federal or Yukon governments, air criteria from British Columbia were used. British Columbia is the next nearest jurisdiction and shares some common air quality issues and concerns with Yukon. As such, air criteria from this province are considered reasonable to assess existing air quality.

The British Columbia criteria are defined as follows:

- **Level A** is set as the objective for new and proposed discharges and, within the limits of best practicable technology, to existing discharges by planned staged improvements for these operations.
- **Level B** is set as the intermediate objective for all existing discharges to meet within a period of time specified by the Director (MLWAP), and as an immediate objective for existing discharges which may be increasing in quantity or altered in quality as a result of process expansion or modification.
- **Level C** is set as the immediate objective for all existing chemical and petroleum industries to reach within a minimum technically feasible period of time.

British Columbia has set ambient air quality criteria for all key air quality indicators, except for some of the particulate matter constituents. To fill these gaps, air quality criteria from Ontario were used. Ontario has developed the most complete list of air quality criteria among the Canadian provinces and territories. These criteria are effect-based levels in air, with variable averaging periods appropriate for the effect that they are intended to protect against. The effects considered may be based on health, odour, vegetation, soiling, visibility, corrosion or other effects.

The Ontario criteria for local air quality are defined as follows:

- **Standard** is a maximum point-of-impingement concentration acceptable as a worst-case impact from a single facility.
- **Guideline** is a level reflecting general air quality independent of location, meant for use in environmental assessment or air monitoring studies.
- **Jurisdictional Screening Level (JSL)** is a screening level for assessing the potential for concern caused by contaminants that do not yet have Standards or Guidelines in Ontario, but have levels set out by other jurisdictions, principally Michigan and Texas.

The applicable federal and provincial criteria relating to ambient air quality are summarized in Table 1.2-2 for Criteria Air Contaminants and Table 1.2-3 for metals and non-metals.

Ambient Air Quality Monitoring Historical Data

For any environmental effect assessment it is essential to accurately determine a baseline against which predicted effects can be gauged and assessed. A review of readily available air quality literature and information sources suggests that relatively little air quality monitoring is, or has been, undertaken in the vicinity of the Faro Mine Project. The nearest air monitoring station is the Whitehorse National Air Pollution Surveillance network station over 200 km away from the project site.

RWDI conducted two ambient air monitoring programs in 2005 to assess ambient air quality in the project region. No useful data were obtained. Due to very wet weather conditions during the sampling period, negligible amounts of fugitive emissions were detected from the mine site during both sampling programs (RWDI 2005).

Ambient Air Quality Monitoring Results

Baseline ambient air quality concentration measurements for the project region were obtained from an ambient air quality monitoring campaign conducted in 2008 by Senes Consultants Limited. The details of the monitoring program can be found in the attached report in **Appendix A**.

Samples of TSP and respirable PM_{10} were collected by Senes at eight sites located in the Faro Mine Complex and one site in the town of Faro. The monitoring program consisted of thirteen (13) 24-hour sampling periods in July, August, September and October.

The locations of the (9) nine environmental effects air monitoring stations were distributed widely to include tailings impoundments, rock dumps, heavy haul road/mill areas, and the Faro town site. The nine (9) air sampling locations were distributed among the two main Faro Mine Complex areas – the Faro pit, and the Grum and Vangorda pits – and the neighboring town of Faro. Five (5) sites were established in the vicinity of the Faro mine pit and tailings area. Three (3) sampling sites were located in the vicinity of the Vangorda and Grum mine pits. One (1) site was located in the Town of Faro to provide a measure of background concentrations. Each of these three regions is separated by a minimum of 8 km. The locations of the sampling sites are presented in Figure 1.2-1 and described in Table 1.2-4.

The ambient air monitoring program measured specific contaminants known or thought to exist at the Faro Mine Complex.

Monitored Parameters

The program included particulate matter sampling and 30 metals parameters. The parameters of the air monitoring program were consistent with a review of chemicals that were identified during prior investigations of the site, and an initial air monitoring study done by RWDI assessing monitoring parameters that should be considered.

Monitoring Methodology

Sampling methodology is discussed with reference to the following sampling procedures:

- British Columbia Field Sampling Manual British Columbia Field Sampling Manual, HiVol Particulate Sampling Procedure ;
- BC Air Monitoring Guidelines: Volume 1 Particulate Non-Continuous (British Columbia Ministry of Environment, 1996);
- British Columbia Environmental Laboratory Manual; and
- National Air Pollution Surveillance network schedule (Environment Canada and Health Canada, 1998, “National Ambient Air Quality Objectives for Particulate Matter”).

The program methodology sampled 24-hour average concentrations of TSP and PM_{10} at nine sites on a 1-in-6 day sampling schedule. This is consistent with the BC Air Monitoring Guidelines: Volume 1 Particulate Non-Continuous (British Columbia Ministry of Environment, 1996), and the National Air Pollution Surveillance network schedule.

Samples were collected using MiniVol™ 5 liter-per-minute (LPM) samplers and standard USEPA 47 mm Teflon filters. Note that the MiniVol™ is not a reference sampler in any aforementioned sampling procedures. The MiniVol™ comprises the majority of the US EPA Saturation Monitor Repository. However, the 47 mm filter size is standard and consistent with the BC Air Monitoring Guidelines: Volume 1 Particulate Non-Continuous (British Columbia Ministry of Environment, 1996).

Data on the maximum deposition rate and trace constituents in dustfall were obtained using two canisters. The results were analyzed by CANTEST according to methods prescribed by the British Columbia

Environmental Laboratory Manual, using gravimetric analysis for total mass of particulates, and inductively coupled plasma mass spectrometry (ICP/MS) for elemental composition.

Discussion of Results

A summary of the sampling results for TSP and PM_{10} concentrations are presented in Table 1.2-5. Results are grouped into three areas: the Faro mine area; the Grum and Vangorda area; and the town of Faro.

The maximum 24-hour TSP concentration was 95 µg/m^3, which is below the NAAQO acceptable level of 120 µg/m^3. The maximum result occurred in the Vangorda and Grum Area on the breach dam beside the effluent discharge pond between the Vangorda and Grum pits.

The maximum 24-hour PM_{10} concentration for a valid sample was 19 µg/m^3, which is below the British Columbia Level B threshold of 50 µg/m^3. This maximum also occurred in the Vangorda and Grum Area, northwest of the Grum pit beside the ore transfer pad.

This analysis included data from three days with elevated 24-hour precipitation (greater than 1 mm). Precipitation is known to scavenge suspended particles through a process known as wet deposition, thereby reducing the atmospheric concentration. The amount and frequency of precipitation during the Senes sampling program did not significantly affect data collection or the results.

Also, only valid samples were considered for the analysis. A sample was not considered valid if the sampling time was not within 10% of 24 hours, as per the Ontario Ambient Air Monitoring Manual (Ontario PIBS 6687, 2005). Additionally, a sample was considered invalid if the TSP concentration was less than the PM_{10} concentration. These samples were considered suspect, as PM_{10} is a subset of TSP and should be present in mass concentrations less than or equal to TSP.

A summary of the sampling results for the particulate constituent concentrations are presented in Table 1.2-6.

Seven parameters measured were not detected during the monitoring campaign. The concentrations of these parameters were below their Method Detection Limits for over 98% of the samples. They are indicated as MDL in Table 1.2-6 and are listed below:

- Antimony (Sb);
- Beryllium (Be);
- Boron (B);
- Cobalt (Co);
- Selenium (Se);
- Tellurium (Te); and
- Vanadium (V).

Twenty-one parameters were detected above their Method Detection Limits. These results are grouped into three areas: the Faro mine area, the Grum and Vangorda area, and the town of Faro. Maximum concentrations for seventeen parameters occurred in the Faro Mine Area; four maxima occurred in the Vangorda and Grum Area, and one occurred in the Town of Faro.

Of the 30 constituents analyzed, none were found to exceed their respective air criteria. This is shown in Table 1.2-7.

Most parameters were detected in small amounts, with maximum concentrations lower than 1 µg/m^3. The only compounds with maximum concentrations exceeding 1 µg/m^3 were Sodium (with the highest measured concentration at 9.4 µg/m^3) and Iron (with the highest concentration at 1.4 µg/m^3). Sodium has no air criterion, and is only toxic at high levels of ingestion (TOXNET, US National Library of Medicine, Toxicity record of sodium, chem.sis.nlm.nih.gov/chemidplus). The maximum concentration for iron was well below the air criterion of 4 µg/m^3.

Gap Analysis

Siting of Air Monitoring Stations

The level of confidence needed to ensure that the maximum concentration levels are observed is dependent on the air monitoring sites being located in areas that are downwind from the Project location. For this analysis, wind directions and speeds during the sampling program were reviewed. The wind direction and speeds are illustrated in Figure 1.2-2 as windroses and frequency distribution graphs. Windroses are a convenient way to assess winds. In the windroses below, the length of radial barbs indicate the total percent frequency of winds from the indicated direction, while portions of the barbs of different colors and widths indicate the frequency of associated wind speed categories.

The predominant wind directions in the Faro Mine area during the monitoring periods were from the southwest directions. The predominant winds in the Vangorda area during the monitoring periods were from the north-westerly directions. These wind directions suggest that monitoring equipment would capture on-site emissions best if placed southeast of emissions sources in the Vangorda Grum area. While the wind directions in the Faro Mine area suggest monitoring equipment would capture on-site emissions best if placed northeast of emission sources.

Table 1.2-8 provides a more detailed wind analysis for each monitoring day. For majority of the monitoring program, the following monitoring stations were not downwind of the Project site:

- TL1 and TL2 for the mine tailings in the Faro Mine area;
- RC1 for the mine tailings and pit in the Faro Mine area;
- A1 for the pit in the Faro Mine area; and
- VG1 for the Grum pit and transfer pad in the Vangorda area.

As a result, these stations were primarily impacted by natural dust and not mine related dust. However, TL3, VG2 and G1 were in locations that captured downwind emissions relevant to the Project site.

Analysis of the wind speed frequencies illustrate that there is no evidence of particularly high wind speeds or otherwise unusual or atypical conditions that would adversely affect the monitoring results.

Analysis of Data Recovery

The acceptability of data recovery for the 2008 air monitoring program is assessed using the following sampling procedures:

- British Columbia Field Sampling Manual, HiVol Particulate Sampling Procedure;
- British Columbia Air Monitoring Guidelines: Volume 1 Particulate Non-Continuous (1996);
- British Columbia Environmental Laboratory Manual;
- Ontario Ambient Air Monitoring Manual (Ontario PIBS 6687, 2005); and
- National Air Pollution Surveillance network schedule (Environment Canada and Health Canada, 1998, "National Ambient Air Quality Objectives for Particulate Matter").

For the data analysis of the ambient air monitoring program, a sample was not considered to be valid if the sampling time was not above 10% of 24 hours, as per the Ontario Ambient Air Monitoring Manual. Additionally, a sample was considered invalid if the TSP concentration was less than the PM_{10} concentration. These samples were considered suspect, as PM_{10} is a subset of TSP and should be present in mass concentrations less than or equal to TSP.

Sampling for thirteen 24-hour periods at nine sites in the vicinity of Faro Mine yielded 117 samples in total for each of TSP and PM_{10}. Of the 117 samples, eighty were valid samples. This results in a data recovery of 68%. This is below the 85% limit outlined in the British Columbia Field Sampling Manual, HiVol Particulate Sampling Procedure; and the 75% minimum recovery prescribed by the Ontario Ambient Air Monitoring Manual. The data recovery of 68% is lower than that of typical air monitoring protocols. The low data recovery may be a result of technical issues encountered during the original field surveys and monitoring data periods.

In summary, the data recovery is lower than best practices permit, suggesting that these results should be supplemented with other sources of information. Therefore, emissions inventories were also assessed for the baseline environment.

1.2.4.2 Criteria Air Emissions Inventory

It is useful to examine the existing releases of air contaminants from local sources in the Assessment Area. This serves as a benchmark for comparing the emissions related to the proposed Project. These existing releases of air contaminants are generally classified as criteria air contaminants (CACs), which include PM, SO_2, NOx, CO and VOCs.

There are no industrial facilities in the vicinity of the Faro Mine Site reporting emissions. Therefore, the only other significant source of air emissions in the study area is the town of Faro. The town of Faro produces air contaminant emissions that are typical of a small urban center, such as transportation fuel emissions.

Table 1.2-9 presents the 2006 emissions for each sector in the Yukon. The 2006 emission inventory is the most recent available compiled data and is considered to be representative of a typical year.

According to Table 1.2-9, the leading sources of air contamination are natural sources. In the Yukon, VOCs were the most significant air contaminant (by mass). Natural sources were the largest emitter of VOCs.

A review of the data above, demonstrates that open sources and natural sources account for majority of the particulate emissions in the existing environment. Open sources comprise of anthropogenic processes such as construction, waste, mine tailings, and agriculture.

115,085 tonnes of CO were emitted in 2006. The majority of CO emissions were emitted from natural sources. The industrial, non-industrial, and mobile sectors also contributed to the air contaminant emissions, with mobile sources as the most prevalent within these three sectors. Both CO and NOx represented a substantial quantity of the total emissions produced by these three sectors.

1.2.4.3 GHG Emission Inventory

Environment Canada's *"Turning the Corner, Regulatory Framework for Industrial Greenhouse Gas Emissions"*, issued in March 2008 (Environment Canada 2008c), outlines Canada's initiatives in reducing GHGs. The document outlines the regulations that will be implemented in 2010 to govern GHG emissions by major industrial sectors. The regulations will be reviewed every five years to ensure that Canada meets their GHG reduction targets: 20% reduction from 2006 levels in 2020; and a 60% - 70% reduction by 2050.

The Yukon government has yet to implement provincial reduction targets. However, in 2006 they issued *"The Government of Yukon, Climate Change Strategy".* This strategy outlines four main goals as part their initial plans for addressing the climate change issue, which include:

1. Increasing knowledge and awareness;
2. Reduce emissions by improving efficiency in the short term, while creating long term solutions;
3. Adaptability to climate change, to recognize potential opportunities that can result from the change; and
4. To become a leader in climate change knowledge and technologies.

The greenhouse gas effect is caused by absorbing gases that trap solar radiation within the atmosphere. These absorbing gases (known as GHGs) include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). GHGs are emitted from both anthropogenic and biogenic sources. Major anthropogenic emissions including fossil fuel combustion and industrial sources are adding to the biogenic concentration of GHGs in the atmosphere. This leads to an unbalanced absorption and release of energy within the atmosphere causing climate change. For this reason, the anthropogenic source emissions are often recorded.

Total GHG emissions are determined based on the major greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These GHGs are typically reported as total GHGs called CO_2 equivalents (CO_{2e}). To determine CO_{2e}, a Global Warming Potential (GPW) factor is assigned to the various gases. The GPW is used to calculate each gas' relative emission to CO_2. The GPW for the above gases are listed below:

- CO_2 = 1.0
- CH_4 = 21.0
- N_2O = 310.0

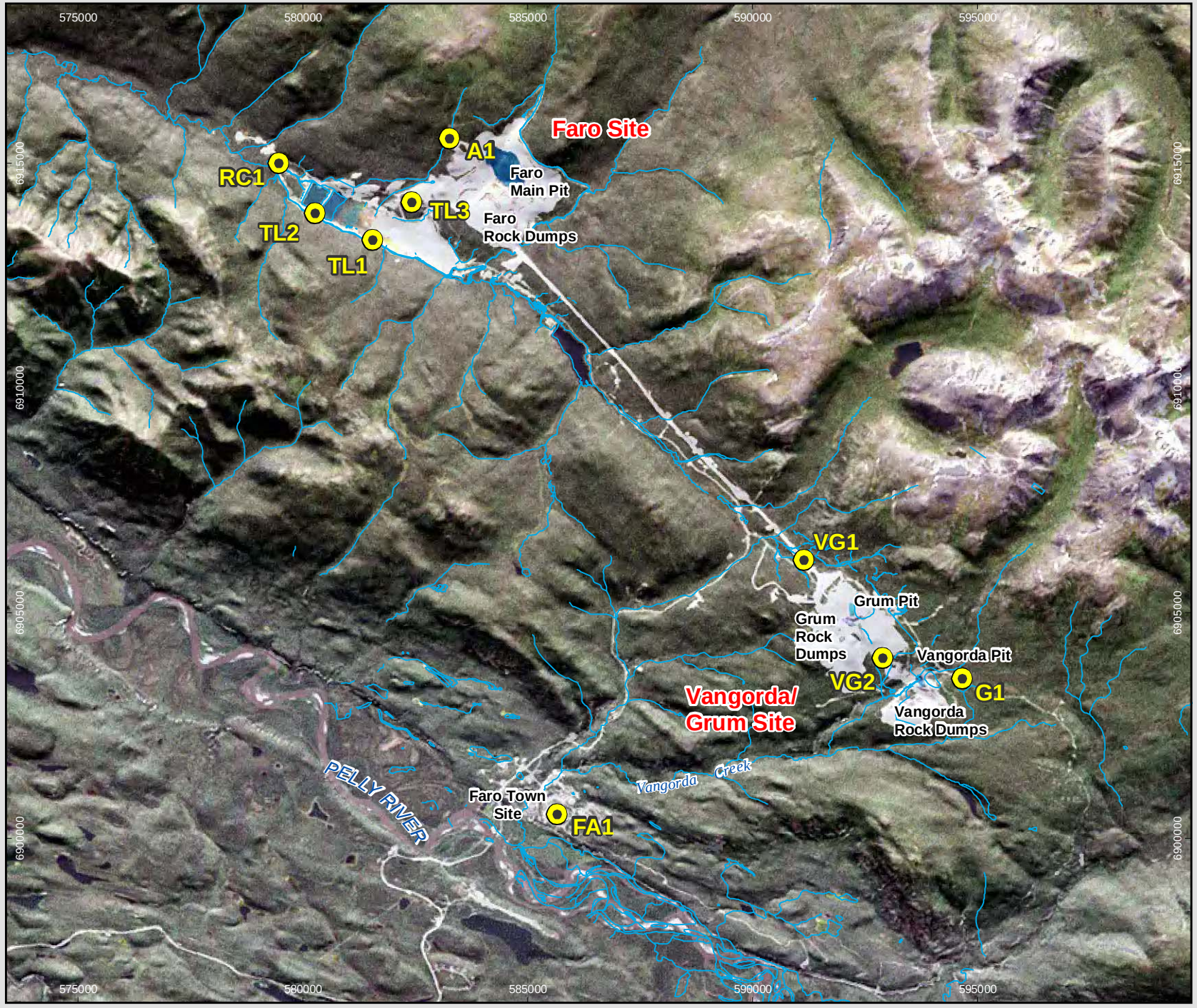
Using these values, total GHG emissions are calculated using the equation below:

Total CO_{2e} tonnes = (CO_2 tonnes x 1.0) + (CH_4 tonnes x 21.0) + (N_2O tonnes x 310.0)

Total GHGs for Yukon in 1990 and 2004 are presented in Table 1.2-9.

Energy is the leading source for GHG emissions in the Yukon. Energy represents a combination of both stationary combustion sources and transportation sources. Transportation accounts for the majority of the emissions for both 1990 and 2004 energy emissions, at 57% and 65%, respectively. Overall there is a decreasing trend in energy GHG emissions in the Yukon.

As illustrated in Table 1.2-9 above, total GHG emissions decreased 124 kt CO_{2e} between 1990 and 2004 and Yukon's percentage of national greenhouse gas emissions has also slightly decreased since 1990. The impact of mining on GHG levels has been decreasing, with oil and gas development, tourism and public administration growing in importance. In 2006, Yukon's GHG emission total was 0.4 Mt. This is a 27% reduction since 1990 levels. Since 1990, Yukon's population has increased by 12%, yet the per capita GHG emissions have decreased from 19.4 to 12.6 t GHG per person. Yukon is now one of the lowest per capita GHG emitters in Canada.



Legend

- Air Quality Monitoring Station
- Watercourse

Air quality monitoring locations from 2008 Baseline Air Quality Monitoring Assessment for Faro Mine Complex, SENES Consultants Limited, January 2009.

N
W E
S

0 1 2
Kilometers

1:120,000

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro

Air Quality Monitoring Stations

March, 2009

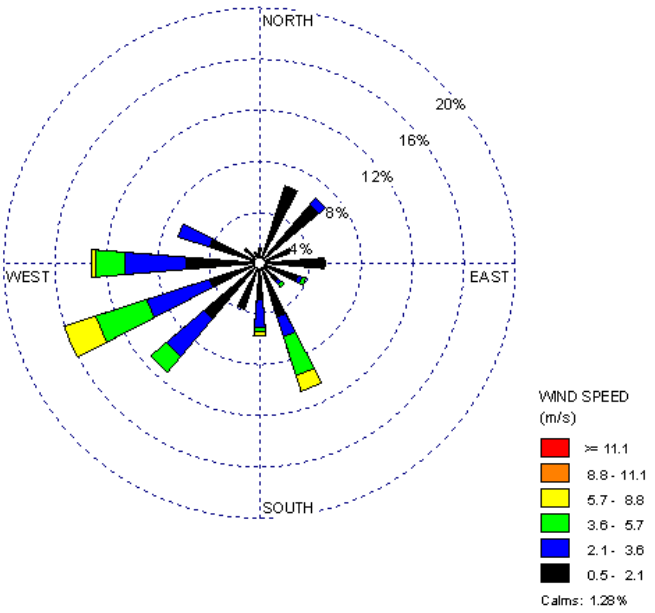
AECOM

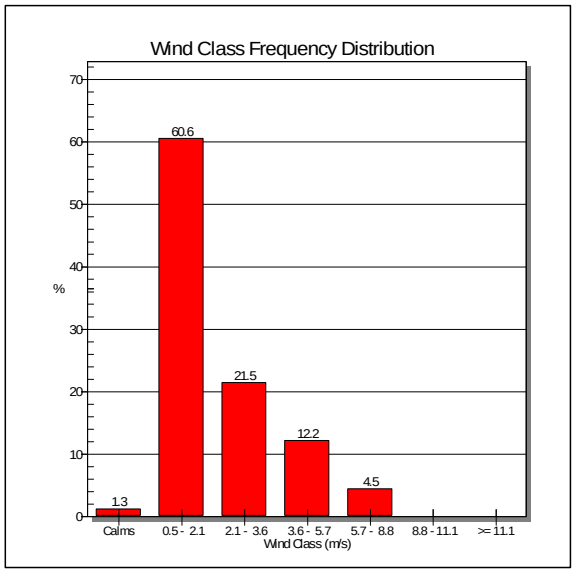
Figure 1.2-1

File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GW\By4_AirQuality\107403_By4_Fig1-2-1_AirQual_Locations_09cMar31.mxd Date Revised: March 31, 2009 Prepared by: MM Project: 107403 (80642-1)

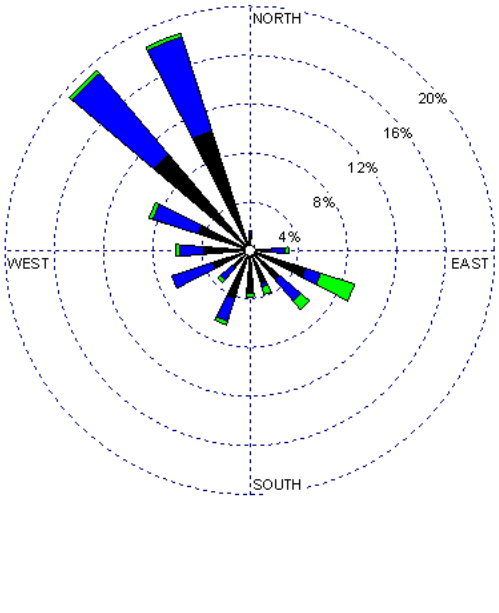
Figure 1.2-2 Meteorological Assessment for Ambient Air Monitoring Days

Faro Mine Area





Vangorda Grum Area



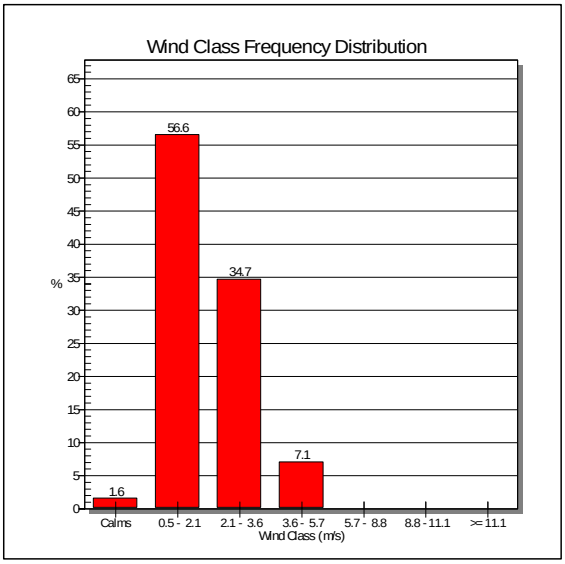


Table 1.2-1. Summary of Issues and Measureable Parameters

Issue/Effect	VC	Measureable Parameters
Alterations in air quality associated with: Construction Phase: • Road Traffic emissions • Construction equipment diesel emissions • Particulate emissions from Staging and Storage Areas • Construction Activities air emissions • Fugitive mine-related dust emissions Post-Closure Phase: • Reduced fugitive emissions of mine and traffic-related dust	Air Quality	• Total Suspended Particulates (TSP) • Fine Particulate Matter (PM_{10} and $PM_{2.5}$) • Sulphur Dioxide (SO_2) • Nitrogen Dioxide (NO_2) • Carbon Monoxide (CO) • Volatile Organic Compounds (VOCs) • Mine – related metals and non-metals
Alterations in GHG baseline levels associated with: Construction Phase: • Road Traffic emissions • Construction equipment diesel emissions	GHGs	• Carbon Dioxide equivalents (CO_2e)

Table 1.2-2. Federal and Provincial Ambient Air Quality Criteria for Criteria Air Contaminants

Pollutant	Averaging Time Period	British Columbia[a]			Canada			
		Level A	Level B	Level C	Canada Wide Standards[b] (Pending)	Ambient Air Quality Objectives[c]		
						Maximum Desirable	Maximum Acceptable	Maximum Tolerable
NO_2 ($\mu g/m^3$)	1 hour	-	-	-	-	-	400	1000
	24 hour	-	-	-	-	-	200	300
	Annual	-	-	-	-	60	100	-
SO_2 ($\mu g/m^3$)	1 hour	450	900	1,300	-	450	900	-
	24 hour	160	260	360	-	150	300	800
	Annual	25	50	80	-	30	60	-
TSP ($\mu g/m^3$)	24 hour	150	200	260	-	-	120	400
	Annual	60	70	75	-	60	70	-
PM_{10} ($\mu g/m^3$)	24 hour	-	50	-	-	-	-	-
$PM_{2.5}$ ($\mu g/m^3$)	24 hour	-	-	-	30	-	-	-
CO (mg/m^3)	1 hour	14	28	35	-	15	35	-
	8 hour	6	11	14	-	6	15	20

Sources:
a BC Ministry of Environment (2004), Air Quality Objectives and Standards.
b CCME (2000).
c Government of Canada (2004), National Ambient Air Quality Objectives.

Table 1.2-3. Provincial Ambient Air Quality Criteria for Metals and Non-metals

Element	AAQC 24-h average (µg/m^3)	Jurisdiction	Effect
Aluminum	4.8	Ontario JSL	n/a
Antimony	25	Ontario Standard	Health
Arsenic	0.3	Ontario Guideline	Health
Barium	10	Ontario Guideline	Health
Beryllium	0.01	Ontario Standard	Health
Boron	120	Ontario Standard	particulate matter
Cadmium	0.025	Ontario Standard	Health
Calcium	n/a		
Chromium	1.5	Ontario Guideline	Health
Cobalt	0.1	Ontario Guideline	Health
Copper	50	Ontario Guideline	Health
Iron	4	Ontario Standard	Soiling
Lead	4	BC Level A	Health
Magnesium	0.2	Ontario JSL	n/a
Manganese	2.5	Ontario Guideline	Health
Molybdenum	120	Ontario Guideline	particulate matter
Nickel	2	Ontario Standard	Vegetation
Phosphorus	0.35	Ontario JSL	n/a
Potassium	8	Ontario JSL	n/a
Selenium	10	Ontario Guideline	Health
Silver	1	Ontario Standard	Health
Sodium	n/a		
Strontium	120	Ontario Guideline	particulate matter
Tellurium	10	Ontario Standard	Health
Thallium	n/a		
Tin	10	Ontario Standard	Health
Titanium	120	Ontario Standard	particulate matter
Vanadium	2	Ontario Standard	Health
Zinc	120	Ontario Standard	particulate matter
Zirconium	20	Ontario JSL	n/a

Sources:
BC Air quality Objectives and Standards.
Ontario Jurisdictional Screening Level List, www.ene.gov.on.ca/publications/6547e.pdf
Ontario Summary of Standards and Guidelines to support O.Reg. 419, 2008, www.ene.gov.on.ca/publications/6569e-cas.pdf
Ontario Ambient Air Quality Criteria, 2008, www.ene.gov.on.ca/publications/6570e-cas.pdf

Table 1.2-4. Ambient Air Monitoring Locations

Station	Location	Description
TL1	South of Intermediate Tailings area	Located south of the Intermediate Tailings area, 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 Tailings area, 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 Tailings 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 (GLL 2006: Anvil Range Mine Complex – Terrestrial Effects Study: Investigation into Metal Concentrations in Vegetation, Wildlife and Soils, September 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 in a 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 Faro for traditional purposes

Table 1.2-5. Summary of Ambient Air Quality Results for Particulate Matter at Monitoring Sites

Parameter	Sampling Area	Sampling Sites Included	24-hour max ($\mu g/m^3$)	24-hour average ($\mu g/m^3$)	24-hour 99th percentile ($\mu g/m^3$)	24-hour 75th percentile ($\mu g/m^3$)
TSP	**TSP - all sites**	All nine sites	95.5	12.6	75.6	11.7
	Faro Mine Area					
(TL1, TL2, TL3, RC1, A1)	**Located SE, E, and NW of tailings area, NW of Mine pit**	70.6	11.3	56.7	11.4	
	Vangorda & Grum Area					
(VG1, VG2, G1)	**NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits**	95.5	14.6	78.5	13.9	
	Town of Faro (FA1)	Medical clinic on Bell Ave	17.2	10.8	16.9	10.7
PM10	**PM10 - all sites**	All nine sites	19.3	6.6	17.7	7.1
	Faro Mine Area					
(TL1, TL2, TL3, RC1, A1)	**SE, E, and NW of tailings area, NW of Mine pit**	17.3	6.5	15.6	6.3	
	Vangorda & Grum Area					
(VG1, VG2, G1)	**NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits**	19.3	6.6	17.4	7.6	
	Town of Faro (FA1)	Medical clinic on Bell Ave	12.1	7.4	12.0	10.0

Notes:
For each parameter, the maximum concentration is in red to highlight the measurement area in which it occurred.

Table 1.2-6. Summary of Ambient Air Quality for Metals at Monitoring Sites

Parameter	Sampling Area	Sampling Sites Included	24-hour max (µg/m^3)	24-hour average (µg/m^3)	24-hour 99th percentile (µg/m^3)	24-hour 75th percentile (µg/m^3)
Aluminum	All sites	All nine sites	6.59E-01	5.92E-02	4.90E-01	5.64E-02
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**6.59E-01**	5.72E-02	4.67E-01	5.30E-02
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	5.61E-01	6.20E-02	4.09E-01	5.62E-02
	Town of Faro (FA1)	Medical clinic on Bell Ave	1.34E-01	6.07E-02	1.29E-01	7.24E-02
Antimony	All sites	All nine sites	MDL	MDL	MDL	MDL
Arsenic	All sites	All nine sites	4.92E-03	1.74E-03	4.67E-03	2.38E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**4.92E-03**	1.71E-03	4.73E-03	2.31E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	3.39E-03	1.75E-03	3.32E-03	2.46E-03
	Town of Faro (FA1)	Medical clinic on Bell Ave	2.97E-03	1.96E-03	2.97E-03	2.63E-03
Barium	All sites	All nine sites	4.56E-02	3.74E-03	3.76E-02	3.63E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**4.56E-02**	4.08E-03	4.13E-02	3.53E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	2.76E-02	3.12E-03	2.05E-02	3.03E-03
	Town of Faro (FA1)	Medical clinic on Bell Ave	1.75E-02	4.50E-03	1.64E-02	5.32E-03
Beryllium	All sites	All nine sites	MDL	MDL	MDL	MDL
Boron	All sites	All nine sites	MDL	MDL	MDL	MDL
Cadmium	All sites	All nine sites	2.46E-03	2.15E-04	1.70E-03	2.50E-04
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**2.46E-03**	2.31E-04	1.80E-03	2.43E-04
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	1.70E-03	1.99E-04	1.06E-03	2.51E-04
	Town of Faro (FA1)	Medical clinic on Bell Ave	5.00E-04	1.77E-04	4.90E-04	1.76E-04

Parameter	Sampling Area	Sampling Sites Included	24-hour max ($\mu g/m^3$)	24-hour average ($\mu g/m^3$)	24-hour 99th percentile ($\mu g/m^3$)	24-hour 75th percentile ($\mu g/m^3$)
Calcium	All sites	All nine sites	9.75E-01	1.27E-01	6.30E-01	1.44E-01
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**9.75E-01**	1.28E-01	6.59E-01	1.37E-01
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	6.51E-01	1.22E-01	4.71E-01	1.49E-01
	Town of Faro (FA1)	Medical clinic on Bell Ave	2.25E-01	1.52E-01	2.25E-01	2.01E-01
Chromium	All sites	All nine sites	2.61E-01	7.09E-02	1.26E-01	7.74E-02
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	1.27E-01	7.10E-02	1.26E-01	7.62E-02
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	**2.61E-01**	7.14E-02	1.75E-01	7.88E-02
	Town of Faro (FA1)	Medical clinic on Bell Ave	8.55E-02	6.76E-02	8.50E-02	7.44E-02
Cobalt	All sites	All nine sites	MDL	MDL	MDL	MDL
Copper	All sites	All nine sites	4.77E-01	7.66E-03	7.82E-02	3.60E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**4.77E-01**	1.07E-02	1.50E-01	3.60E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	6.04E-02	3.85E-03	3.37E-02	3.55E-03
	Town of Faro (FA1)	Medical clinic on Bell Ave	1.51E-02	4.29E-03	1.45E-02	5.85E-03
Iron	All sites	All nine sites	1.39E+00	1.43E-01	1.10E+00	1.45E-01
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**1.39E+00**	1.48E-01	1.09E+00	1.37E-01
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	1.18E+00	1.36E-01	8.87E-01	1.36E-01
	Town of Faro (FA1)	Medical clinic on Bell Ave	2.89E-01	1.48E-01	2.88E-01	2.05E-01
Lead	All sites	All nine sites	8.39E-02	3.93E-03	5.93E-02	2.80E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**8.39E-02**	5.27E-03	7.49E-02	2.90E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	2.38E-02	2.37E-03	1.68E-02	2.48E-03

Parameter	Sampling Area	Sampling Sites Included	24-hour max ($\mu g/m^3$)	24-hour average ($\mu g/m^3$)	24-hour 99th percentile ($\mu g/m^3$)	24-hour 75th percentile ($\mu g/m^3$)
	Town of Faro (FA1)	Medical clinic on Bell Ave	5.40E-03	1.95E-03	5.28E-03	3.10E-03
Magnesium	All sites	All nine sites	6.26E-01	5.48E-02	4.89E-01	3.68E-02
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	4.94E-01	4.77E-02	4.28E-01	3.19E-02
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	**6.26E-01**	6.70E-02	5.41E-01	3.74E-02
	Town of Faro (FA1)	Medical clinic on Bell Ave	8.60E-02	4.33E-02	8.36E-02	4.98E-02
Manganese	All sites	All nine sites	2.10E-02	2.03E-03	1.64E-02	2.00E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**2.10E-02**	1.95E-03	1.70E-02	1.95E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	1.63E-02	2.10E-03	1.35E-02	2.00E-03
	Town of Faro (FA1)	Medical clinic on Bell Ave	6.10E-03	2.30E-03	5.99E-03	3.50E-03
Molybdenum	All sites	All nine sites	1.10E-03	3.16E-04	6.17E-04	3.00E-04
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**1.10E-03**	3.16E-04	4.84E-04	3.00E-04
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	8.00E-04	3.18E-04	6.17E-04	3.00E-04
	Town of Faro (FA1)	Medical clinic on Bell Ave	4.00E-04	3.09E-04	3.90E-04	3.00E-04
Nickel	All sites	All nine sites	8.50E-03	1.58E-03	5.43E-03	2.48E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**8.50E-03**	1.58E-03	6.12E-03	2.40E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	5.20E-03	1.54E-03	5.02E-03	2.35E-03
	Town of Faro (FA1)	Medical clinic on Bell Ave	4.80E-03	1.82E-03	4.66E-03	3.10E-03
Phosphorus	All sites	All nine sites	1.71E-01	1.09E-01	1.56E-01	1.24E-01
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**1.71E-01**	1.08E-01	1.57E-01	1.22E-01
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	1.56E-01	1.10E-01	1.50E-01	1.25E-01
	Town of Faro (FA1)	Medical clinic on Bell Ave	1.25E-01	1.05E-01	1.25E-01	1.18E-01

Parameter	Sampling Area	Sampling Sites Included	24-hour max ($\mu g/m^3$)	24-hour average ($\mu g/m^3$)	24-hour 99th percentile ($\mu g/m^3$)	24-hour 75th percentile ($\mu g/m^3$)
Potassium	All sites	All nine sites	4.39E-01	7.82E-02	1.74E-01	7.77E-02
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**4.39E-01**	7.99E-02	2.05E-01	7.76E-02
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	1.75E-01	7.50E-02	1.68E-01	7.40E-02
	Town of Faro (FA1)	Medical clinic on Bell Ave	1.49E-01	8.22E-02	1.47E-01	9.93E-02
Selenium	All sites	All nine sites	MDL	MDL	MDL	MDL
Silver	All sites	All nine sites	9.00E-04	2.16E-04	6.39E-04	2.00E-04
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	4.00E-04	1.98E-04	2.24E-04	2.00E-04
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	7.00E-04	2.31E-04	6.39E-04	2.00E-04
	Town of Faro (FA1)	Medical clinic on Bell Ave	**9.00E-04**	2.73E-04	8.50E-04	2.00E-04
Sodium	All sites	All nine sites	9.42E+00	2.25E+00	8.81E+00	5.95E+00
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	8.64E+00	2.13E+00	8.59E+00	6.09E+00
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	**9.42E+00**	2.44E+00	9.07E+00	5.64E+00
	Town of Faro (FA1)	Medical clinic on Bell Ave	7.67E+00	2.09E+00	7.66E+00	3.61E+00
Strontium	All sites	All nine sites	4.20E-03	7.02E-04	2.99E-03	6.00E-04
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**4.20E-03**	7.22E-04	2.97E-03	6.00E-04
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	3.30E-03	6.89E-04	2.08E-03	6.00E-04
	Town of Faro (FA1)	Medical clinic on Bell Ave	7.00E-04	6.18E-04	7.00E-04	6.00E-04
Tellerium	All sites	All nine sites	MDL	MDL	MDL	MDL
Thallium	All sites	All nine sites	9.00E-04	1.10E-04	3.39E-04	1.00E-04
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	4.00E-04	1.08E-04	3.12E-04	1.00E-04
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	**9.00E-04**	1.15E-04	4.73E-04	1.00E-04

Parameter	Sampling Area	Sampling Sites Included	24-hour max ($\mu g/m^3$)	24-hour average ($\mu g/m^3$)	24-hour 99th percentile ($\mu g/m^3$)	24-hour 75th percentile ($\mu g/m^3$)
	Town of Faro (FA1)	Medical clinic on Bell Ave	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Tin	All sites	All nine sites	1.48E-02	1.63E-03	1.08E-02	1.68E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**1.48E-02**	1.54E-03	1.01E-02	1.60E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	1.08E-02	1.64E-03	8.36E-03	1.85E-03
	Town of Faro (FA1)	Medical clinic on Bell Ave	1.08E-02	2.25E-03	1.01E-02	2.55E-03
Titanium	All sites	All nine sites	2.71E-02	5.60E-03	2.01E-02	5.70E-03
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**2.71E-02**	5.59E-03	2.11E-02	5.50E-03
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	2.00E-02	5.60E-03	1.99E-02	5.78E-03
	Town of Faro (FA1)	Medical clinic on Bell Ave	7.70E-03	5.76E-03	7.68E-03	6.65E-03
Vanadium	All sites	All nine sites	MDL	MDL	MDL	MDL
Zinc	All sites	All nine sites	1.01E-01	1.12E-02	8.51E-02	1.28E-02
	Faro Mine Area (TL1, TL2, TL3, RC1, A1)	Located SE, E, and NW of tailings area, NW of Mine pit	**1.01E-01**	1.11E-02	9.37E-02	1.13E-02
	Vangorda & Grum Area (VG1, VG2, G1)	NW of Grum Pit, E Vangorda Pit, Effluent pond between the pits	8.02E-02	1.13E-02	5.67E-02	1.51E-02
	Town of Faro (FA1)	Medical clinic on Bell Ave	3.39E-02	1.12E-02	3.24E-02	1.24E-02
Zirconium	All sites	All nine sites	MDL	MDL	MDL	MDL

Notes:
For each parameter, the maximum concentration is in red to highlight the measurement area in which it occurred.
MDL = below Method Detection Limit for > 98% of samples.

Table 1.2-7. Maximum Metal Concentrations Compared with Air Criteria

Element	Maximum Observed Concentration 24-h average (µg/m^3)	AAQC 24-h average (µg/m^3)	Jurisdiction	Effect
Aluminium	0.66	4.8	Ontario JSL	n/a
Antimony	MDL	25	Ontario Standard	health
Arsenic	0.0049	0.3	Ontario Guideline	health
Barium	0.046	10	Ontario Guideline	health
Beryllium	MDL	0.01	Ontario Standard	health
Boron	MDL	120	Ontario Standard	particulate matter
Cadmium	0.0025	0.025	Ontario Standard	health
Calcium	0.97	n/a		
Chromium	0.26	1.5	Ontario Guideline	health
Cobalt	MDL	0.1	Ontario Guideline	health
Copper	0.48	50	Ontario Guideline	health
Iron	1.39	4	Ontario Standard	soiling
Lead	0.084	4	BC Level A	health
Magnesium	0.63	0.2	Ontario JSL	n/a
Manganese	0.021	2.5	Ontario Guideline	health
Molybdenum	0.0011	120	Ontario Guideline	particulate matter
Nickel	0.009	2	Ontario Standard	vegetation
Phosphorus	0.17	0.35	Ontario JSL	n/a
Potassium	0.44	8	Ontario JSL	n/a
Selenium	MDL	10	Ontario Guideline	health
Silver	0.0009	1	Ontario Standard	health
Sodium	9.42	n/a		
Strontium	0.0042	120	Ontario Guideline	particulate matter
Tellurium	MDL	10	Ontario Standard	health
Thallium	0.0009	n/a		
Tin	0.015	10	Ontario Standard	health
Titanium	0.027	120	Ontario Standard	particulate matter
Vanadium	MDL	2	Ontario Standard	health
Zinc	0.10	120	Ontario Standard	particulate matter
Zirconium	MDL	20	Ontario JSL	n/a

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

Table 1.2-8. Daily Wind Directions

Date	7/17/2008		7/23/2008		7/29/2008		8/4/2008		8/10/2008		8/22/2008		8/28/2008		9/3/2008		9/9/2008		9/15/2008		9/21/2008		9/27/2008		10/3/2008	
Station ID	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**	**Vangrum**	**Faro**
Wind Direction During Sampling Period	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
N	4						4			4							8			8		4				
NNE		8			4	13		13		13				4			4			8		17		4		8
NE		4			4	8		21		25						17		4		4		4				
ENE		4						4		8						17						4				
E		4				4		4			8	17		8		13	8	8		4		8	4		4	
ESE			4	13	33	8		8	8		8	13						8					54		25	
SE			4	8	29	4					4	4		4		4	4						38	4	13	4
SSE			8			21				4	21	21		4	8	4	8							42	8	42
S				4		21					21	4		8	17	4	4			4	4	4		21	4	4
SSW	9		17	4		4		4	13	4	8	4		4	13		4	4		4	17	4		13	4	
SW	4	8	8	25	4	13		17	8	4			8	17		25	4	17		4	4	4		4	8	8
WSW	26	42	8	21	4		33	8	4		4	4		8	13	13		21	8	42	8	21			4	29
W	9	29	4	13		4	21	17	4	8	4	21	17	17		4	4	29	4	8		21	4			
WNW	17			4			13	4	4	21	13	13	17	21				8	29	8	4	4		8	4	
NW	13		17	8	4		21		25	4	8		46		21		29		29	4	33			4	8	4
NNW	17		29		17		8		33	4			13	4	29		21		29		29	4			17	
Calm																										
Average Wind Speed (m/s)	2.4	3	1.41	2.18	2.16	2.48	2.01	1.7	2.05	1.65	1.49	1.65	2.14	1.16	1.9	1.66	1.7	2.3	2.72	3.29	2.19	1.5	1.46	1.65	3.89	4.6
Total Precipitation (mm)	0	0	0	0.508	0	0	0	0	0	0	0	3.56	8.64	5.33	0	0	0	0	0	0.51	0	0	0	2.03	0	0.51

Table 1.2-9. Yukon Territory Sector Emissions: 2006

Source	Criteria Air Contaminant Emissions (tonnes/year)						
	CO	NO_X	SO_2	VOCs	TSP	PM_{10}	$PM_{2.5}$
Industrial Sources	36	112	978	43	275	71	23
Non-Industrial Sources	759.5	136.8	16.7	183.6	132.6	122.6	121.7
Mobile Sources	13288.0	1165.6	27.0	1482.8	85.2	85.1	76.7
Miscellaneous	9.2	0.0	0.0	301.9	9.2	9.2	9.1
Open Sources	23.3	3.8	0.5	22.0	23788.6	6730.8	1243.8
Natural Sources	115085.0	7238.1	8.2	795849.6	13974.6	11878.4	9782.2

Source: Extracted from NPRI 2006 (Environment Canada, 2008).

Table 1.2-10. Greenhouse Gas Emissions: Yukon

	1990 Emissions (kt CO2e)	% of 1990 National Emissions	2004 Emissions (kt CO2e)	% of 2004 National Emissions
Energy	526	0.1%	398	0.06%
Industrial Processes	1.38	0.003%	0.49	0.0009%
Solvent and Other Product Use	0.18	0.1%	0.2	0.1%
Agriculture	0.0	0%	0.0	0%
Land Use, Land-Use Change and Forestry	N/A	N/A	N/A	N/A
Waste	10	0.05%	15	0.08%
Total	538	0.1%	414	0.05%

Source: Environment Canada, 2007.

2. Geology

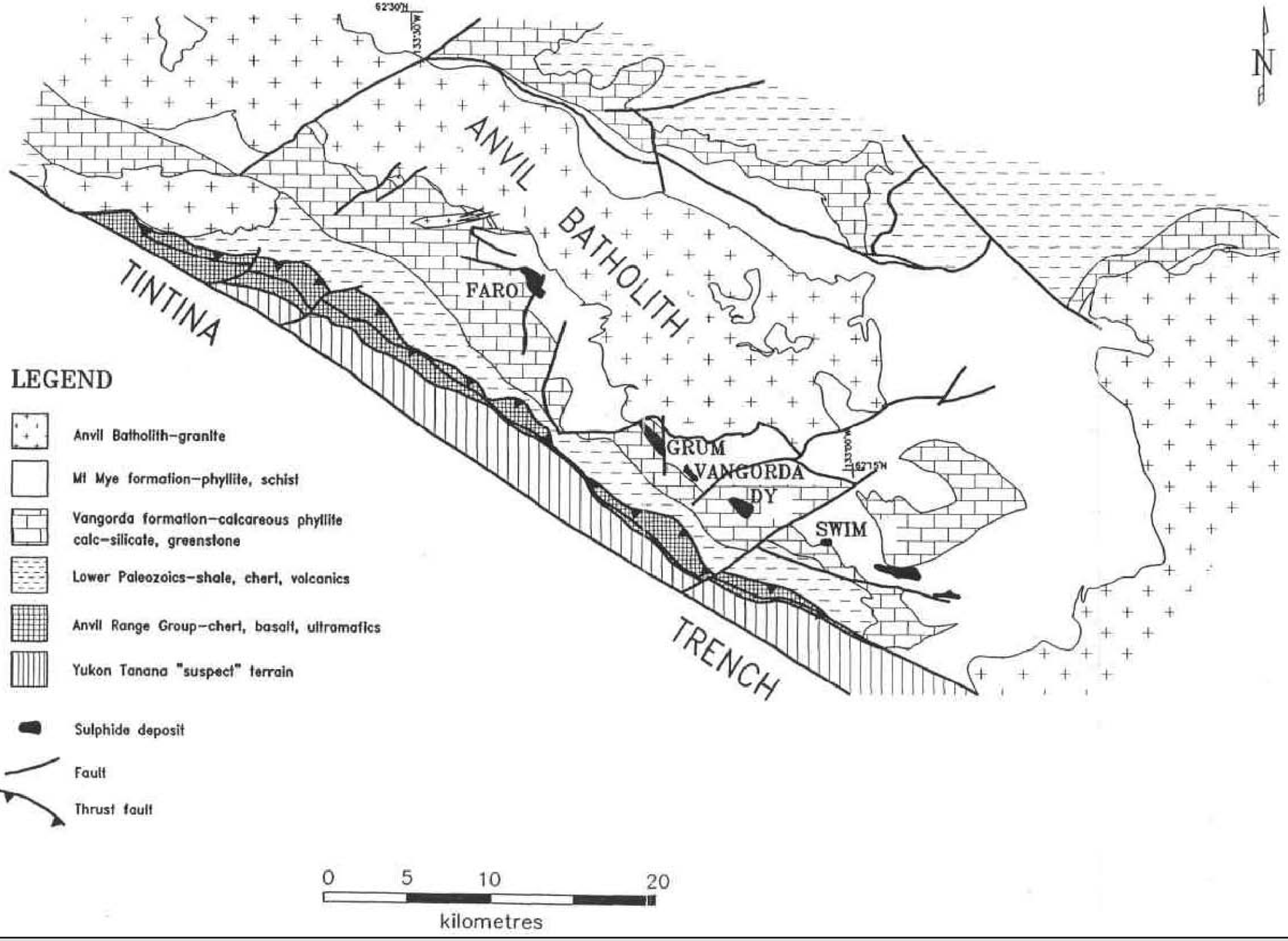
2.1 Regional Setting

The area surrounding the Faro Mine Complex is underlain by metamorphic and volcanic bedrock. The Proterozoic and Paleozoic schists and phyllites were intruded by the Anvil Batholith, which consists of granite, granodiorite and quartz monzonite. The crystalline nature of these rocks typically creates a very low primary porosity (0-10%), therefore and groundwater flow through the bedrock likely occurs along planes of weakness or deformation, such as fractures, faults or shear zones. Predicting the occurrence of groundwater and its flow direction in this type of rock is difficult at best, and there is little information available for the Anvil District.

Bedrock is overlain by various types of surficial deposits (or overburden) consisting primarily of glacial till, glaciofluvial sediments and alluvium. In topographically elevated areas, these surficial deposits are thin and irregularly distributed. Surficial deposits are generally thickest in the valley bottoms, although significant thicknesses of till have been documented in the uplands of the Vangorda Plateau.

The presence, characteristics and thickness of surficial deposits (natural, waste rock and tailings) are the primary control on flow of groundwater in the study area. Groundwater flow occurs primarily in the overburden, or through the upper most weathered surface of the bedrock. Flow direction is controlled mainly by surficial and bedrock topography. Recharge occurs via infiltration of precipitation to the water table and mostly horizontal flow, generally following topography to discharge zones into local creeks or shallow depressions. The bedrock valley sides act as recharge sites and groundwater flow progresses to the valley bottom as a discharge zone. Recharge to valley aquifers may also occur locally through the beds of losing streams occupying the valley.

Large glaciated valleys, including the Pelly River, Rose Creek, and Blind Creek valleys, have been filled with significant thickness of glacial sediments. Where these deposits are primarily glaciofluvial sands and gravel, they represent relatively high yield aquifers. Valley aquifers are usually unconfined, with shallow depths to water and significant groundwater yields. However, if confining layers, such as glacial till or other fine-grained deposits such as tailings extend across the valley floor and partially up the valley sides, confined aquifers, with significant hydraulic heads may be encountered.



Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

Regional Geology

March 2009

AECOM

Figure 2.1-1

N
W E
S

Drawing shown derived from report by Robertson Geoconsultants, Inc. Report No. 033001/3 dated November 1996. "Anvil Range Mining Complex - Integrated Comprehensive Abandonment Plan."

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File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy6_Geology\107403_By6_Fig2-1-1_Reg_Geology_09sMar31.mxd
Prepared by: MM
Project: 107403 (80642-1)
Date Revised: March 31, 2009

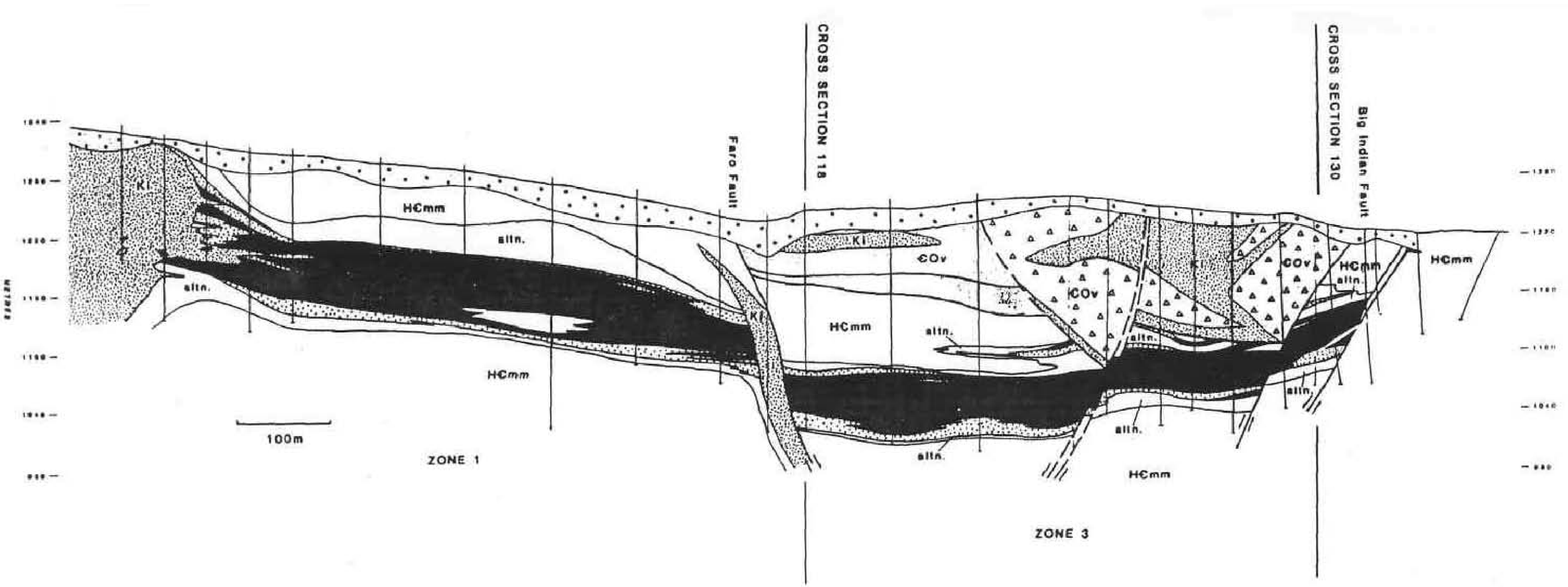

FIGURE Vertical longitudinal section 22 of the Faro deposit, looking northeast, no vertical exaggeration. Units are same as Figure 4-3 Zones 1 and 3 are indicated, the largely eroded northeast extension of zone 2 is just beneath the overburden southeast of the Big Indian Fault. Within about 150 m of the diorite dyke at the northwest end of the section, the massive sulphides are altered to pyrrhotite rich assemblages containing local large magnetite octahedra and partly reverted to pyrite. Adjacent to the diorite dyke along the Faro Fault massive magnetite is developed in the sulphides.

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

Faro Orebody

March 2009

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Figure 2.1-2

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NOT TO SCALE

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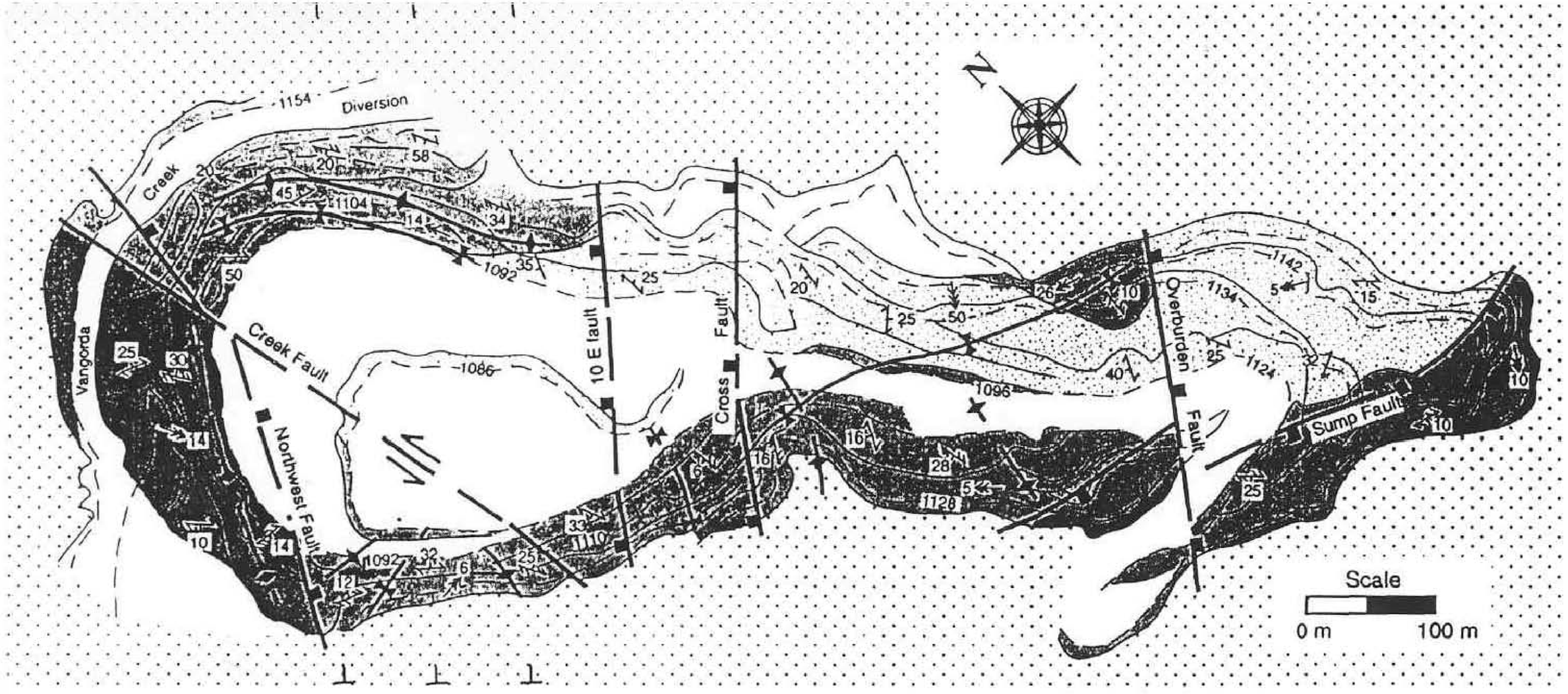
Date Revised: March 31, 2009



Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

Vangorda Orebody

March 2009

AECOM

Figure 2.1-3

N
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Drawing shown derived from report by Steffen, Robertson Kirsten (Canada), Inc. Report No. 60647, dated May 1992. "Construction Report Vangorda Creek Diversion Realignment Vangorda Plateau Development."

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

Grum Orebody

March 2009

AECOM

Figure 2.1-4

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NOT TO SCALE

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2.2 Bedrock Geology

The geology of the Anvil District has been described in detail in Robertson GeoConsultants Inc. (1996). A regional geology map, repeated from Robertson GeoConsultants Inc. 1996, is provided in Figure 2.1-1.

The stratigraphy of the Anvil District consists of regionally metamorphosed sedimentary bedrock, ranging in age from late Precambrian to Permian (approximately 900 to 250 million years ago). The degree of metamorphism ranges from moderate (schist) to low (phyllite). The lower part of the sequence, Silurian aged and earlier, as represented primarily by the Mt. Mye and Vangorda Formations, is the most important with respect to the Anvil Range ore bodies. During the Cretaceous, the meta-sediments were intruded by the Anvil Batholith, a granitic pluton that varies in composition from granite to granodiorite to quartz monzonite. A higher degree of metamorphism is generally observed near the Anvil Batholith contact. The meta-sediment rocks dip northeast and southwest, away from the Batholith.

The Mt. Mye Formation is represented by schists, with the dominant rock type being grey, non-calcareous, weakly carbonaceous phyllite with lesser interlayered black carbonaceous phyllite and schists. Mafic meta-igneous rocks, now amphibolites, are present locally but are volumetrically minor. A white, calc-silicate and marble marker horizon occurs about 500 to 700 m below the top of the Mt. Mye Formation, which has a structural thickness of at least 2,000 m (the base is not exposed).

The Vangorda Formation is represented by light to medium grey to greenish-grey calcareous phyllites. At higher metamorphic grade (amphibolite facies), the calcareous phyllite is transformed to calc-silicate rocks. Major interbanded units in the Vangorda Formation include meta–igneous greenstone, which is more common near the top of the Formation, and carbonaceous pelite. The Vangorda Formation varies from 0.5 to 2 km in apparent thickness.

Five ore deposits have been identified in the Anvil Range area: Faro, Grum, Vangorda, Grizzly (previously DY) and Swim. Mining is complete (depletion of known economic reserves) in Faro and Vangorda deposits, partially complete in Grum and has not occurred in Grizzly or Swim. The three deposits at which mining has taken place are described below.

2.3 Faro Ore Body

Rocks of the Faro Mine site were metamorphosed in the amphibolite facies of regional metamorphism. The result is that schists are more important at Faro than elsewhere, and the calc-silicate gneiss, a rock type not seen at other sites, is widespread as the major rock of the Vangorda Formation. The increased metamorphism generally tended to coarsen mineral grain sizes, including sulphide minerals.

Deformation is so complex and flattening into the metamorphic foliation is so pronounced at the Faro site that the geology appears to be a simple layer cake of stratigraphy. The ore-body is concordant to formational boundaries and is stratigraphically approximately 75 m below the top of the Mt. Mye Formation. It consists of a gently dipping, stratiform zinc-lead-silver massive sulphide deposit, offset by faults. The main deposit (Zones 1 and 3) was approximately 1.5 km long, 500 m wide and averaged 46 m thick. The satellite Zone 2 deposit was approximately 300 m long, 180 m wide and average 24 m thick.

The main ore body was composed of two zones (Zones 1 and 3) vertically offset by a normal fault as illustrated on Figure 2.1-2. This northeast trending fault, the Faro fault, is sub-vertical and bisects the main ore-body. The east block is down dropped approximately 50 m. A diorite dyke is intruded along the fault zone. The satellite Zone 2 ore body was geologically part of the same sulphide lens but was separated by normal fault offset. The Big-Indian – North Fork fault system separates Zone 2 from Zone 3. This fault set consists of several strands with a throw of roughly 75 m, west block down.

The Zone 2 Pit was one of the few areas where the Faro deposit was exposed on surface. Thus, a weathered mantle was present over part of the deposit. The Zone 2 ore body was at the edge of the overall Faro deposit and was rich in ribbon banded quartzite ore. Massive sulphide was limited and the ore grade was low compared to Zone 1 and 3 in the Main Pit. Anvil Batholith instrusives were found along the northeast side of the Zone 2 ore body.

2.4 Vangorda Ore Body

The Vangorda deposit was a small deposit for this area and had a number of characteristics that made it unusual. These included:

a) shallow depth and a greater degree of weathering;
b) abundance of foot wall sulphides; and
c) degree of development of strongly altered phyllites.

The Vangorda deposit was relatively close to the ground surface and was more affected by weathering than the other ore deposits of the district. The thickest part of the ore body occurred below a ridge of highly compacted till east of Vangorda Creek.

The Vangorda deposit consisted of one major sulphide horizon located about 50 to 120 m beneath the basal carbonaceous member of the Vangorda Formation. The host rocks for the deposit were dominantly non-calcareous phyllites. A number of thin horizons occurred above the sulphide horizon. These horizons were too thin or of too low a grade to be economically mineable, with the exception of the south-east end of the deposit where the ore horizons were shallow (resulting in a low stripping ratios). The deposit itself contains the same sulphide rock types as the other deposits in the Anvil District.

A major fault is found at the northwest end of the Vangorda Pit as illustrated in Figure 2.1-3. This fault truncated the ore body and juxtaposed the black graphitic phyllite of the basal member of the Vangorda Formation against the ore body.

2.5 Grum Ore Body

The Grum Deposit, with mineable reserves of approximately 25 million tonnes, has a number of characteristics that make it unique. These include:

a) the high proportion of disseminated sulphide ore types compared to massive ores;
b) the generally weak alteration overprint; and
c) the complex, large scale, fold structure.

The deposit was covered by up to 100 m of till and glaciofluvial silt, sand and gravel. The material fills a buried channel trending north-south through the southeast pit area. No notable weathering features are present at Grum as were observed at Vangorda.

The Grum deposit consists of three to five highly contorted layers of massive and disseminated sulphide mineralization within a 150 m thick section of phyllite. The most important mineralized horizon occurs just beneath the basal carbonaceous member of the Vangorda Formation. There are thin low-grade horizons with the Vangorda Formation and more important horizons in the upper part of the Mt. Mye Formation. A unique feature of the geology of the Grum ore body is the presence of quartoze ore types, which formed up to 50% of the reserves. The other ore types are similar to the other deposits.

The Vangorda Formation at the Grum Deposit consists primarily of soft calcareous phyllites. They are not as strongly altered as at the Vangorda Deposit and are strongly calcareous. The Mt. Mye Formation at the Grum Deposit also consists of phyllites, which are non-calcareous and less distinctly banded than those of the Vangorda Formation.

There are several important faults at the Grum Deposit. The largest displacements occur on moderately dipping structures that truncate the deposit at both its northwest and southeast ends but do not crop out in the pit. A steeply north-west dipping fault set down drops the deposit about 60 m on the north-west. A myriad of smaller steeply dipping faults has also been mapped both underground and in the pit. Figure 2.1-4 illustrates geology for the ultimate design Grum Pit, which is larger than the existing excavation.

2.6 Rose Valley Geology

The mine area is situated within an area of discontinuous permafrost. At the mine site, north facing slopes and areas with older forest cover are more likely to contain permafrost. Permafrost ground, with varying degrees of ground ice content, was encountered during the construction of the Cross Valley Dam and the Rose Creek Diversion Channel. Felsenmeer is formed near the top of high hills due to frost action effects on exposed bedrock.

The surficial geology of the Rose Creek valley generally consists of colluvial, fluvial and morainal deposits forming a discontinuous cover over the bedrock. On the valley sides, bedrock is discontinuously covered with a veneer of morainal and colluvial deposits that increases in thickness towards Rose Creek. A complex assemblage of fan and outwash sand and gravels, dissected by stream channel and lacustrine materials fill Rose Creek Valley. Terraces and fans are prominent on the north side of the valley, where they, in part, underlie the existing tailings area.

Bedrock underlying the Rose Creek valley consists primarily of the Cambrian to Ordovician rocks of the Vangorda Formation. This formation is described as a “soft silvery grey calcareous phyllite with interbands of medium crystalline grey marble” (Robertson GeoConsultants Inc., 1996). This formation has been locally intruded by granodiorites and quartz monzonites of the Anvil Batholith. Foliation in the bedrock underlying the Rose Creek valley is mapped as generally parallel with the valley axis (west northwest to east southeast and dipping shallowly to the southwest (15 to 30 degrees). The competence of the bedrock varies but in most cases is poor. Exposures were found to be easily eroded by freeze –thaw and stream flow processes. In places, the schist is reported as being weathered up to 2 m depth (Golder Associates Ltd. 1989: Appendix 1).

A 2003 Rose Creek aquifer and tailings investigation and monitoring well drilling investigation by Gartner Lee (2003a) and a hydrogeological assessment for groundwater capture scenarios completed by Robertson GeoConsultants Inc. (2007) provided information about the depth and type of overburden sediments at several locations throughout the tailings area and downgradient from the Cross-Valley dam. Several monitoring wells and boreholes were advanced down to bedrock surface.

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

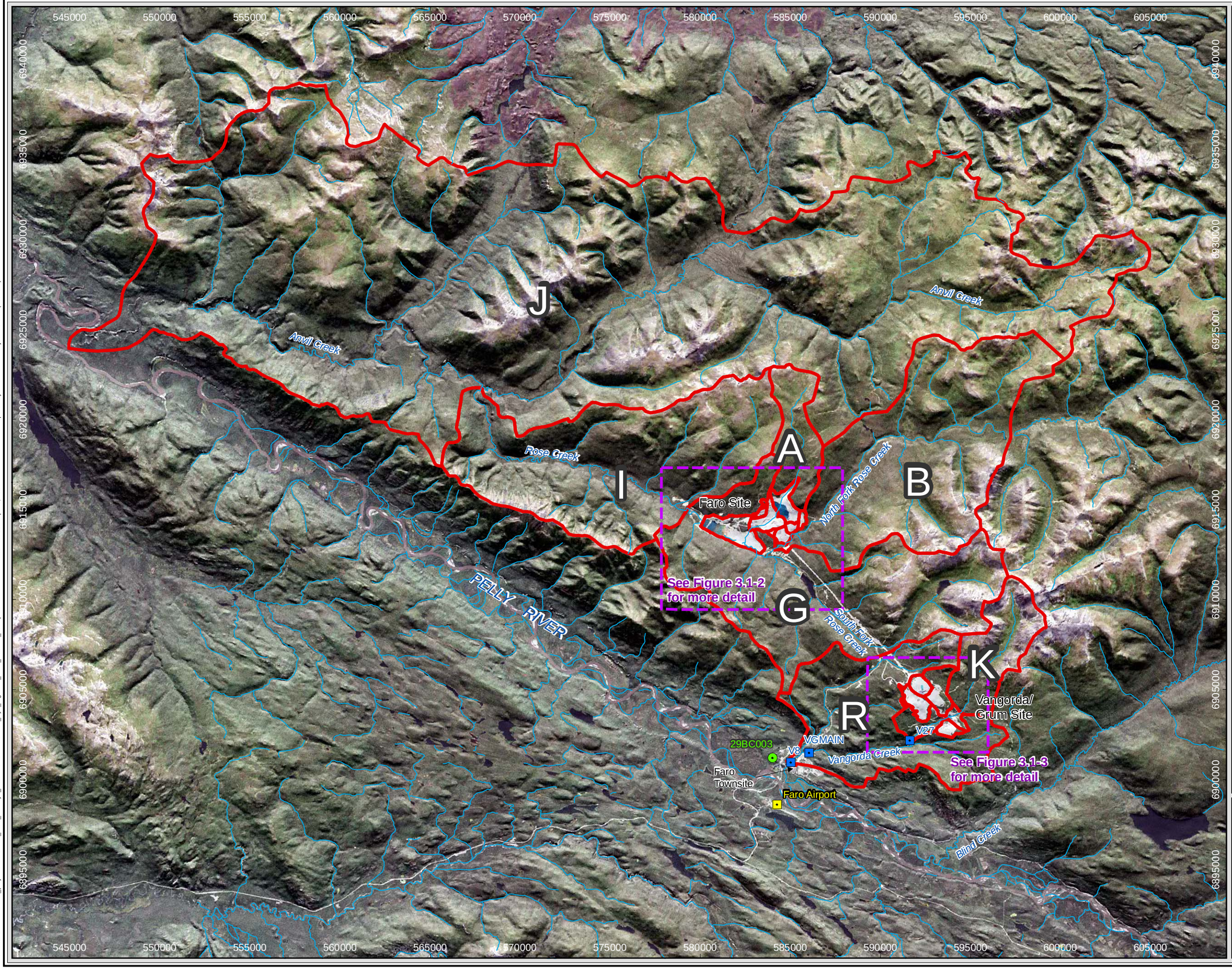
Construction of the historical water balance required records of monthly flows at key locations within the Vangorda Creek catchment spanning the period January 2005 to December 2007. For ungauged locations, this was achieved by transposing a measured record to the point of interest. The transposition 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.

N
W E
S

0 2.5 5
Kilometers

1:200,000

UTM Zone 8N, NAD 83

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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

File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy7_CatchmentsWH\107403_By7_Fig3-1-1_Mine_Catchm_09dApr03.mxd
Date Revised: April 6, 2009
Prepared by: MM
Project: 107403 (80649-1)

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.

N
W E
S

0 250 500
Meters

1:30,000

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation

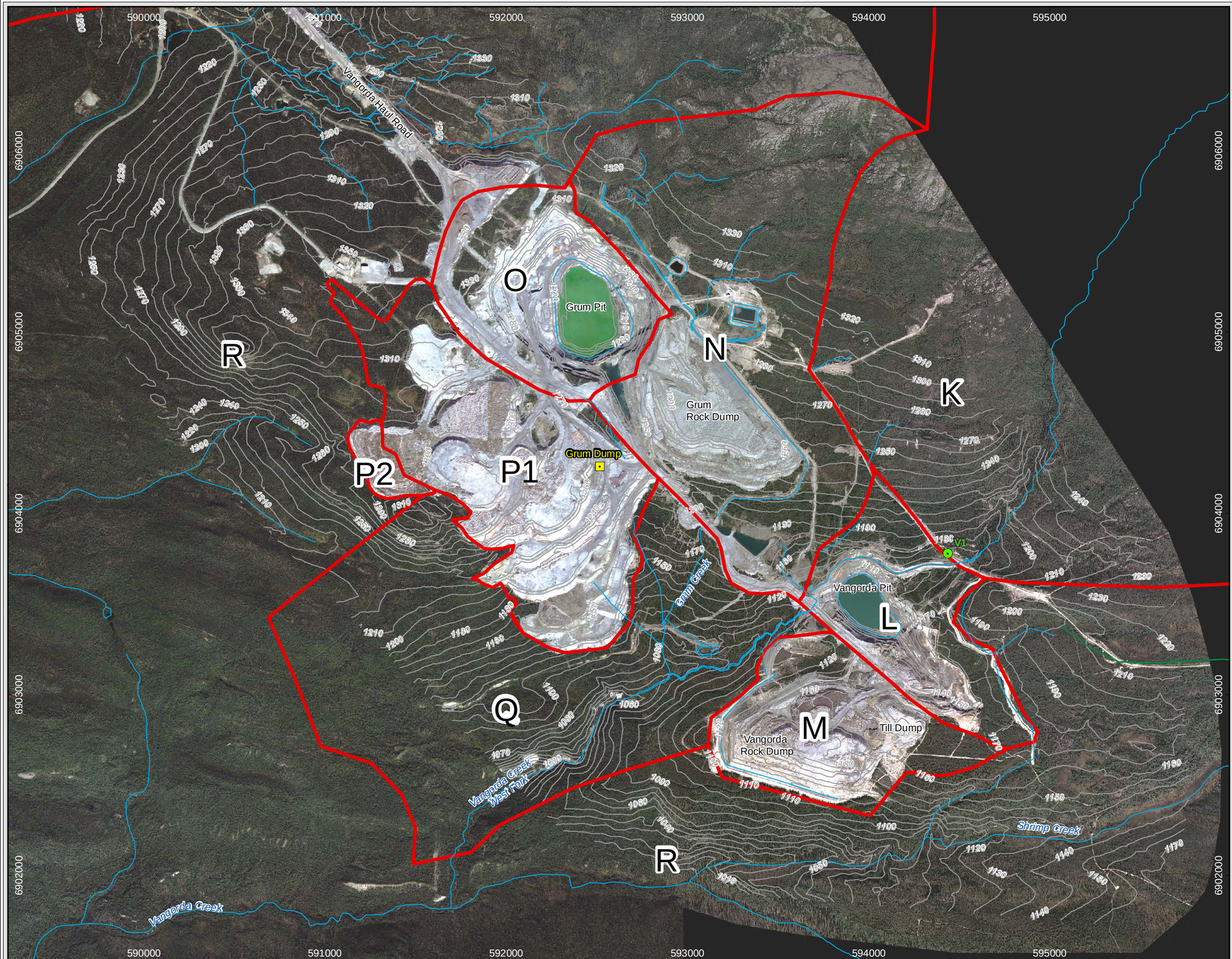
Minesite Subcatchments in the Vicinity of Faro Mine Development

April 2009

AECOM

Figure 3.1-2

File Location: E:\GIS\GIS_pro\Y2009\107403_Faro_GWBy7_CatchmentsWH\107403_By7_Fig2_MineVicFaro_09dApr03.mxd Date Revised: April 6, 2009 Prepared by: MM Project: 107403 (80649-1)



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.

N
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Meters

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UTM Zone 8N, NAD 83

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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

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Date Revised: April 6, 2009
Prepared by: MM
Project: 107403 (80649-1)

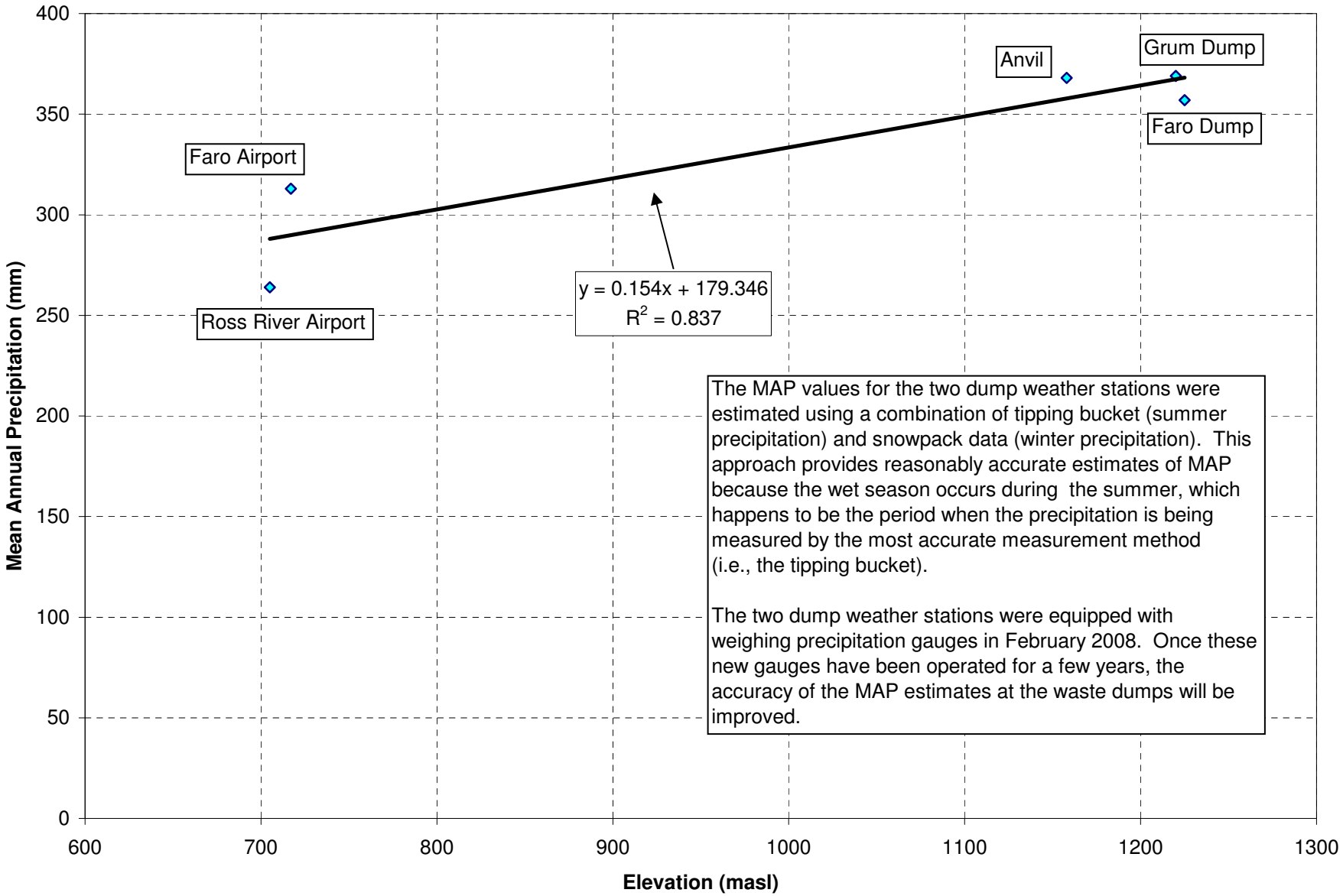


Figure 3.1-4 Relationship Between Mean Annual Precipitation and Elevation

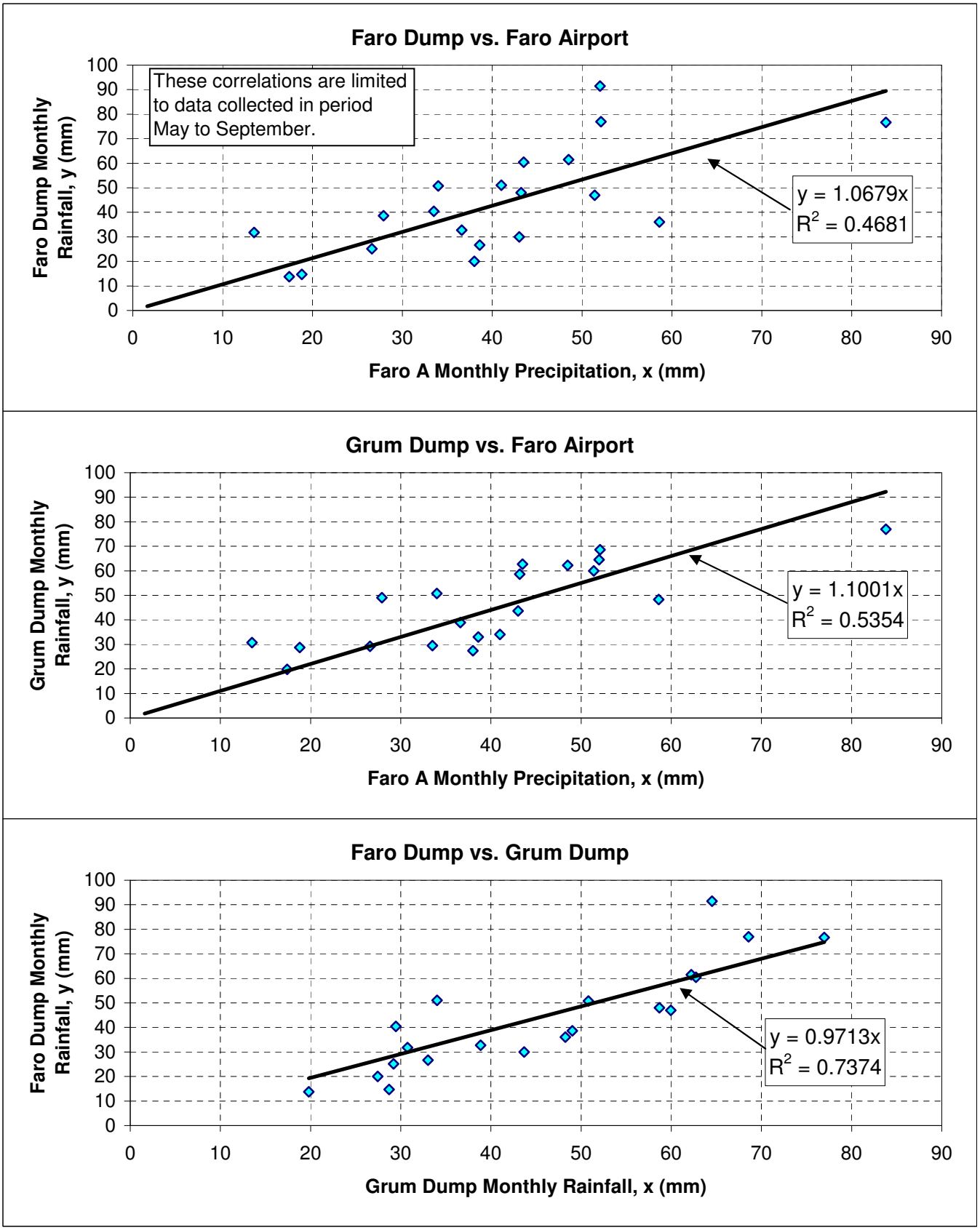


Figure 3.1-5 Examination of Orographic Effects During Rainfall Events

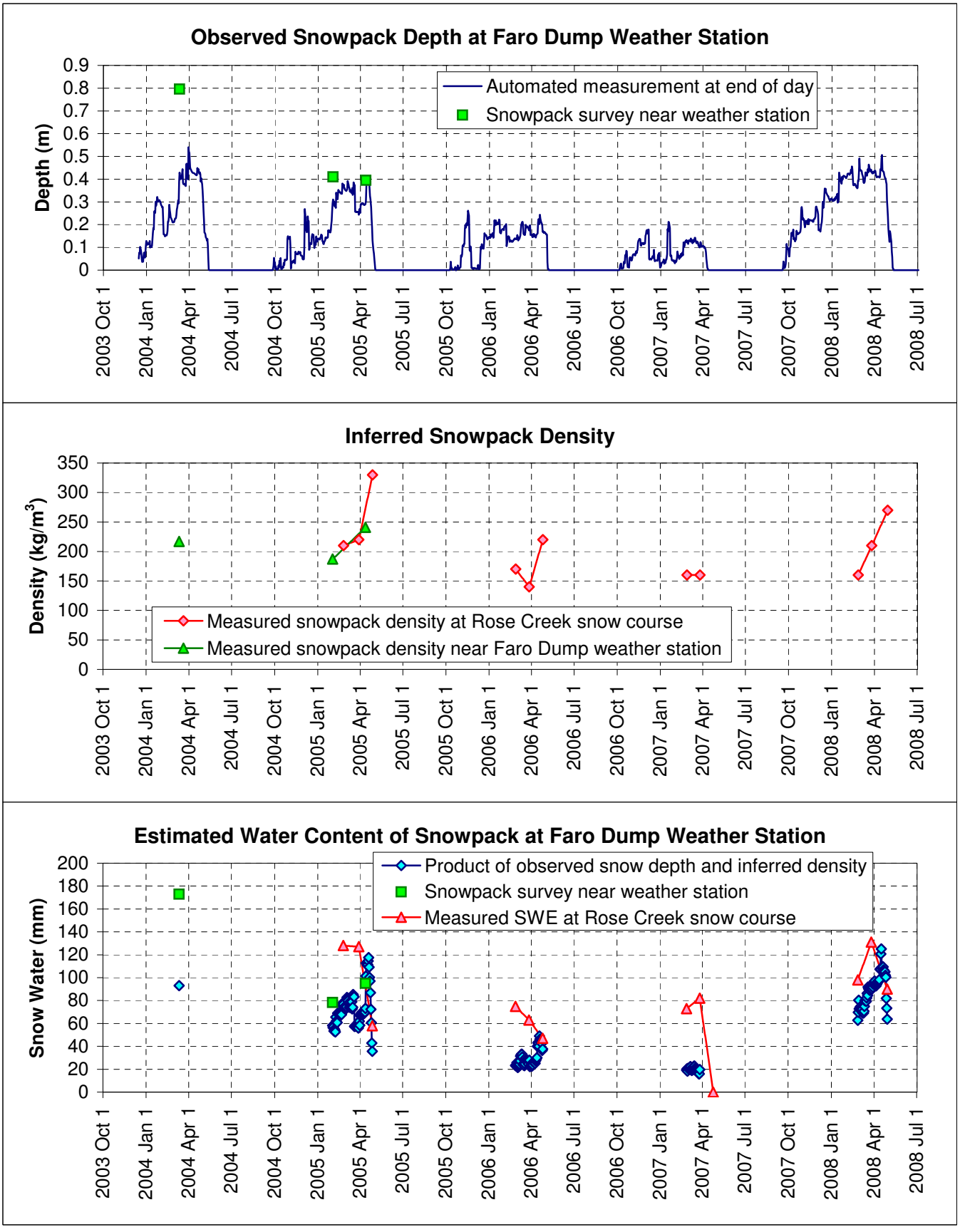


Figure 3.1-6 Snowpack at Faro Dump Weather Station

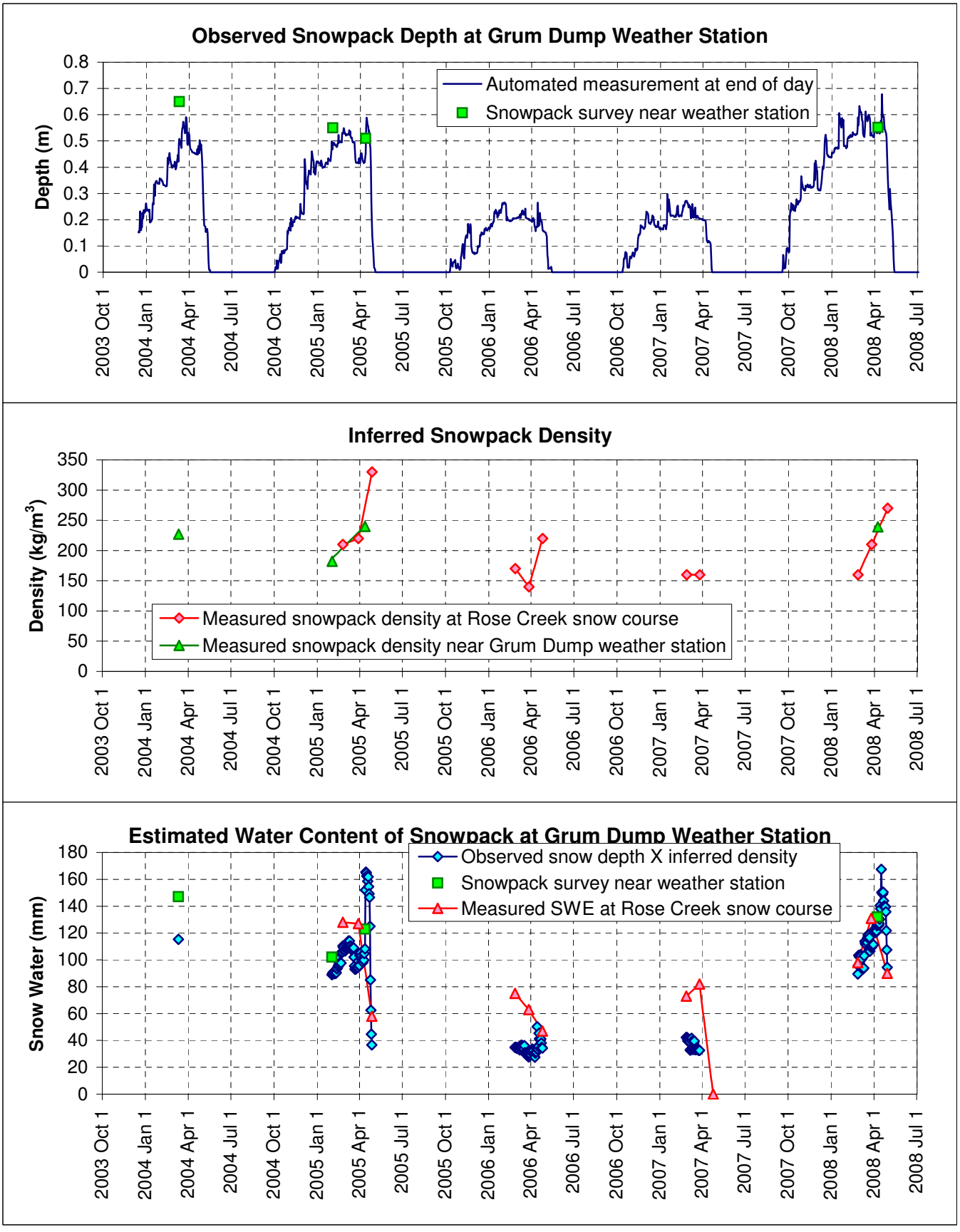


Figure 3.1-7 Snowpack at Grum Dump Weather Station

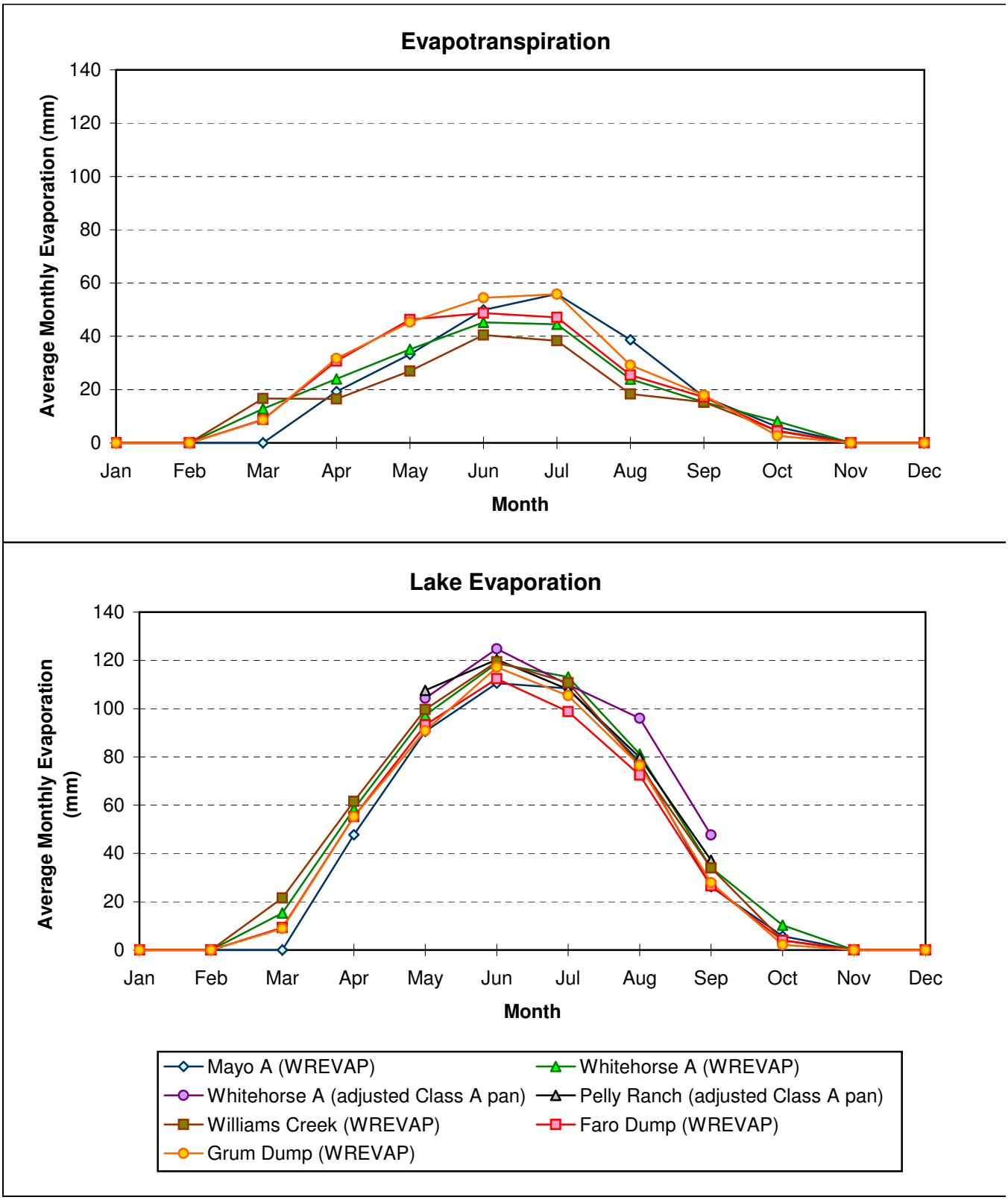


Figure 3.1-8 Estimated Lake Evaporation and Evapotranspiration

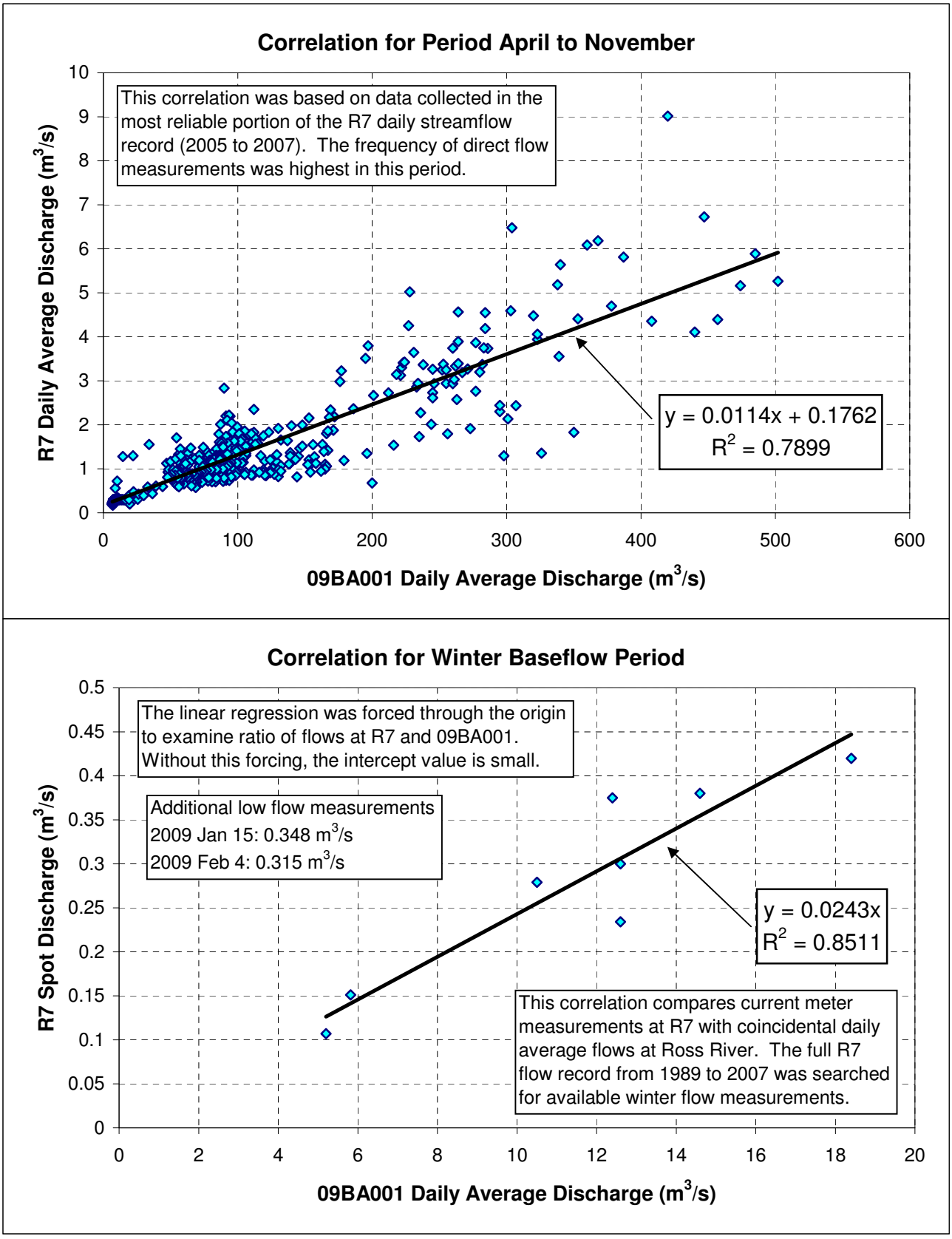


Figure 3.1-9 Correlations Used to Patch R7 Streamflow Record

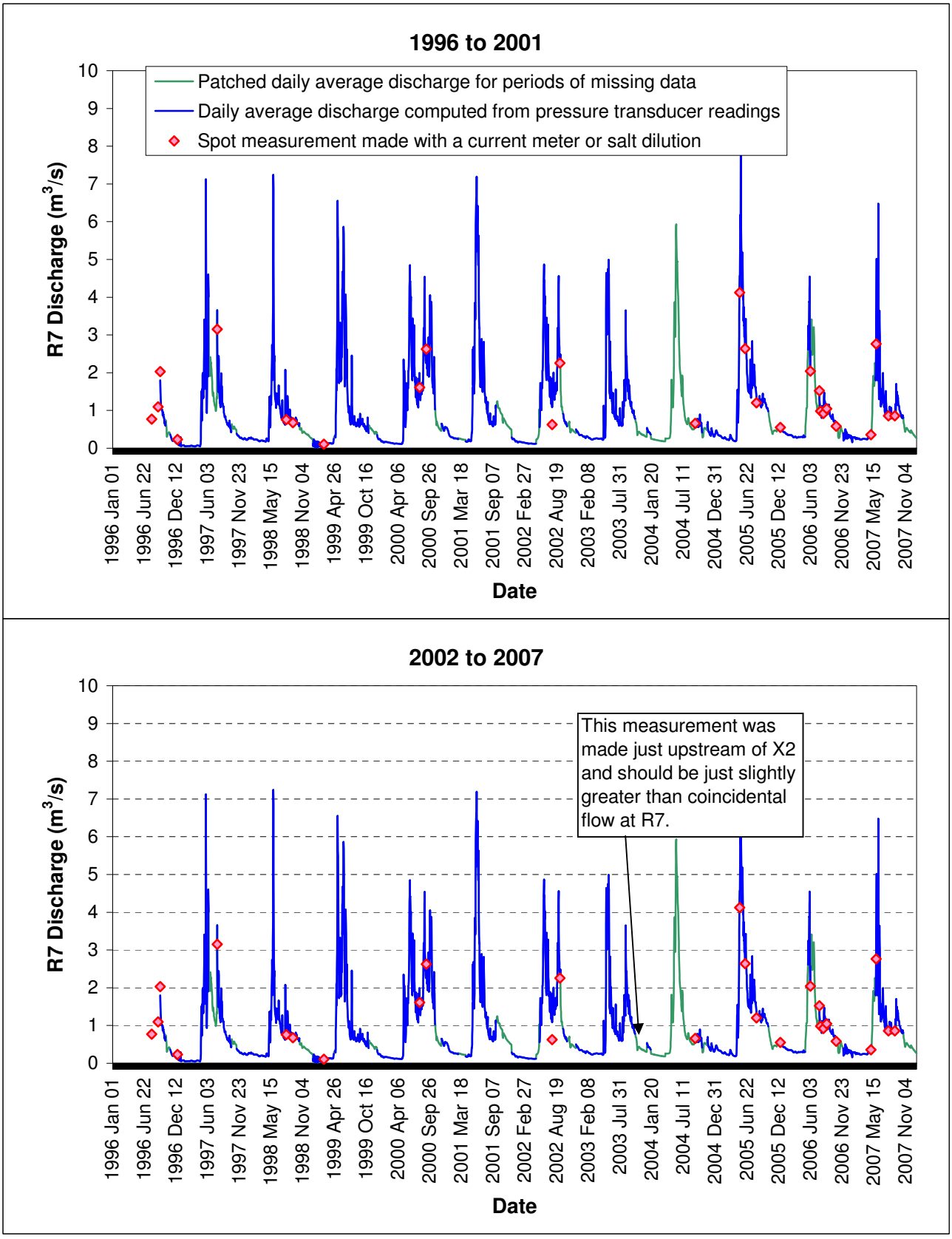


Figure 3.1-10 Daily Flow Record for North Fork of Rose Creek at R7

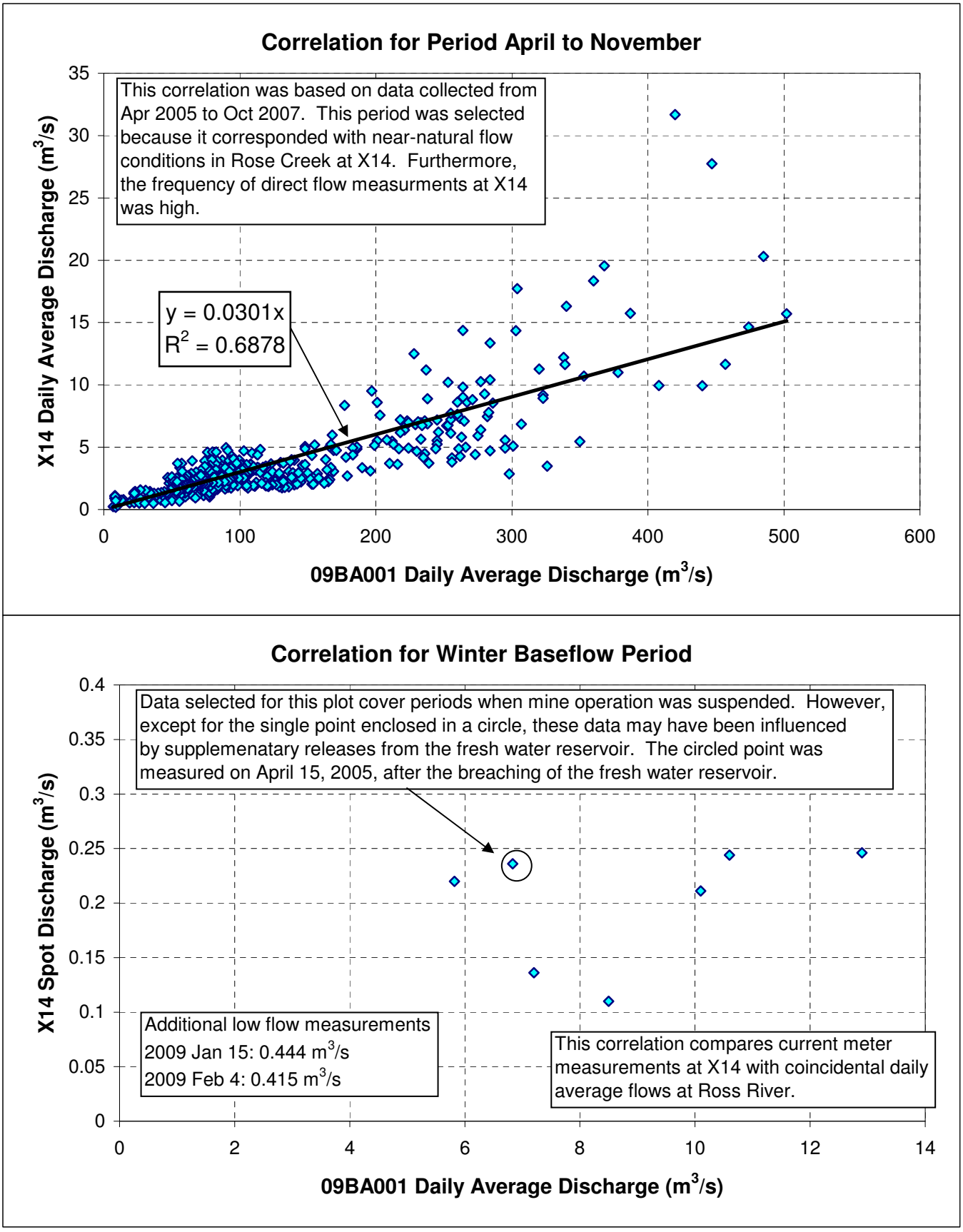


Figure 3.1-11 Correlations Used to Patch X14 Streamflow Record

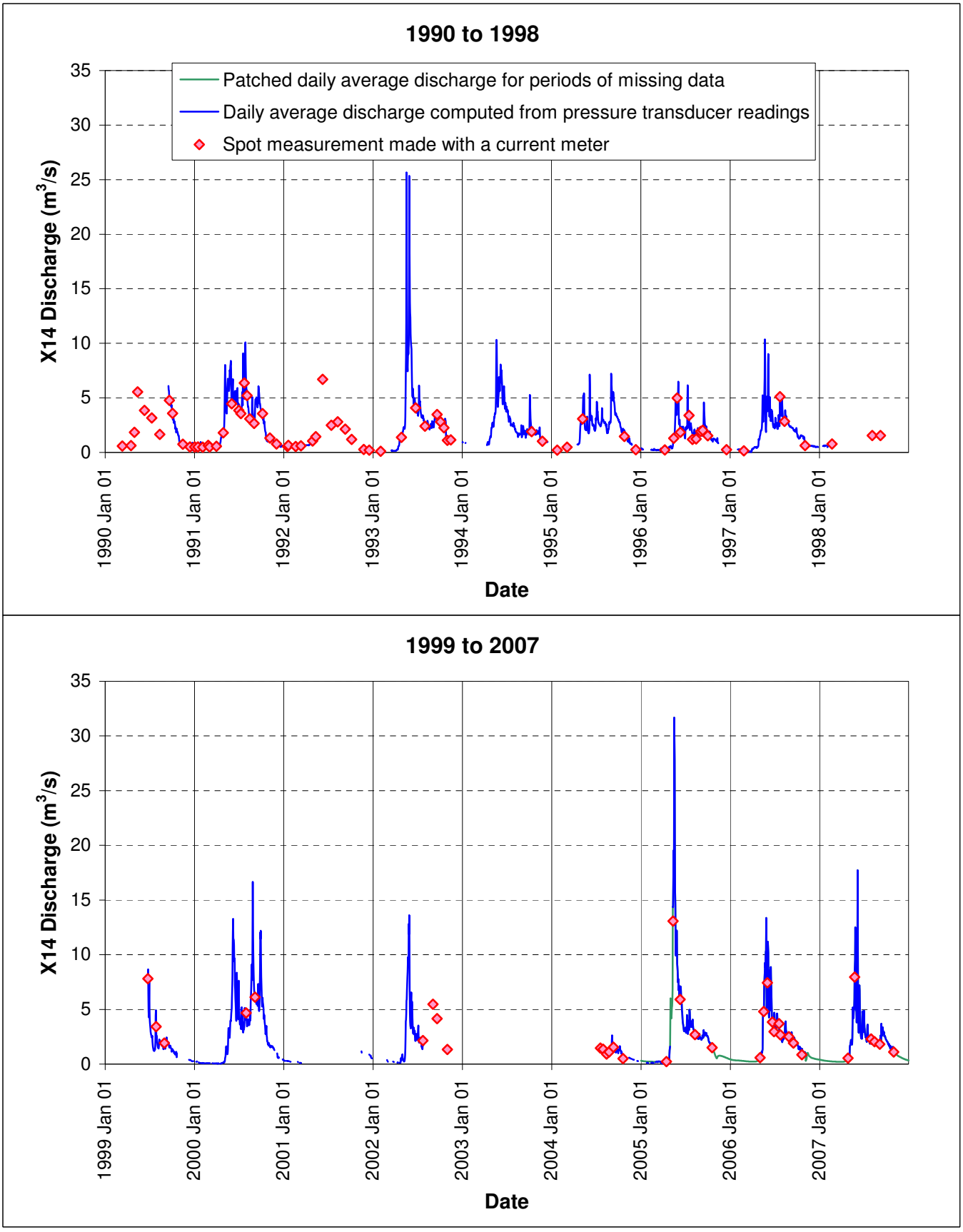


Figure 3.1-12 Daily Flow Record for Rose Creek at X14

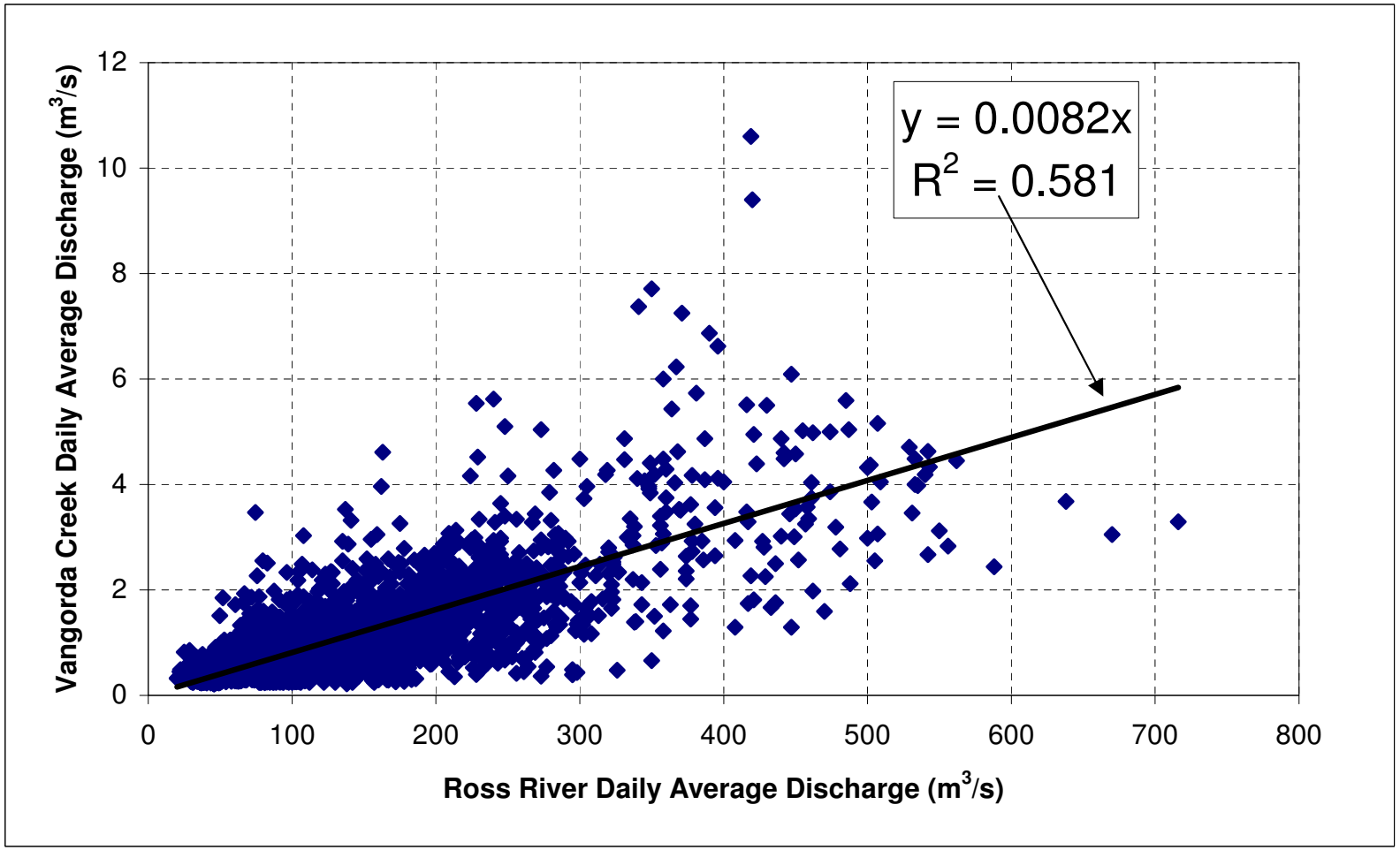


Figure 3.1-13 Correlation Used to Patch 29BC003 Streamflow Record

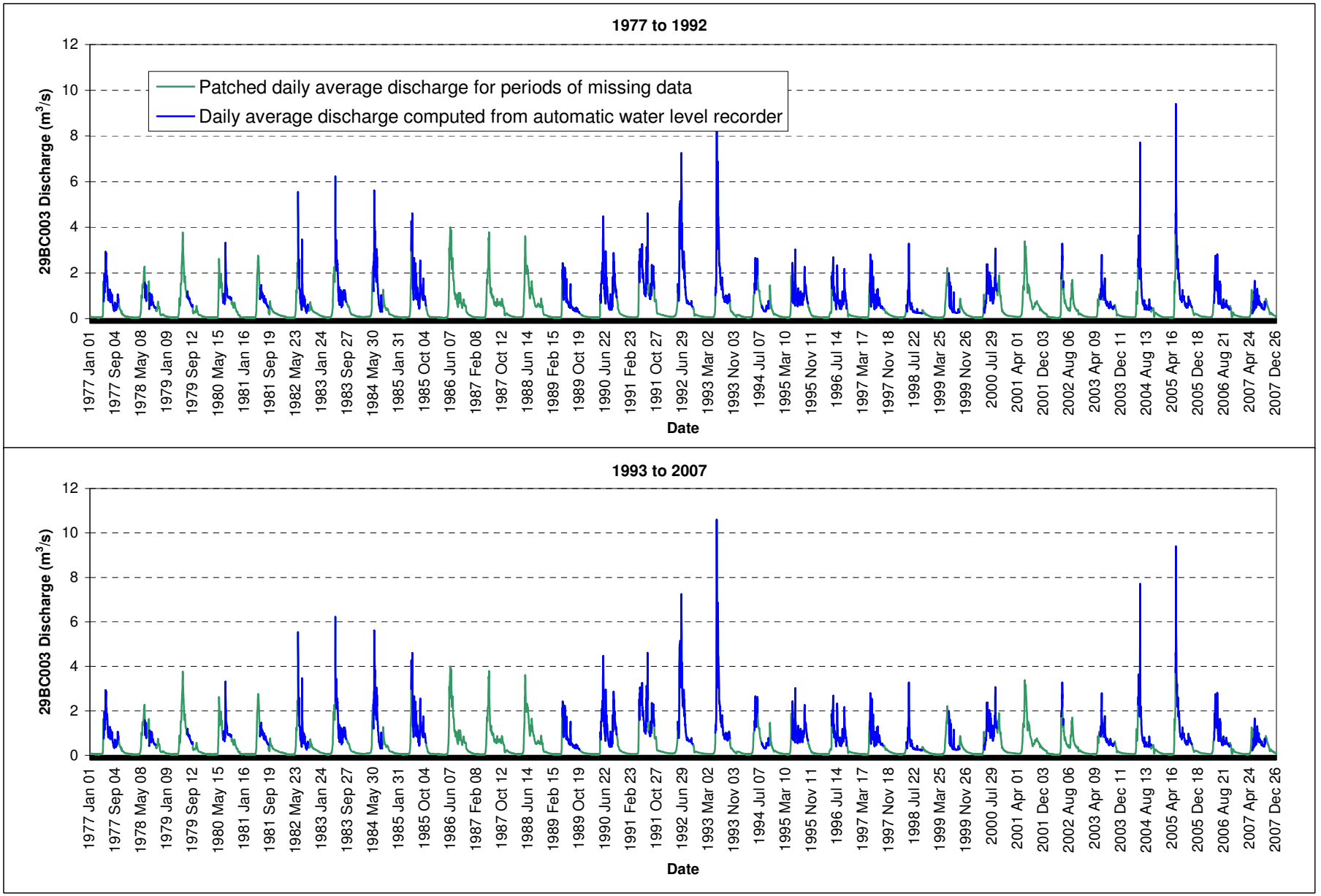


Figure 3.1-14 Patched Daily Flow Record for Vangorda Creek at 29BC003

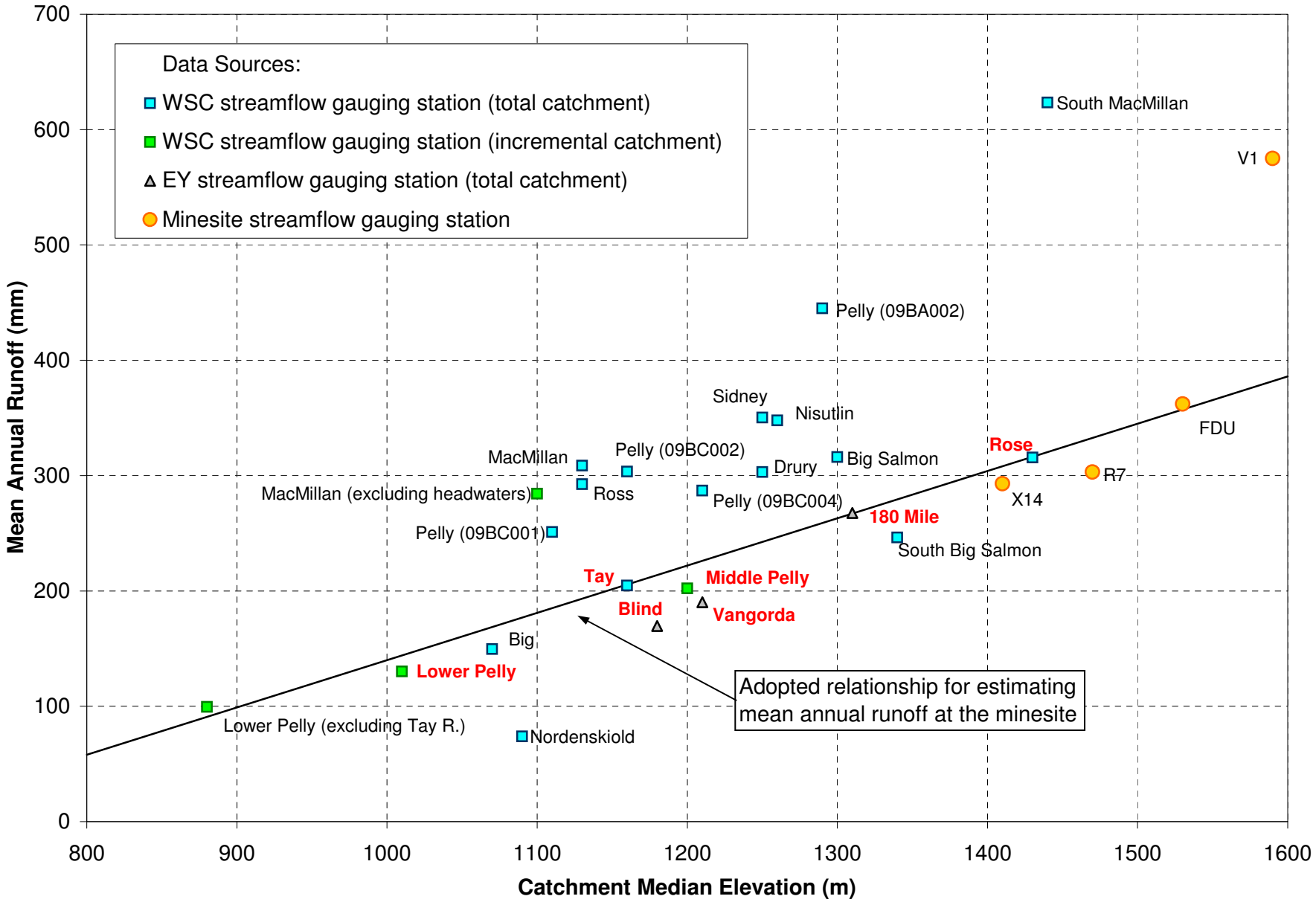


Figure 3.1-15 Regional Relationship Between Mean Annual Runoff and Catchment Median Elevation

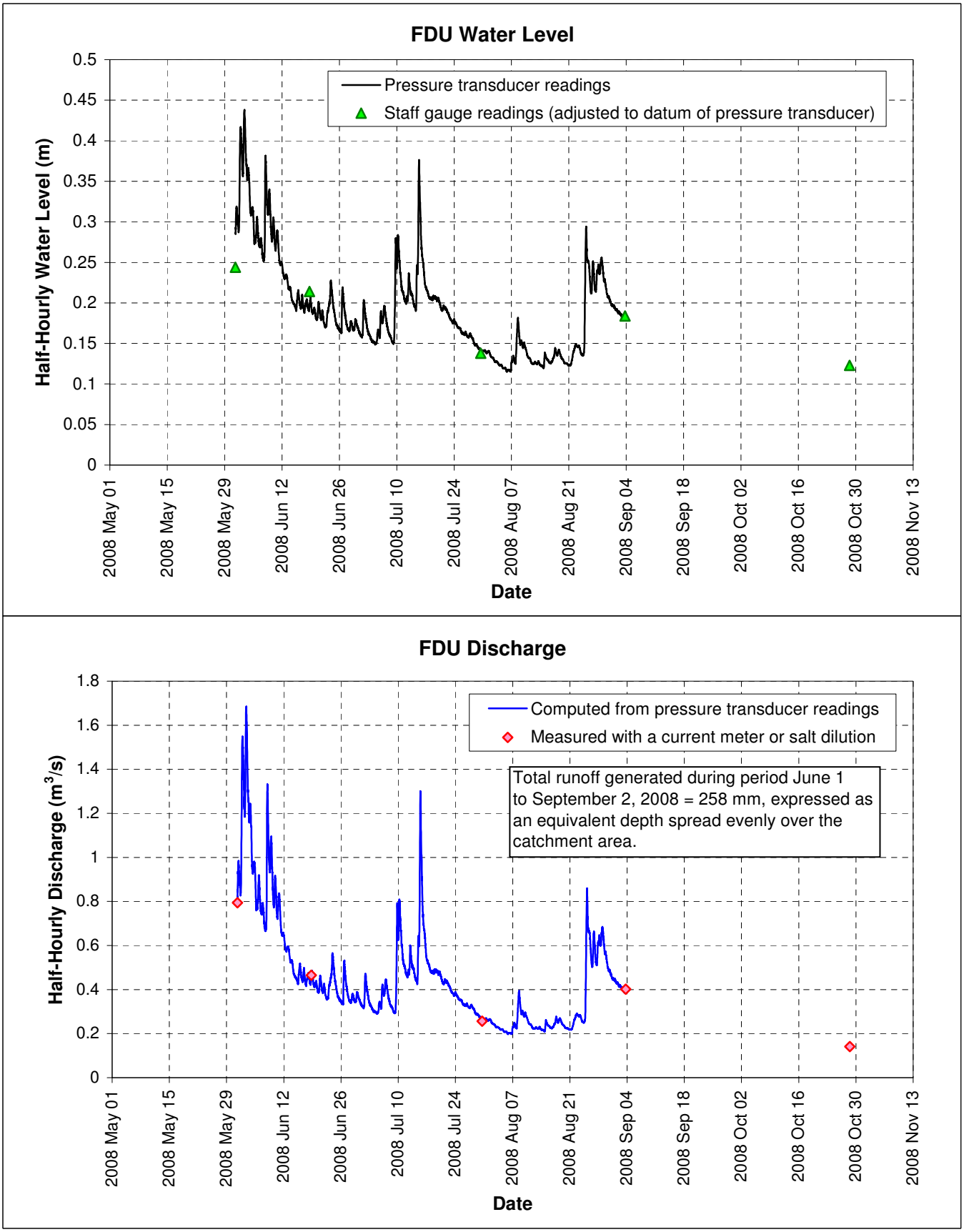


Figure 3.1-16 2008 Stage and Flow Records for Faro Creek at FDU

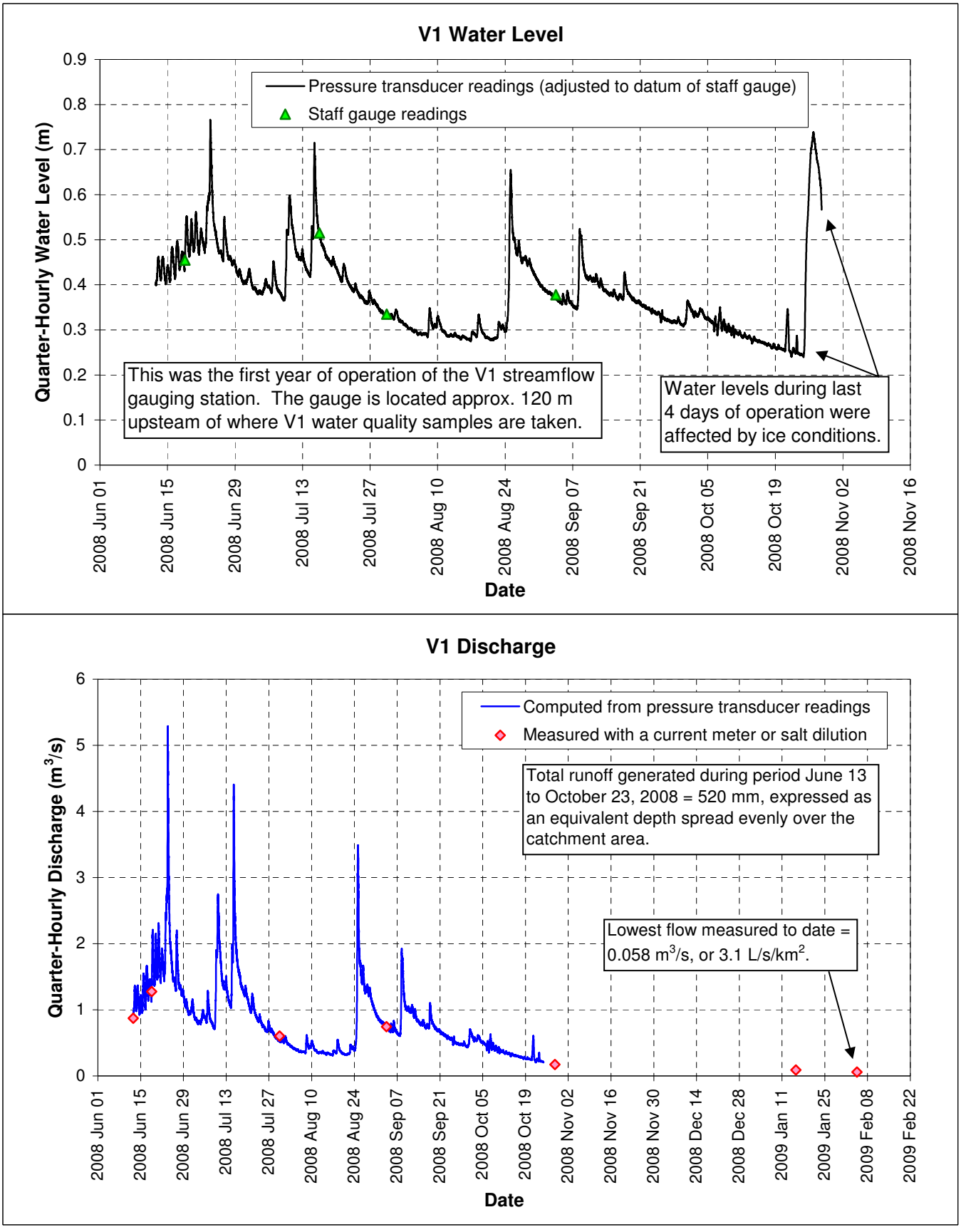


Figure 3.1-17 Stage and Flow Records for Vangorda Creek at V1

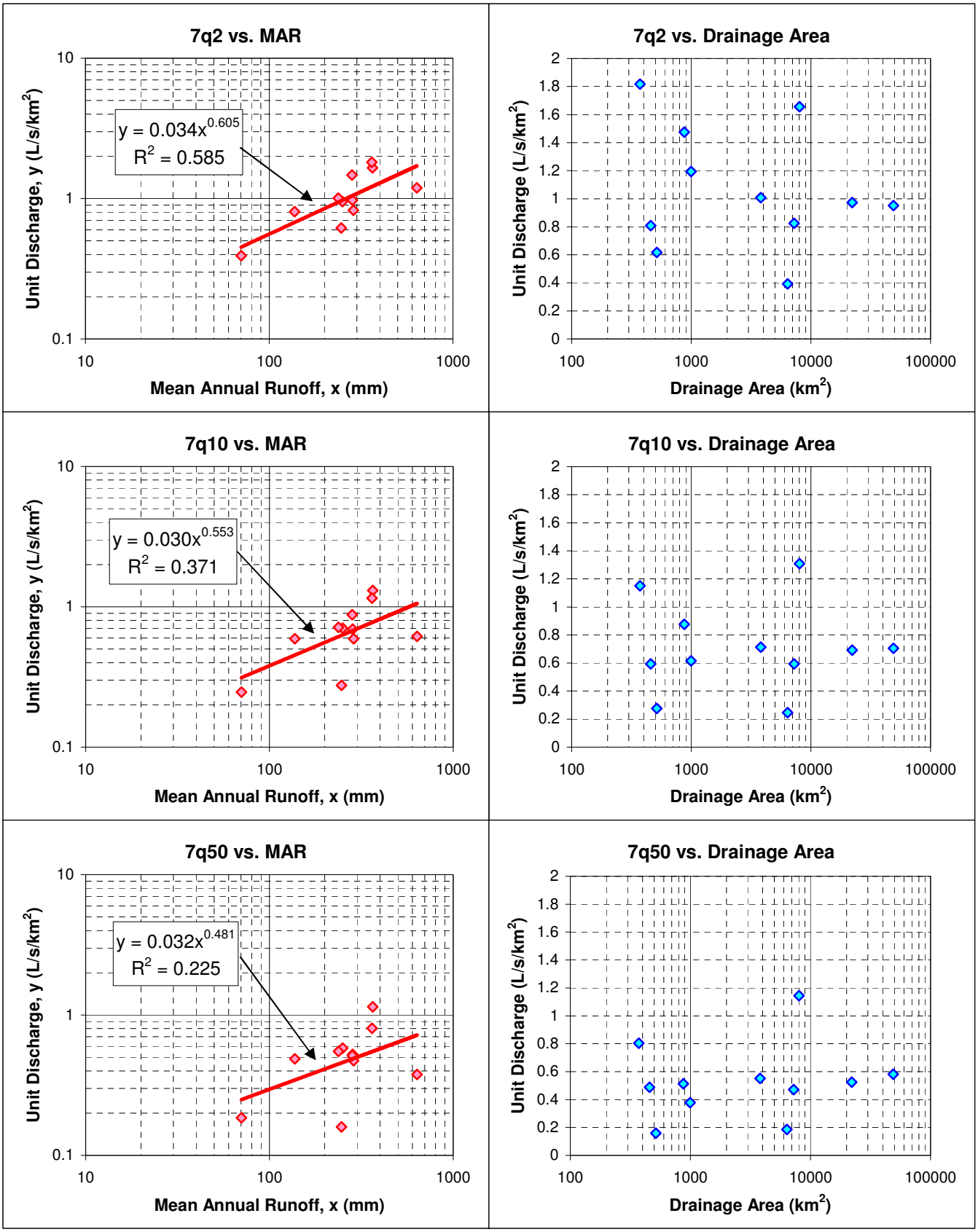


Figure 3.1-18 Annual Minimum 7-Day Low Flow vs. Mean Annual Runoff and Drainage Area

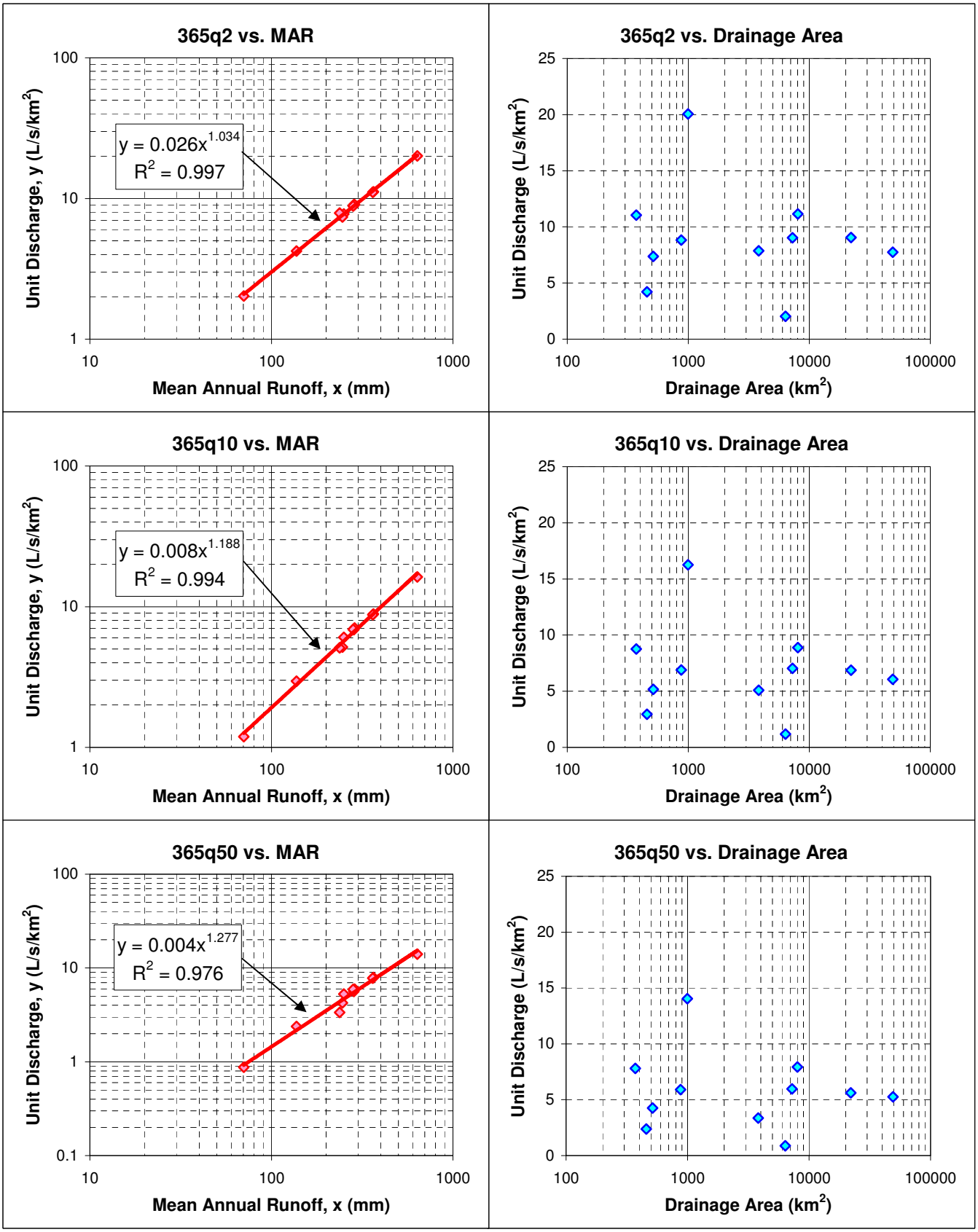


Figure 3.1-19 Annual Minimum 365-Day Low Flow vs. Mean Annual Runoff and Drainage Area

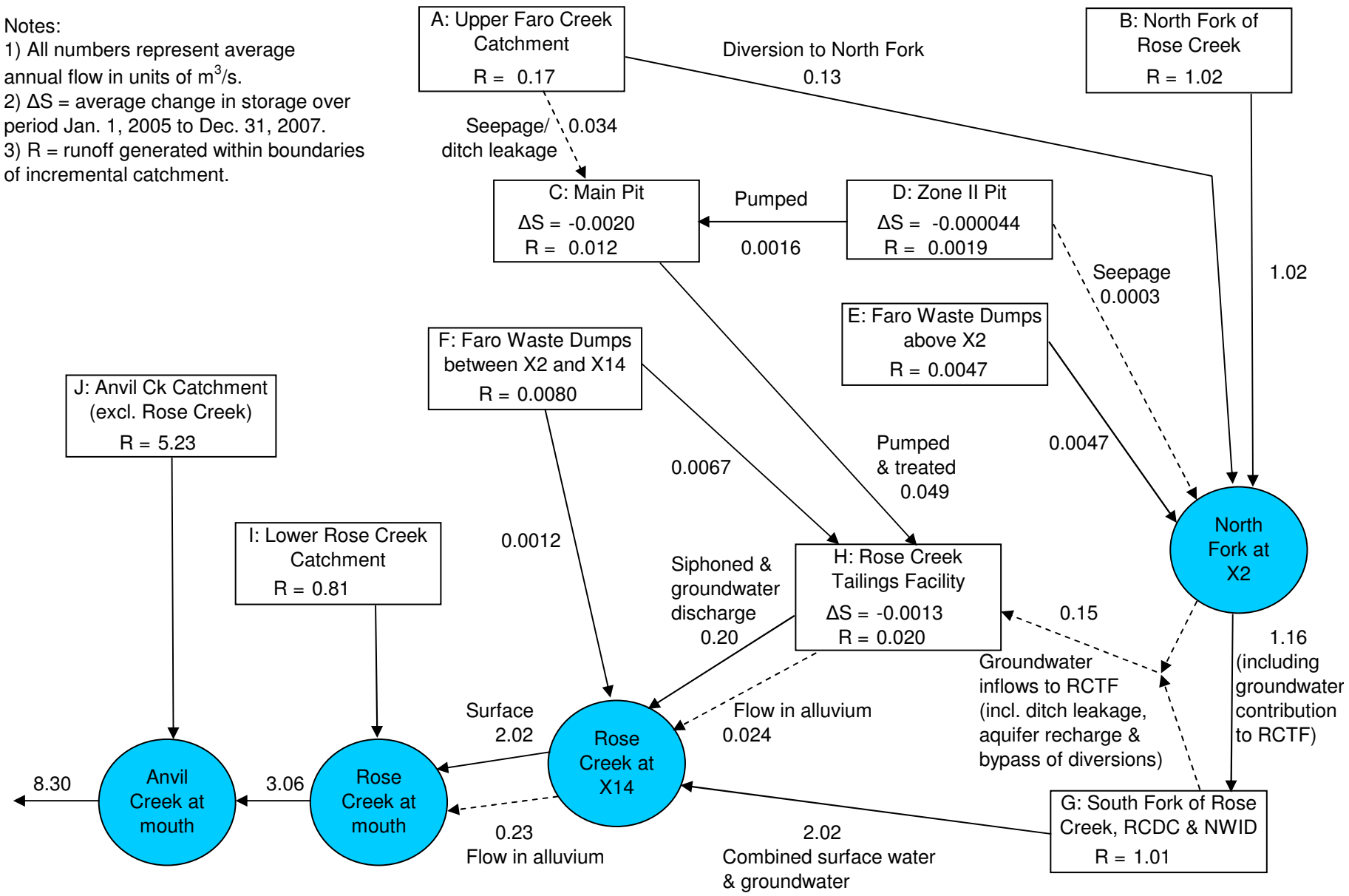


Figure 3.1-20 Average Annual Water Balance for Anvil Creek Catchment (2005 to 2007)

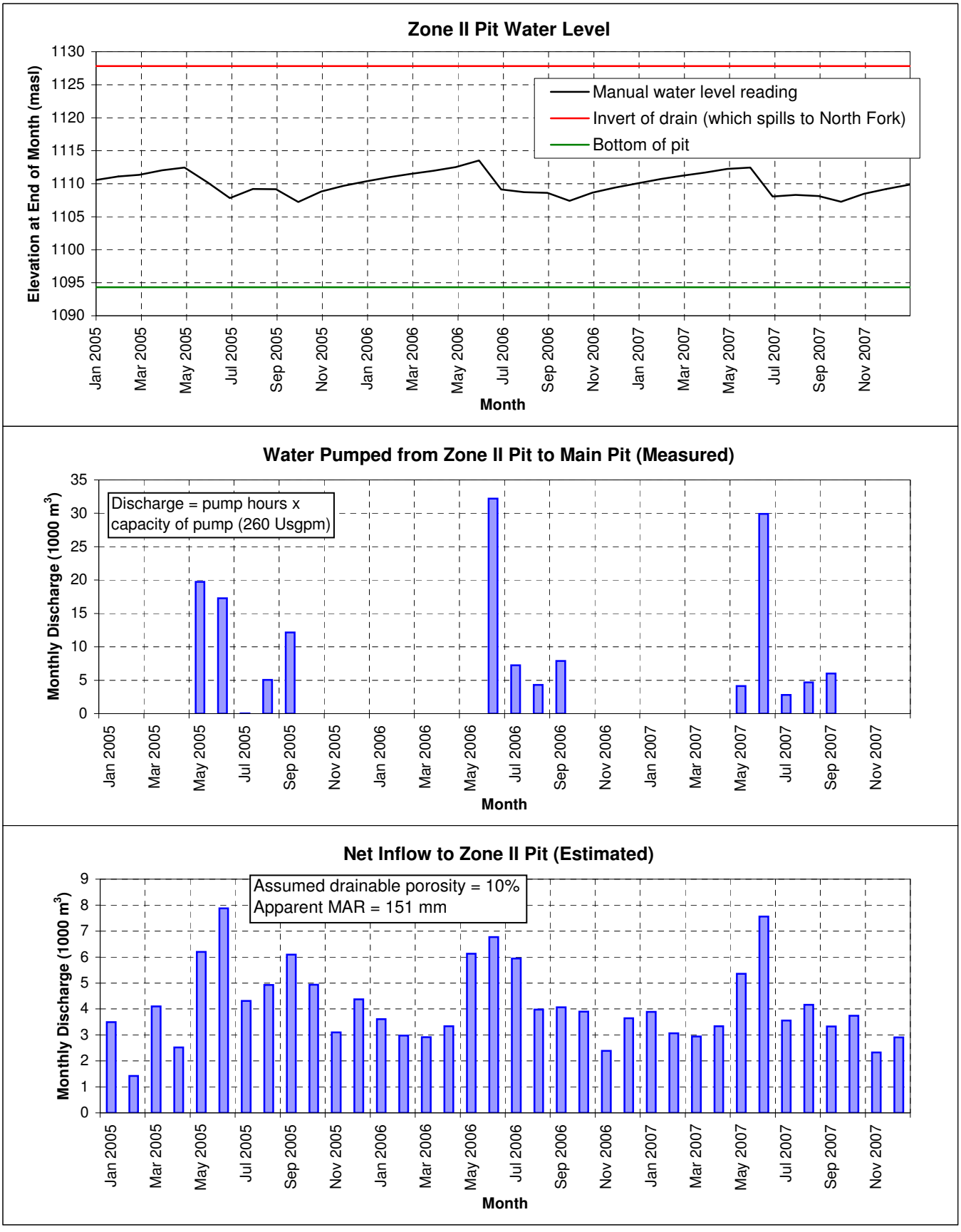


Figure 3.1-21 Water Balance for Zone II Pit (2005 to 2007)

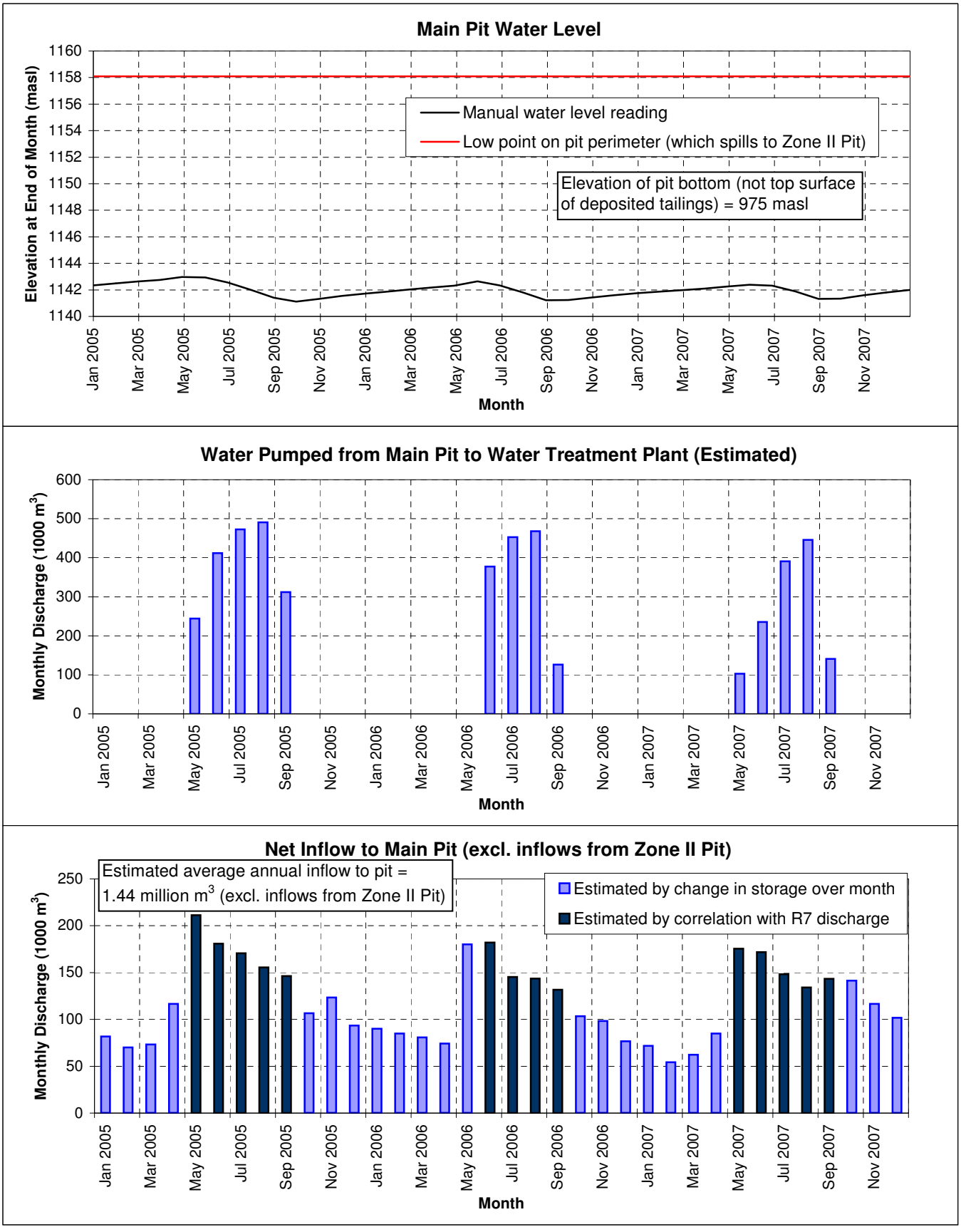


Figure 3.1-22 Water Balance for Main Pit (2005 to 2007)

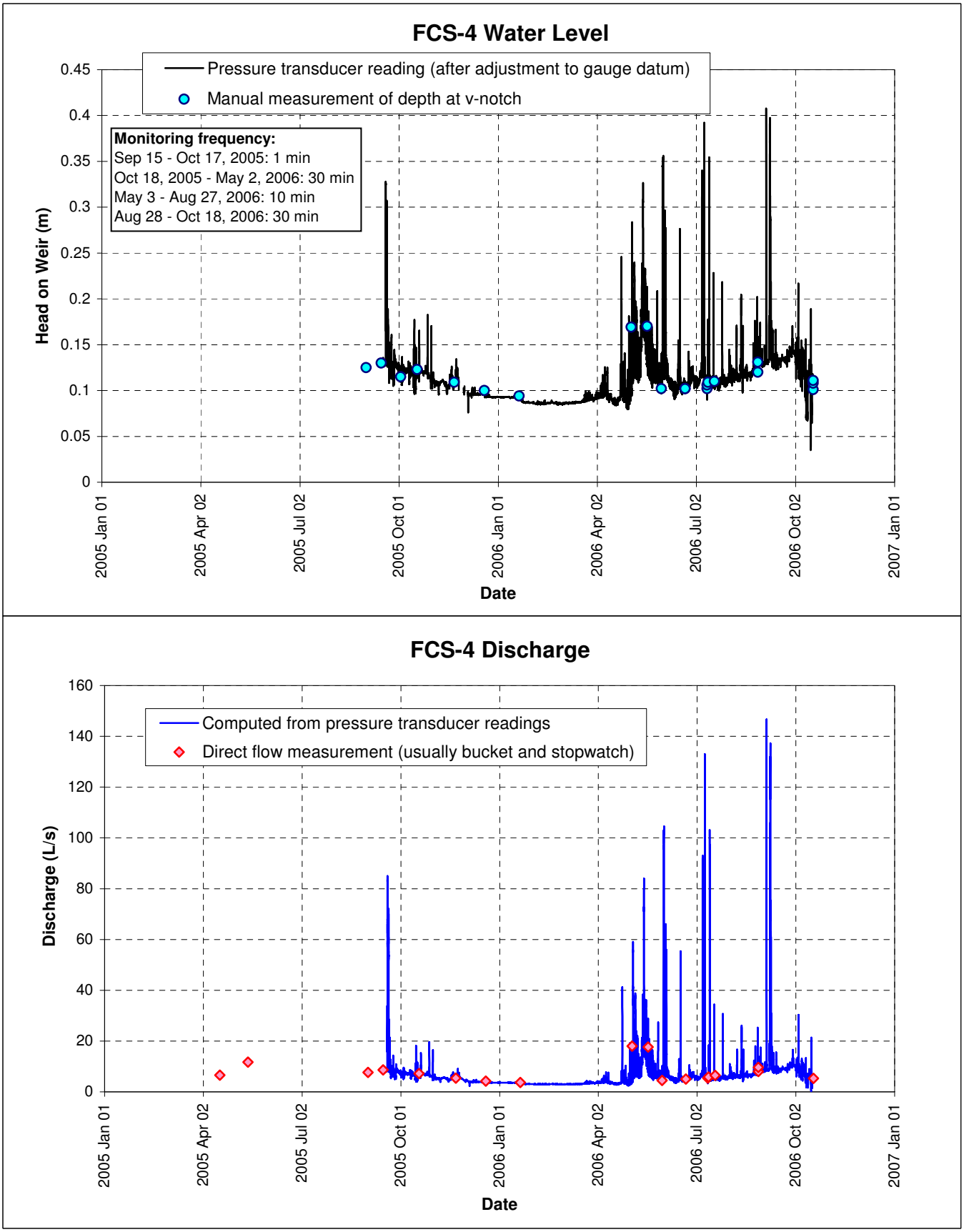


Figure 3.1-23 Stage and Flow Records for Station FCS-4

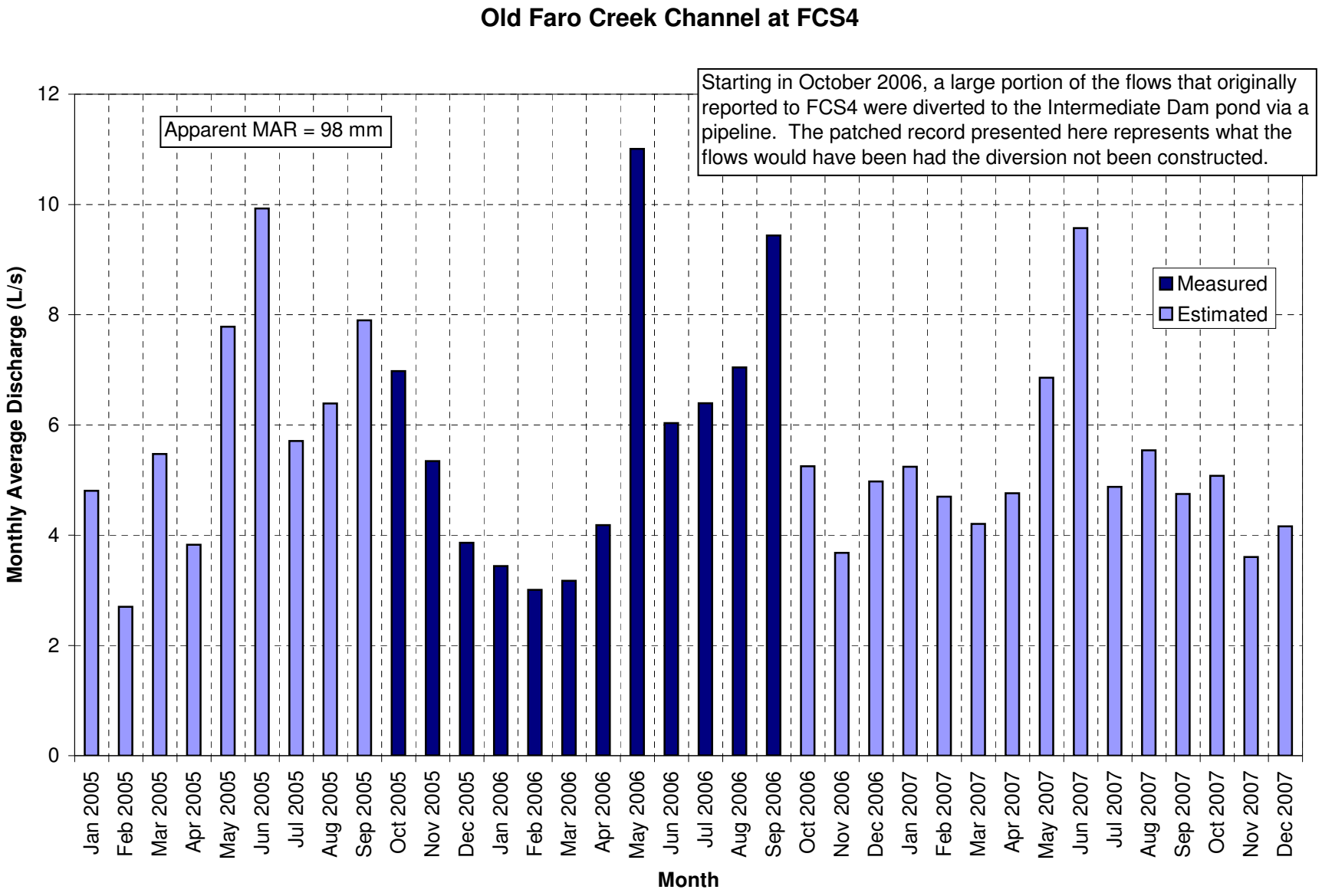


Figure 3.1-24 Patched Monthly Flow Record for Waste Dumps Draining To Old Faro Creek Channel

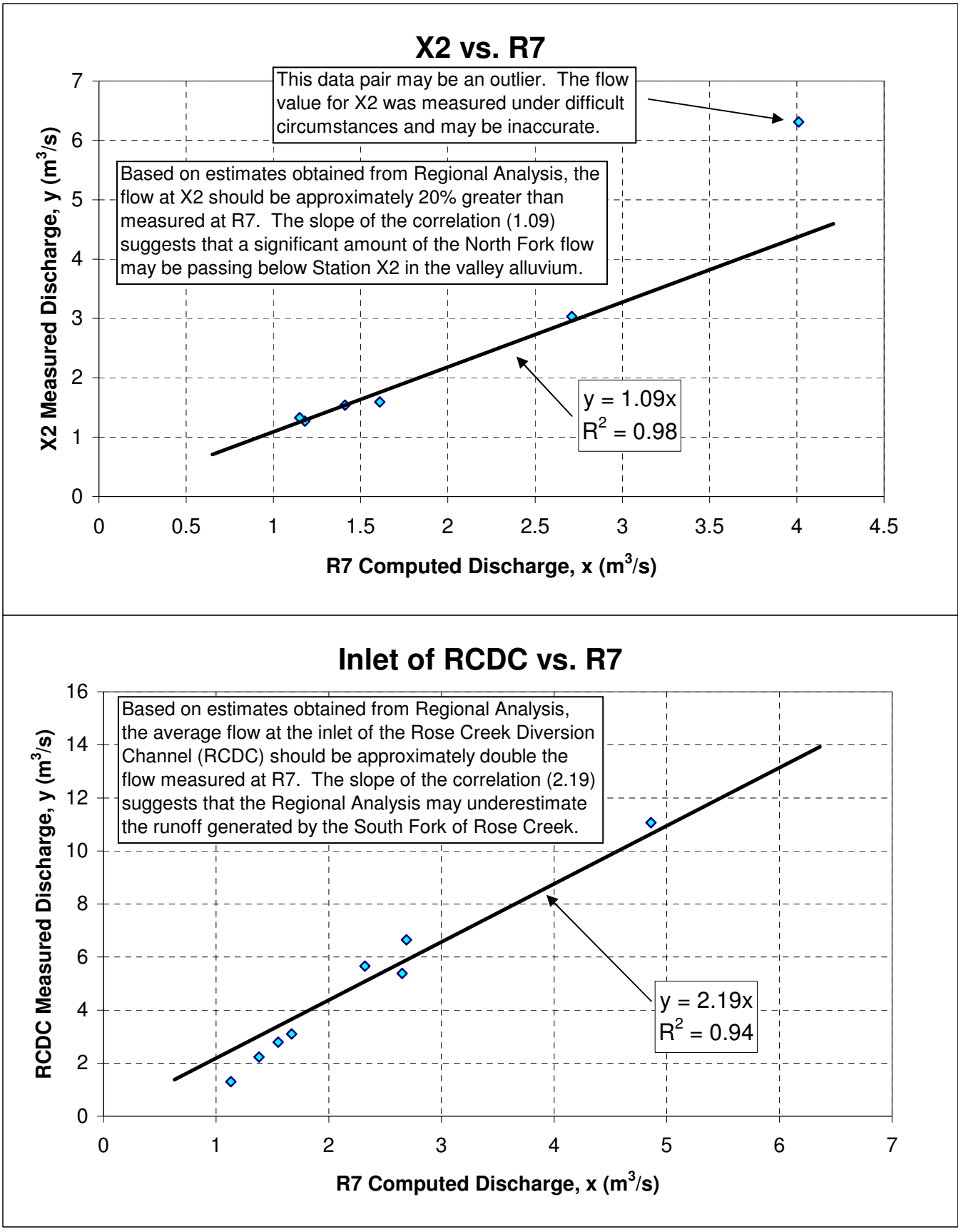


Figure 3.1-25 Comparison of Coincidental Flows at X2, Inlet of RCDC and R7

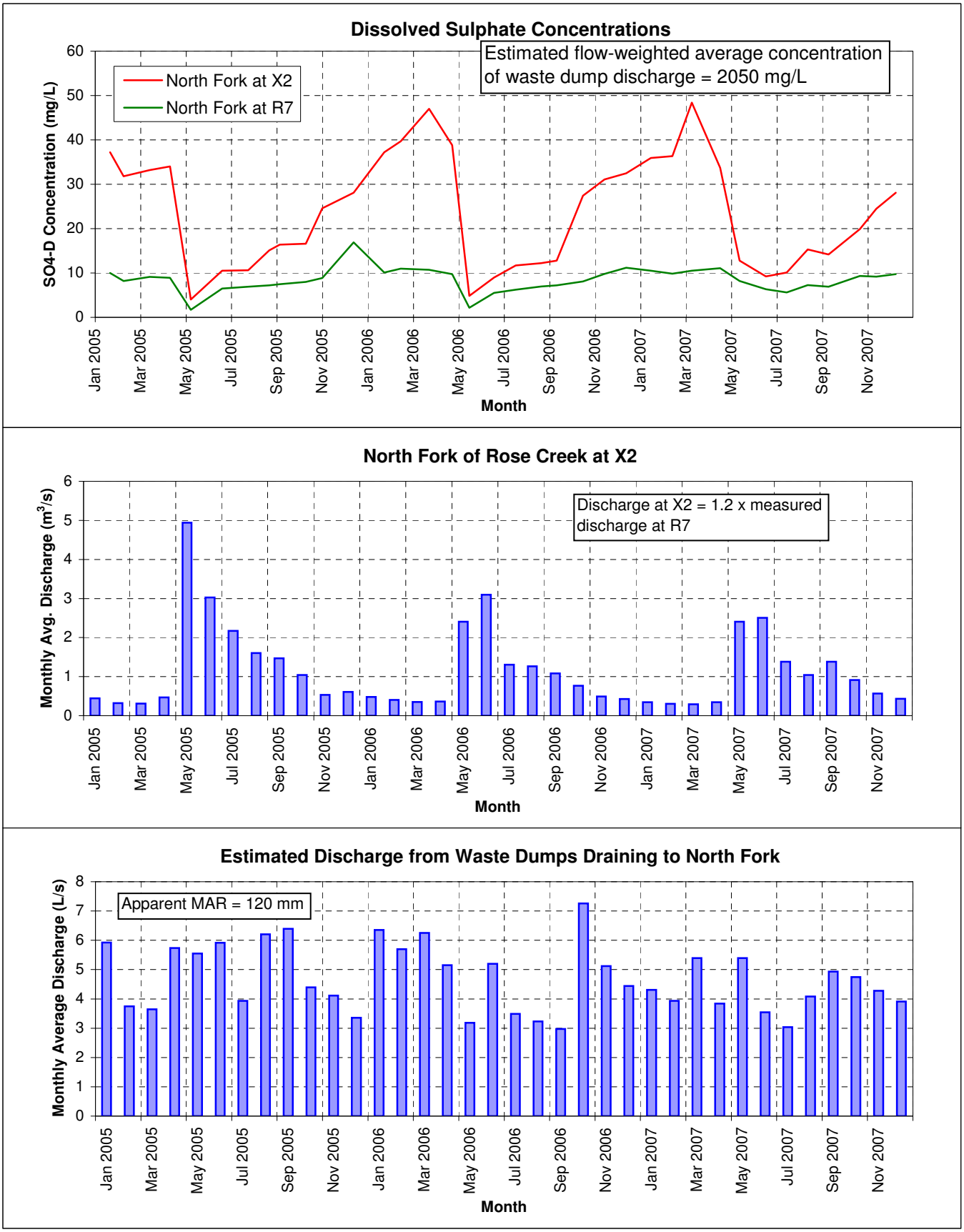


Figure 3.1-26 Estimation of Waste Dump Runoff to North Fork Using a Two-Component Mixing Model

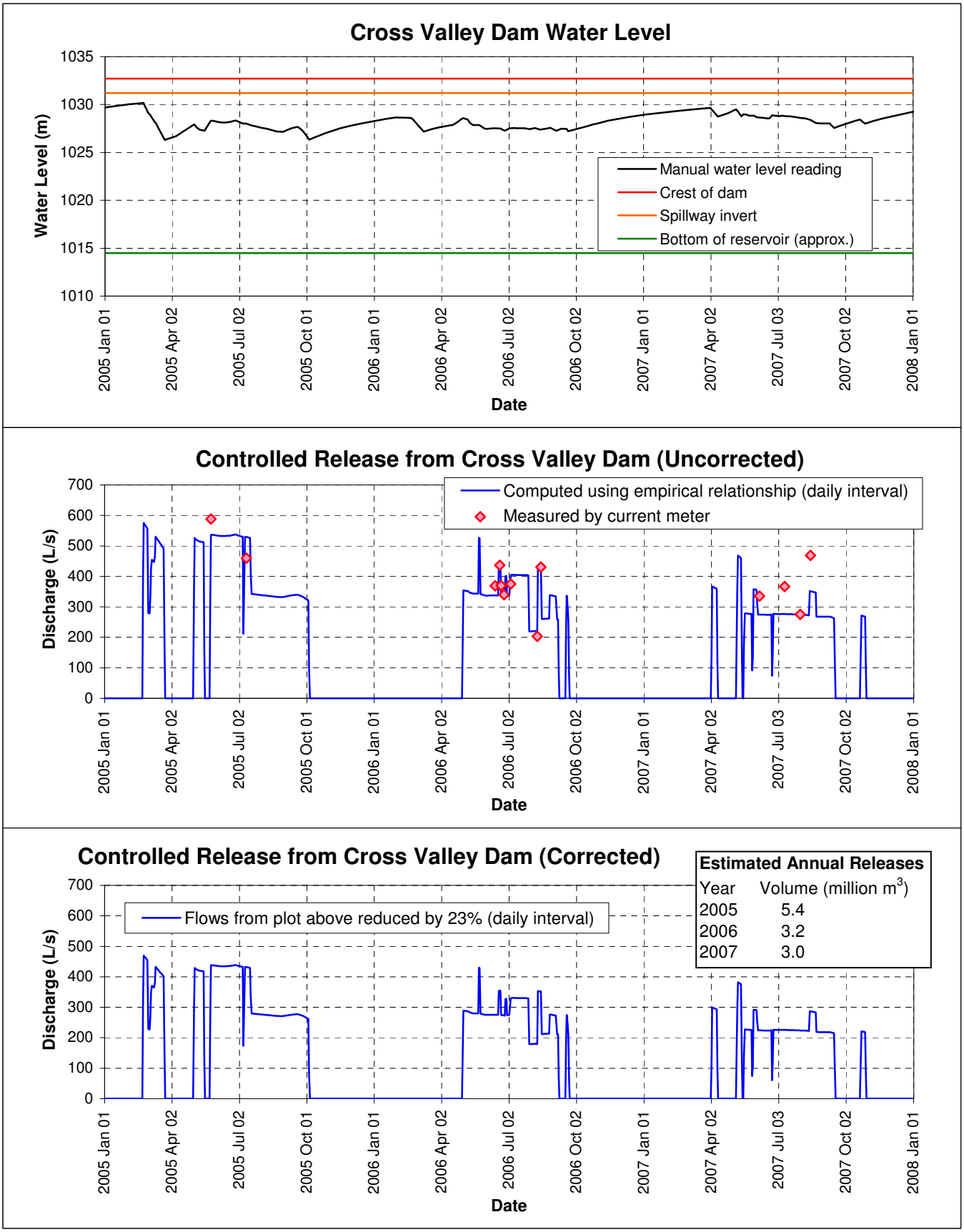
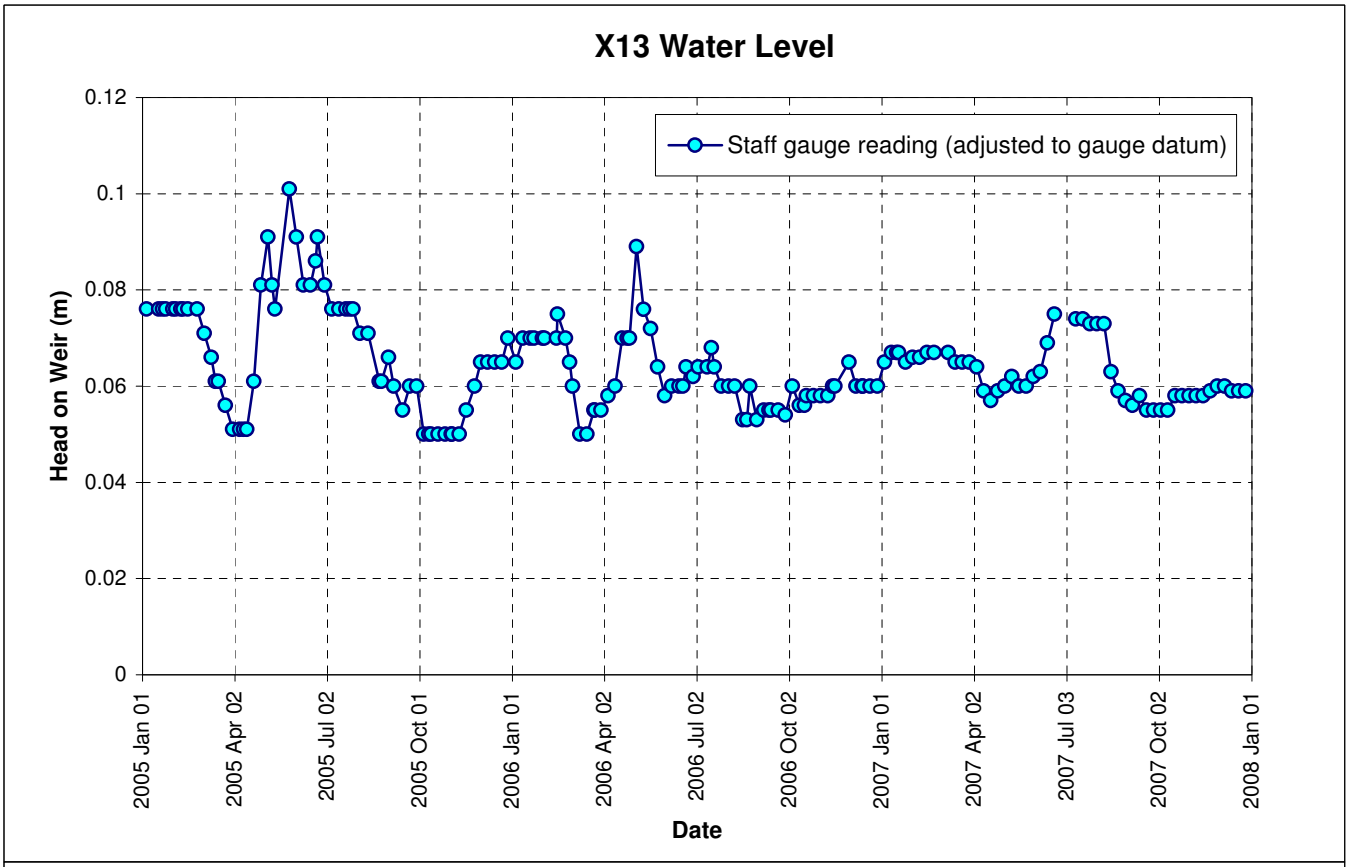


Figure 3.1-27 Reservoir Water Level and Controlled Release Records for Cross Valley Dam (2005 to 2007)



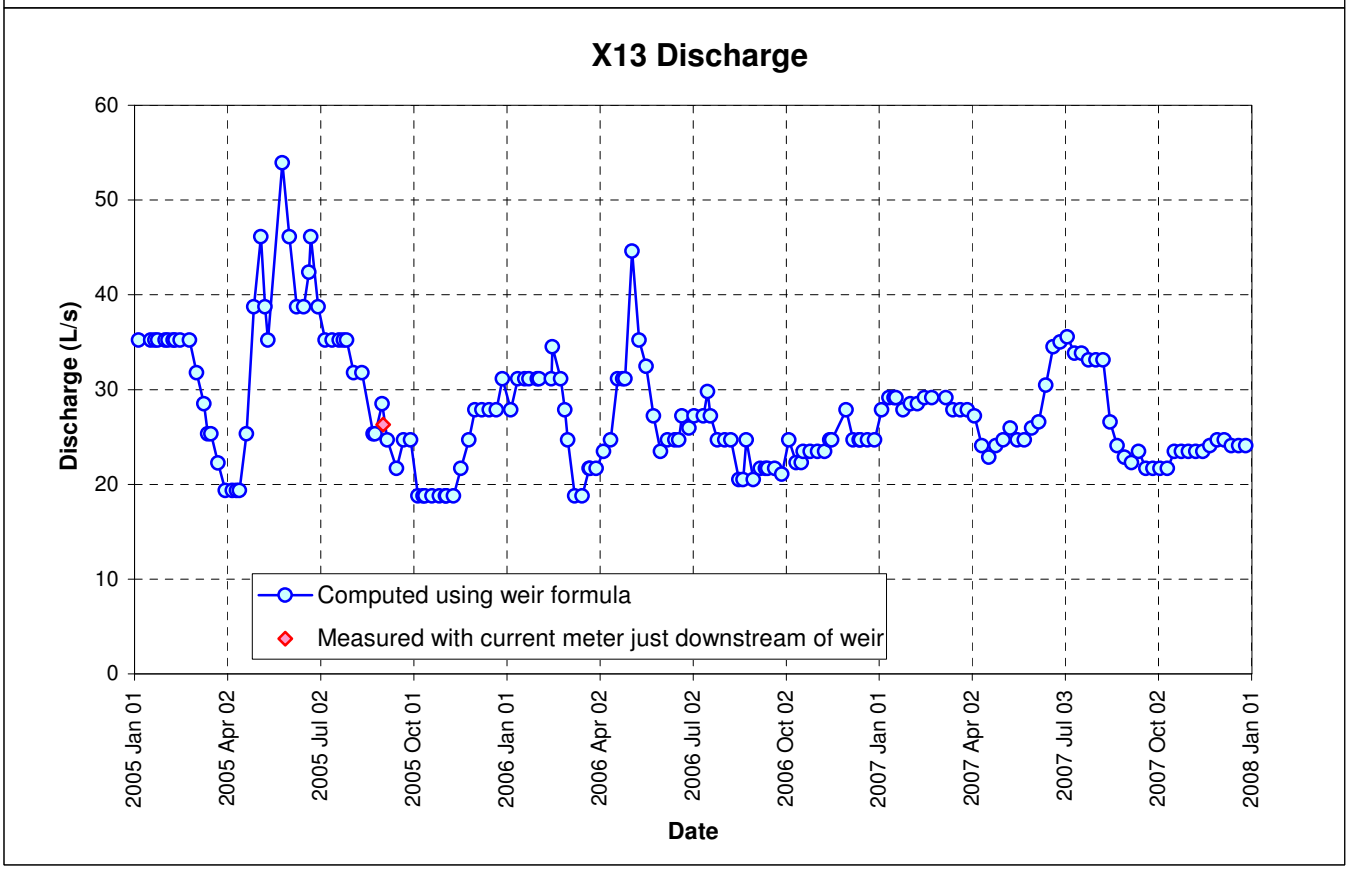


Figure 3.1-28 Weekly Spot Measurements of Dischage at X13 (2005 to 2007)

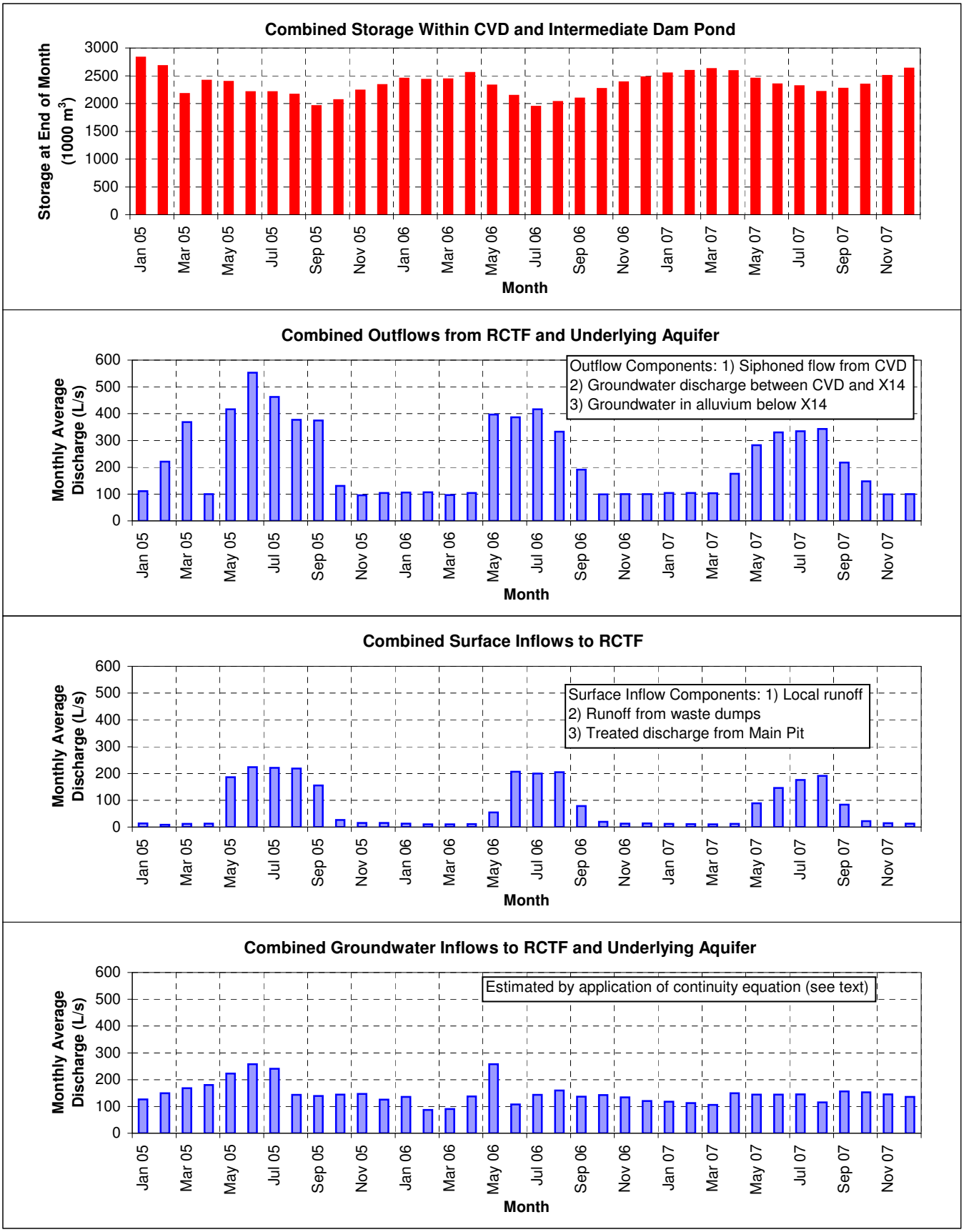


Figure 3.1-29 Water Balance for Rose Creek Tailings Facility and Underlying Aquifer (2005 to 2007)

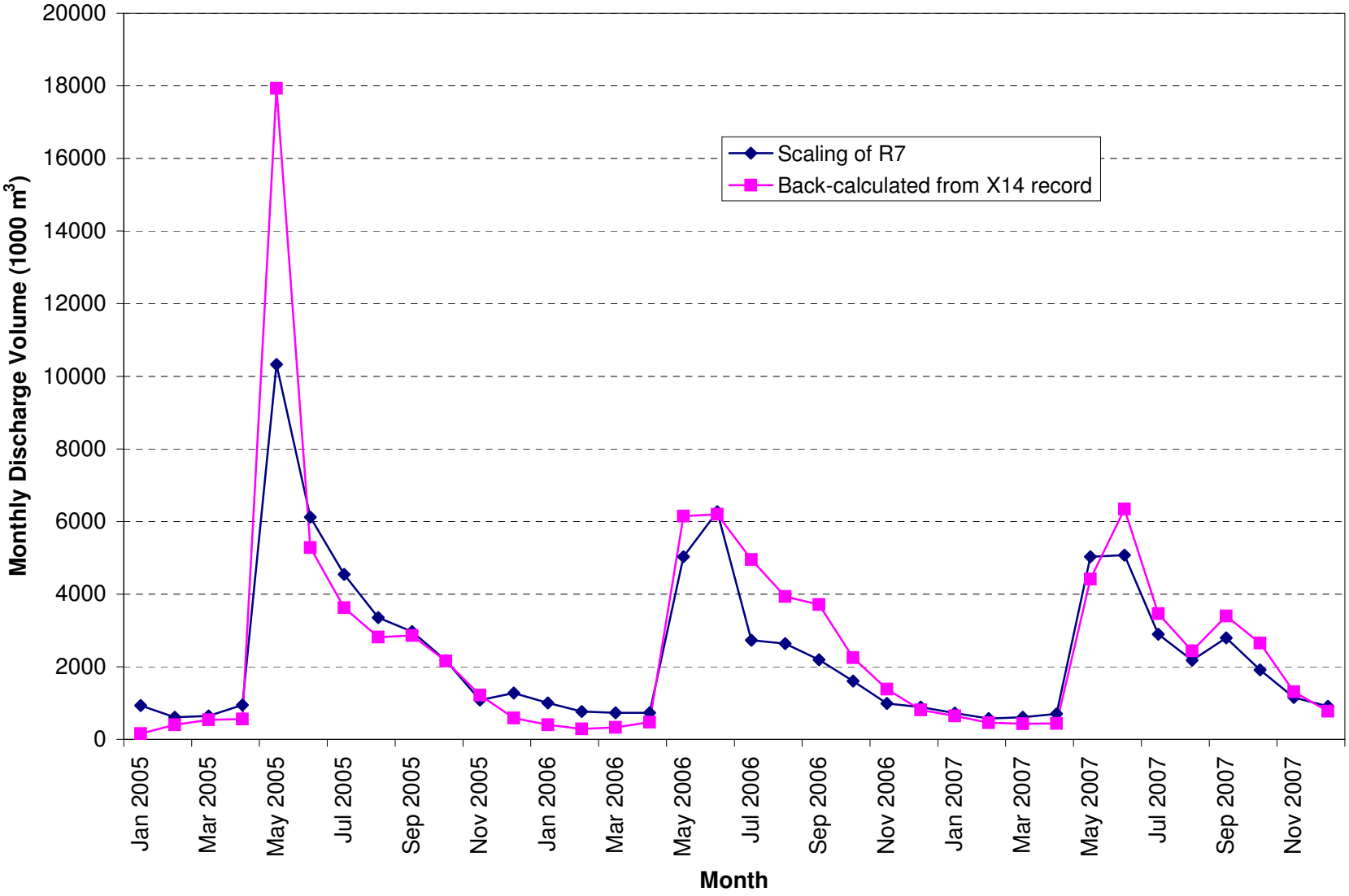


Figure 3.1-30 Estimated Runoff Generated by Subcatchment G

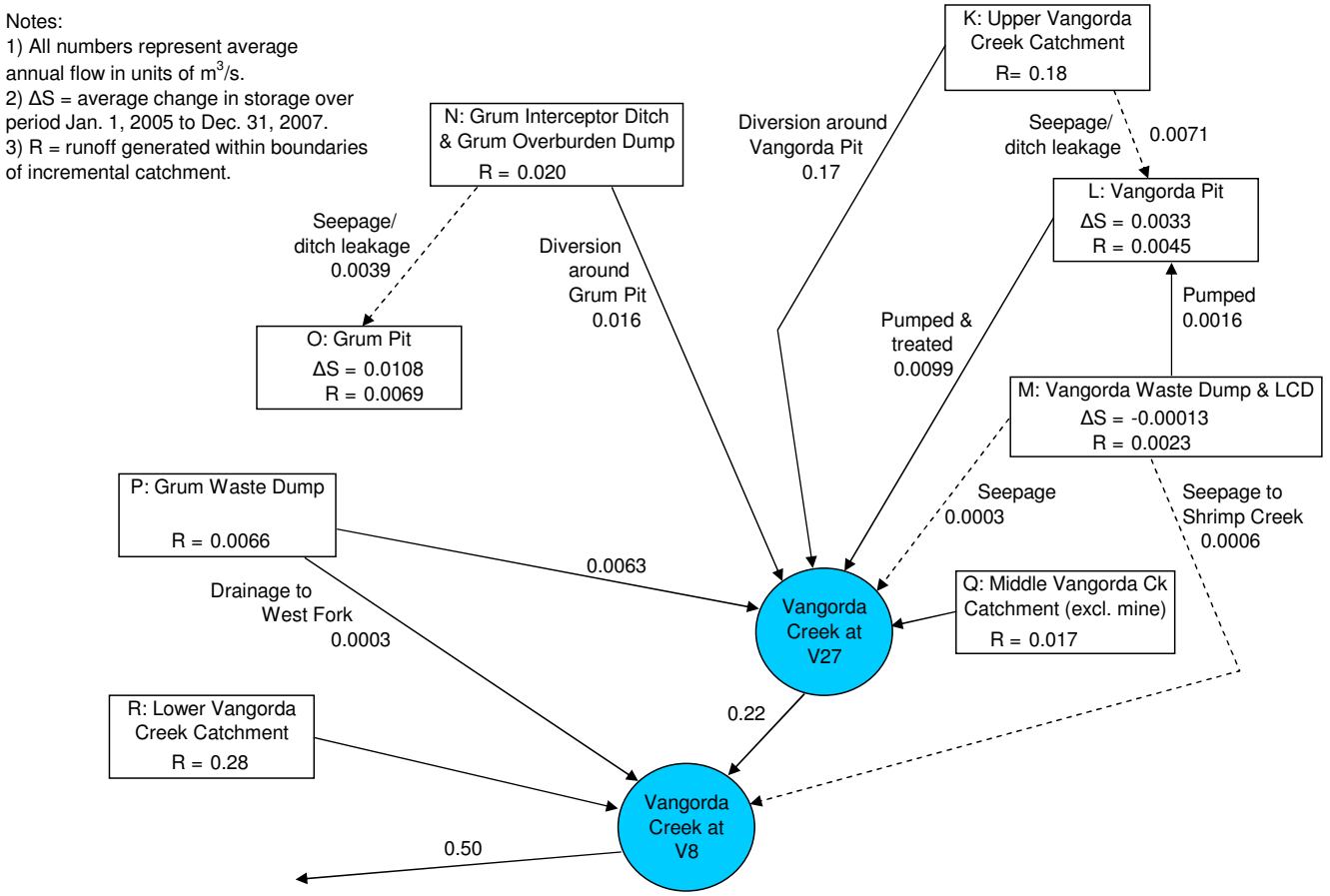


Figure 3.1-31 Average Annual Water Balance for Vangorda Creek Catchment (2005 to 2007)

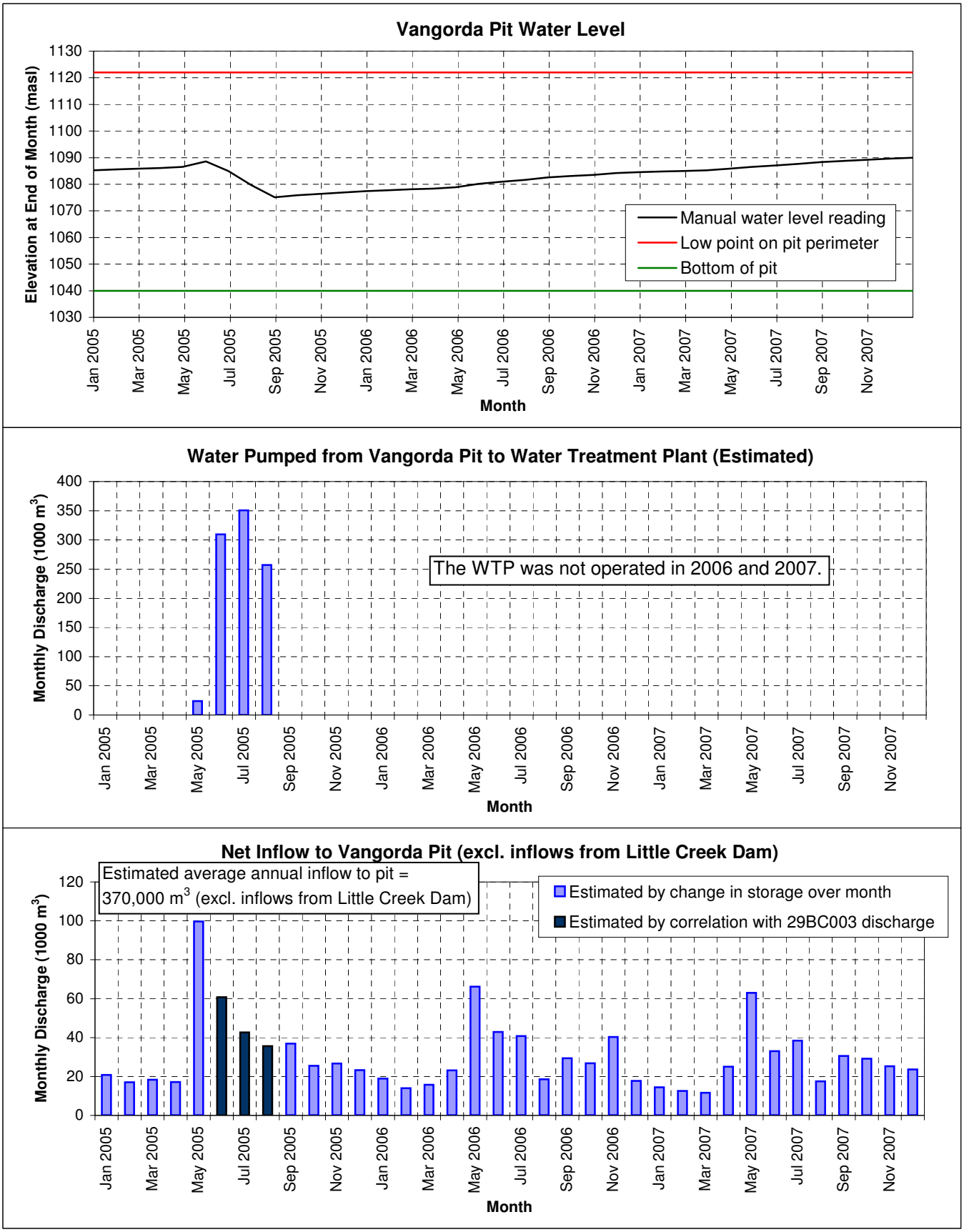


Figure 3.1-32 Water Balance for Vangorda Pit (2005 to 2007)

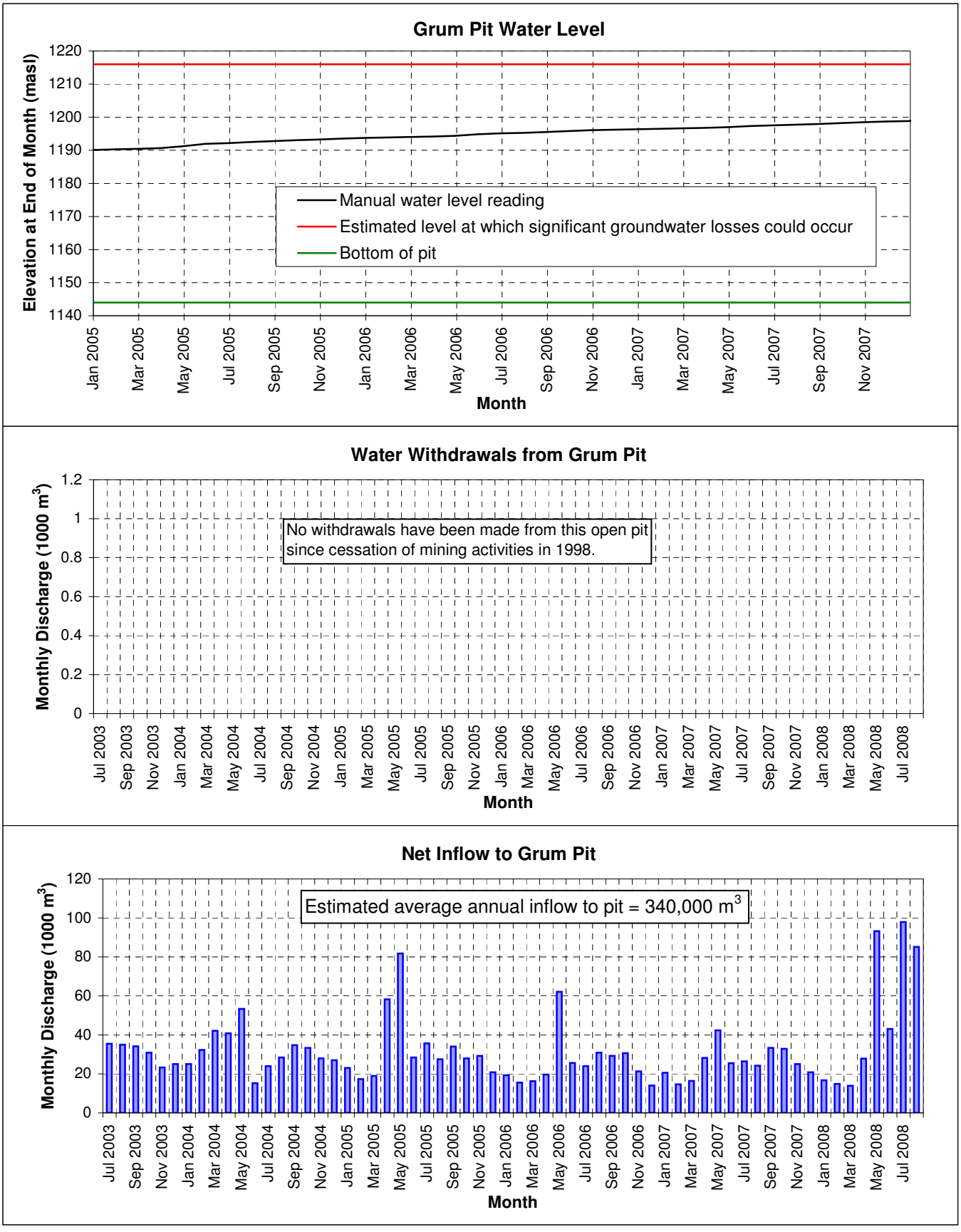


Figure 3.1-33 Water Balance for Grum Pit (2005 to 2007)

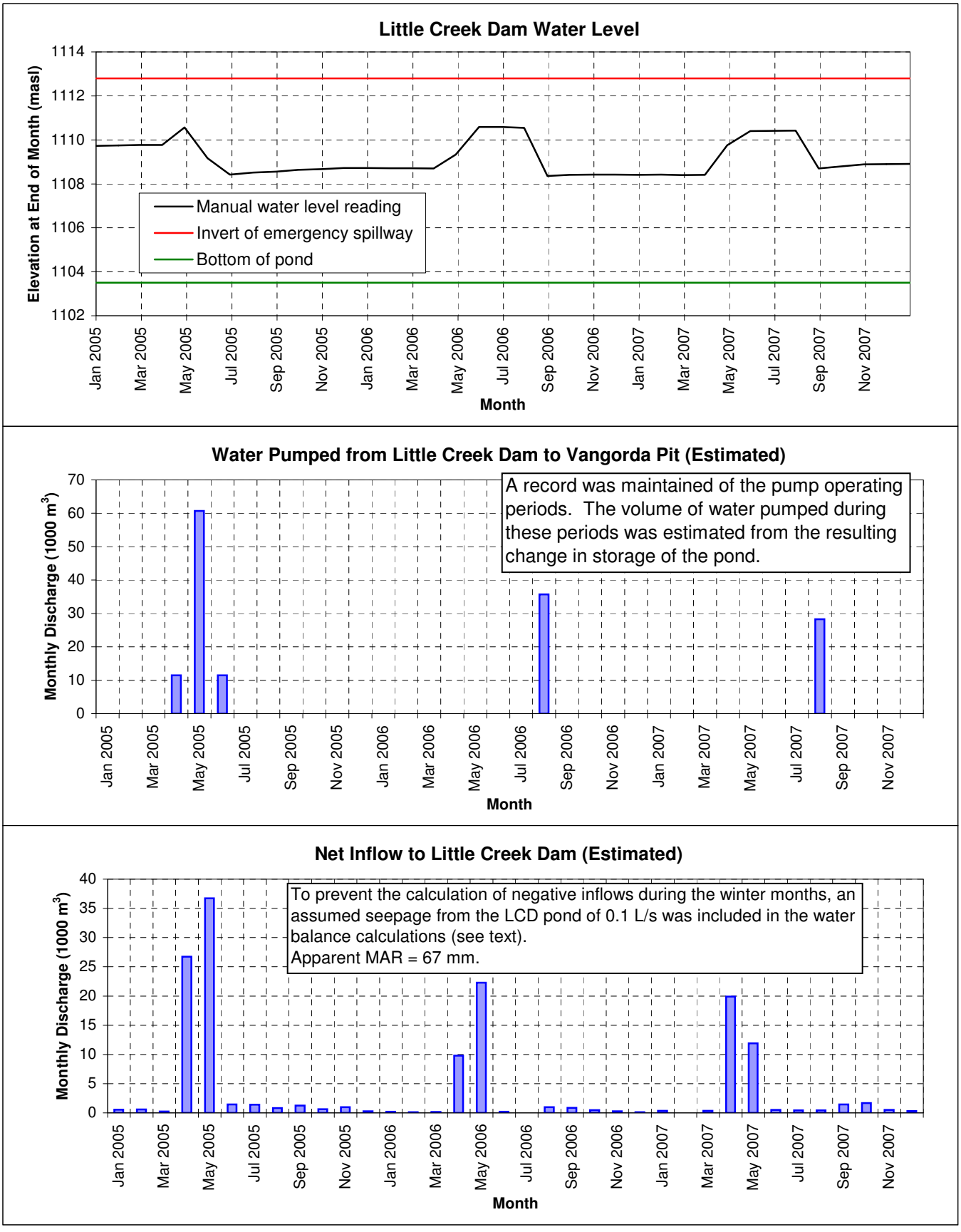


Figure 3.1-34 Water Balance for Little Creek Dam (2005 to 2007)

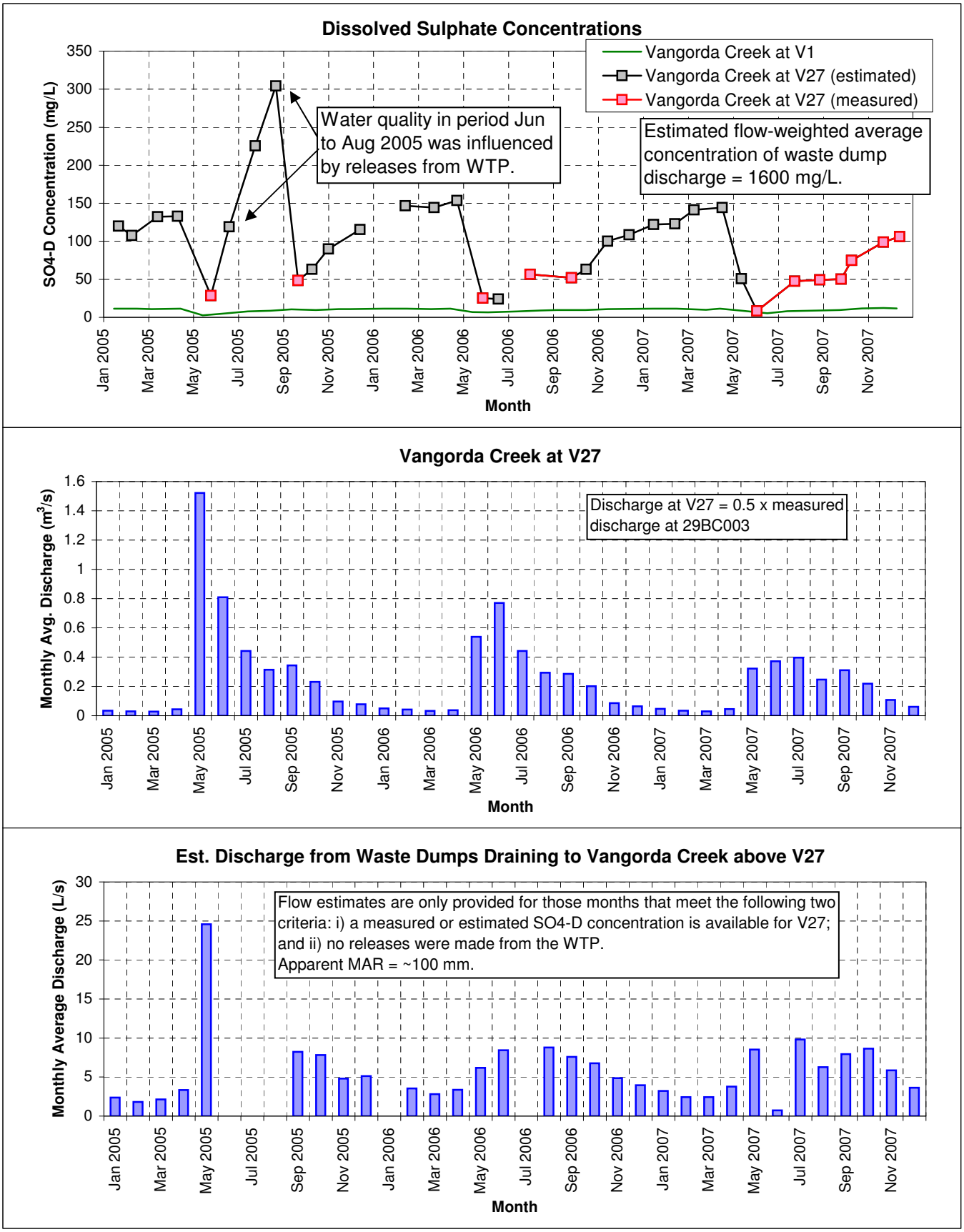


Figure 3.1-35 Estimation of Waste Dump Runoff to Vangorda Creek Using a Two-Component Mixing Model

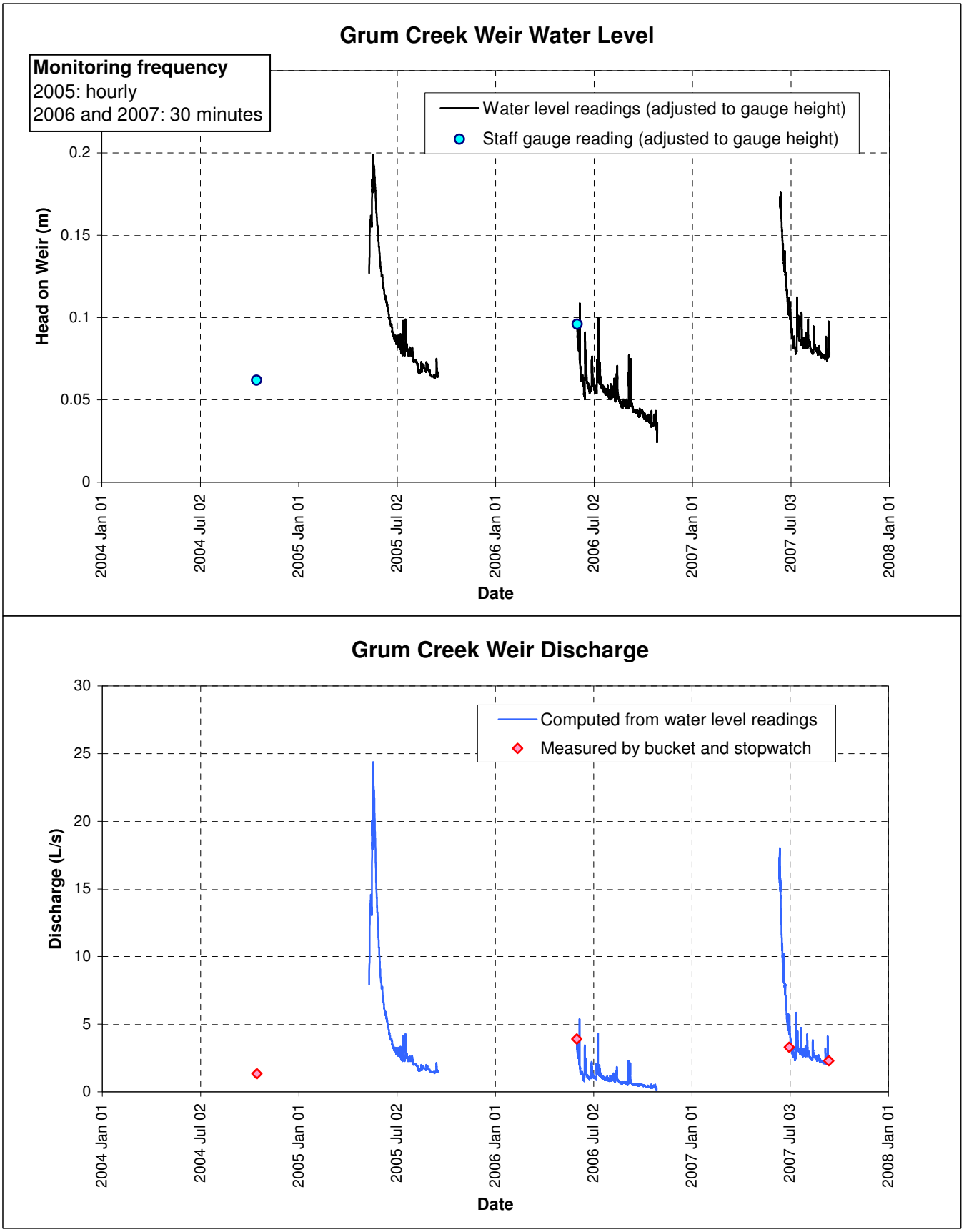


Figure 3.1-36 Stage and Flow Records for Grum Creek above Road Crossing

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.

3.2 Hydrogeology

3.2.1 Introduction

The Faro Mine Complex covers two major areas: the Faro mine area (Faro Site) and the Vangorda/Grum area (Vangorda/Grum Site) as shown in Figure 3.2-1. The Faro Site contains the major historic operations of the mine: the Faro Main Pit, the mill, the tailings impoundments, the tailings ponds and the waste rock piles. The Vangorda/Grum Site is a few kilometres southeast of the Faro Site and contains two smaller open pits and waste rock piles. The following sections are organized to reflect presentation and discussion of these two areas of the mine.

The Faro Mine Complex is located within a discontinuous permafrost region of Central Yukon. Groundwater flow occurs in un-frozen overburden sediments and active zones within bedrock. Shallow bedrock geology, topography and the thickness and distribution of surficial overburden sediments play a critical role in defining the shallow groundwater flow system.

Groundwater contamination, as a result of historic activities, has occurred within the Faro Mine Complex and is an ongoing issue of concern. This report presents a summary of the physical setting in the project area, groundwater flow, and a detailed description of groundwater quality in the different areas of the mine.

Summaries are provided of bedrock geology, overburden geology and hydrostratigraphy of the different units in the various areas of the Faro Mine Complex in the groundwater quantity section (3.2.4). Baseline groundwater quality is presented in section (3.2.5).

3.2.1.1 History of Site Hydrogeology

Mining activities, on-going reclamation, and care and maintenance activities have affected the local groundwater flow in several ways, including the following:

- interception of groundwater in open pits;
- increased permeability in the rock mass through blasting of open pit walls;
- interception of groundwater in diversion ditches/channels;
- alterations to the Rose Valley aquifer from development and operation of the Rose Creek Tailings Impoundments (Faro Site); and
- increased infiltration through un-vegetated and poorly drained areas (e.g., temporary uncovered rock dumps) as well as leakage from diversion channels.

The following presents a brief history of both parts of the Faro Mine Complex: the Faro Site and Vangorda/Grum Site.

Faro Site

Prior to development of the tailings impoundments, the local Rose Creek Valley hosted an unconfined aquifer with an estimated flow of 3,000 to 4,000 m^3 of groundwater per day (GLL, 2002). Development of the

tailings impoundments introduced a confining surface layer (tailings), additional groundwater recharge (tailings slurry water) and surface ponds that have had a substantial effect on local groundwater flow. An interpretation and numerical model of the existing groundwater flow regime are described in Gartner Lee Limited (2002). This study was revised and updated by Robertson GeoConsultants Inc. (2005).

The Faro Site mine development areas are outlined below and shown in Figure 3.2-2.

- Zone II Outwash Area – washout of fines from waste rock dumps (WRD); observed recent increases in zinc and sulphate concentrations
- S-cluster Area – has seen large increases in sulphate and zinc concentrations within the last 5 years
- North Fork Rose Creek (NFRC) – receiving environment for Zone II Outwash Area and S-cluster area
- Emergency Tailings Area (ETA) – contributes high loadings to the Rose Creek valley Aquifer, potentially contaminating Rose Creek on the south side of the valley
- Rose Creek Tailings Facility – includes Original, Second, and Intermediate Impoundments; associated Rose Creek Valley Aquifer
- Downstream of Cross Valley Dam – discharge of treated mine water to receiving environment

The Faro Main Pit was developed on the north side of the Rose Creek valley (Figure 3.2-2). Much of the area was covered by a thin layer of compacted till overlying bedrock. The pit was excavated to a depth of approximately 365 metres below the original ground surface at its deepest point and currently intercepts both shallow groundwater flow at the soil/bedrock interface and deeper groundwater flow in faults and fractures. Faro Pit water elevations are highly seasonal: maximum pit water levels are routinely reached in late April or May, just before pumping commences for the season, while the lowest levels occur in September. The water levels in the Faro Pit remained well below the recommended upper limit of 3,864.2 ft. (mine datum) over the baseline period, where a maximum pit water elevation of 3,860 ft. was reached in May 2005. Over the baseline period, the average annual Faro Pit water level has declined by 1.2 m.

Leakage from the Faro Creek Diversion Ditch into the pit via the northeast pit wall is known to contribute to groundwater inflows. To keep the pit drained from 1986 to 1990, mine dewatering pumping rates were between 40 and 55 L/s (Robertson GeoConsultants Inc., 1996). Groundwater inflow rates are not specifically monitored and separated from surface inflows.

Vangorda/Grum Site

The Vangorda Pit is located on the south side of Vangorda Creek (Figure 3.2-1). The overburden encountered during mining consisted primarily of compacted glacial till, approximately 30 metres in thickness. Groundwater flow into the Vangorda Pit was estimated at 0.14 L/s during mine operations (Robertson GeoConsultants Inc., 1996). Post-operations, a geochemical study conducted in 2000 (SRK, 2007b) identified alkalinity levels that indicate groundwater influx contributes to the pit surface water.

The Vangorda Pit is typically dewatered during the summer months (since 2002) and allowed to recover from fall to spring. In May/June 2008, pit water elevations marginally exceeded the maximum recommended level of 1,091.8 masl by 70 cm. This was because dewatering was not performed in the summer of 2006 or 2007.

Therefore it is expected Vangorda Pit has had minimal impact on groundwater quality over the baseline period.

The Grum Pit is located on the north side of Vangorda Creek and was developed in a small depression in the hillside. A small lake (Doal Lake) was present prior to the development of the pit. The surficial deposits at the Grum Pit were thicker than at the other pits. A north-south trending bedrock valley was intersected in the southeast corner of the pit. The bedrock valley was filled with approximately 100 m of glacial till over a basal layer of sand and gravel. This aquifer was dewatered by pumping wells during mine operations prior to 1997 and has subsequently flowed directly into the Grum Pit since pumping operations ceased. Prior to development of the Grum Pit, surface soils downgradient of the Grum Pit in the Grum Creek area were observed to be largely saturated near surface with some test pits reported as filling with water during excavation. The area is currently observed to be drier near surface than prior to development of this Pit. (Anvil Range, personal communication).

Dewatering does not currently occur within the Grum Pit. Over the course of the baseline period, the pit water level elevation has slowly increased from 1,190 masl to 1,203 masl. Seepage loss from Grum Pit is not expected to occur below pit water level elevations of 1,216 masl and therefore it is not expected that Grum Pit has contributed to groundwater degradation during the baseline period.

3.2.1.2 Data Sources

Data sources for hydrogeology include field data, engineering and scientific reports, technical memos and scholarly literature sources. There are many documents produced by many different authors for the Faro project. The relevant documents relating to the hydrogeology of the site are as follows:

- Anvil Range Mine Annual Groundwater Monitoring Reports (GLL). Prepared for Deloitte & Touche (2003 – 2007).
- Robertson GeoConsultants Inc., 1996. Integrated Comprehensive Abandonment Plan (ICAP). Prepared for Anvil Range Mining Corporation.
- Robertson GeoConsultants Inc., 2004. Initial Review of Groundwater Quality Downstream of Faro, Grum, and Vangorda WRD's, Yukon Territory, Memorandum from C. Wels to D. Hockley, July 14.
- Robertson GeoConsultants Inc., 2005. Water and Load Balance Study for Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory, September.
- Robertson GeoConsultants Inc Consulting Inc., 2007. Groundwater Review, Anvil Range Mining Complex, Yukon Territory – 2007. Draft Report 118012/1 Submitted to Deloitte and Touche Inc., December 2007.
- Seepage Investigations undertaken by SRK in 2005 and 2006:
  - SRK Consulting (Canada) Inc., 2006a. 2005 Seepage Investigation at the S-cluster Area Below the Fan, Waste Rock Dump – 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., November 2006.
  - SRK Consulting (Canada) Inc., 2006b. 2005 Seepage investigation at the Emergency Tailings Area, - 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., November 2006.

- SRK Consulting (Canada) Inc., 2007a. Anvil Range Mining Complex Continued Seepage Investigation Zone 2 Pit Outwash Area, - 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., January 2007.
- SRK Consulting (Canada) Inc., 2007b. Anvil Range Mining Complex, 2005 Seepage Investigation at the Grum Dump Area – 2005/06 Task 20e. Report prepared for Deloitte & Touche Inc., January 2007.

Groundwater level data is provided on a well-by-well basis from 2005 through 2007 and is presented in Appendix B1.1. Appendix B1.2 provides raw water quality data (2005-2007) for each well and a statistical summary based on well location groupings and level of impact. A geochemical interpretation of groundwater quality data for the Faro Mine Complex up to and including May 2007 was completed by Robertson GeoConsultants Inc. (2007). Time series (temporal) concentration plots were updated for this assessment to include data up to November 2007, and can be found in Appendix B1.3. Temporal depth profile plots of water quality in multilevel piezometers are compiled and presented in Appendix B1.4. A listing of groundwater monitoring wells and/or discrete monitoring events, not included in the 2005-2007 baseline assessment (review of Anvil Range Mine 2007 Groundwater Monitoring Report (GLL, 2008a) and 2007 Groundwater Review, Anvil Range Mining Complex, Yukon Territory (Robertson GeoConsultants Inc., 2007)) are included in Appendix B1.5.

3.2.1.3 Data Confidence Limits

Confidence in the baseline data presented in this report is high, as it has undergone rigorous review and QA/QC. Furthermore, most of the sampling stations have an extended period of record with many sampling events. Data confidence, limitations and assumptions include the following:

- Confidence in the water quality down-gradient of the Cross Valley Dam (Figure 3.2-2) is high because there is a long record of data for these monitoring locations and all data has undergone rigorous review and QA/QC. Confidence is also high because there are several monitoring locations with sampling points extending through the depth of the overburden aquifer.
- Confidence in horizontal hydraulic head gradient estimates is moderate to high because of the large datasets of water level measurements from groundwater wells extending across the site. Measurements from these wells are considered to have high accuracy.
- Confidence in vertical hydraulic head gradient estimates within the tailings and near the Cross Valley Dam is high because of the large dataset derived from multi-level groundwater wells (i.e., water levels from different depths).
- Confidence in the shallow bedrock hydraulic conductivity in the vicinity of the Intermediate DAM and Cross-Valley Dam is low. The only references found in the reviewed documents were the 1980 and 1981 investigations (Independent Peer Review Panel, 2007).
- Confidence in bedrock hydrogeology of the Rose Creek Valley beneath the Rose Creek Tailings Impoundment is low. As stated by the Independent review panel (2007), deep bedrock structural features have not been investigated, and therefore the quantity of groundwater flow within deeper bedrock at this location is uncertain.

3.2.2 Methods

Valuable data was collected at the site when the mine was operating (starting in the 1980s). Some of this data along with more recent water quality data is valuable for establishing baseline conditions. Most of this data has been documented in previous reports along with the methodology used for data collection. The following summarizes the data collection:

- There is anecdotal evidence that discontinuous permafrost occurs within the tailings sediments. This was noted during several well drilling investigations (GLL, 2003). Quantitative ground temperature information was not found in the documents reviewed.
- Hydraulic conductivity testing was completed during several monitoring well installation studies, during recent groundwater characterization work, and during seepage interception studies.
- Water levels within the mine area have been monitored in a network of groundwater wells. Water level data was summarized and interpreted by GLL (2002) as part of a preliminary assessment and subsequently revised and updated by Robertson GeoConsultants Inc. (2004). Water level information is contained in the site database currently managed by AECOM (Gartner Lee) and summarized in yearly groundwater monitoring reports. This data is presented in Appendix B1.1.
- Groundwater quality throughout the site has been monitored using a network of conventional monitoring wells and multi-level monitoring wells with sampling points extending throughout the overburden aquifer and tailings profile. Some of these wells were designed and located in site specific areas for acquiring information about localized groundwater impacts. Throughout the years, there were operational issues identified with some wells used for monitoring groundwater quality (Ref monitoring reports GLL). The results from wells identified as having operational issues have not been included in the baseline compilation Appendix B1.5 contains the list of wells and the specific data included within the baseline study.
- Statistical summaries and analyses were performed on groundwater quality data for the baseline water quality period (2005-2007). Method detection limits (MDLs) were set to one-half the analytical detection limit for statistical calculations. All groundwater quality calculations and data are presented in Appendix B1.2.

3.2.3 Study Area

3.2.3.1 Local Study Area

The LSA is the area of immediate project influence on the environment. The local study area (LSA), shown on Figure 3.2-3 is based on the physical and hydrogeologic footprint of both mine sites (Faro and Vangorda/Grum), including the haul road. The haul road is included because it is constructed of waste rock. The upper boundary of the LSA is defined by the immediate recharge zones upgradient of the two mine sites. Little-to-no groundwater quality data currently exists in the recharge areas. The downgradient boundary of the LSA is defined by areas where groundwater is not suspected to be influenced by mining operations.

The LSA comprises the surficial overburden aquifers located mostly along valley bottoms, including upper Vangorda Creek, Faro Creek and the North and South Forks of Rose Creek. The aerial extent of the

groundwater LSA is similar to the surface water LSA because of the interaction between the groundwater and surface water systems.

The depth of the LSA includes the thickness of overburden sediments and upper fractured bedrock zone where active groundwater flow occurs. This depth corresponds to the maximum depth of the current monitoring network (and the depth of available groundwater quality information).

3.2.3.2 Regional Study Area

A regional study area (RSA) is defined to incorporate areas outside of the project footprint that may be important if project effects extend beyond the LSA. The RSA was based on the watershed boundaries of Rose and Vangorda Creeks, as well as the zone of influence beyond which the effects of care and maintenance activity and historical mining activities are negligible. The RSA boundary will allow for a determination of cumulative impacts of the mine on downstream receiving environments.

The Faro portion of the RSA includes all upgradient recharge areas for aquifers within the LSA, mainly the Rose Creek Valley aquifer. The RSA extends downgradient to the Rose Creek confluence with Anvil Creek. It is reasonable to expect that potentially impacted groundwater will discharge to surface in Rose Creek before the confluence with Anvil Creek, and therefore impact water quality within the RSA boundary.

The Vangorda/Grum portion of the RSA is defined by all catchment areas upgradient of the mine sites and extends downgradient to the confluence of Vangorda Creek with the Pelly River. The extension of this boundary therefore incorporates the assessment of any mine effects on groundwater flow or quality in the downstream portions of Vangorda Creek. The RSA includes the Town of Faro water supply wells located at the confluence of Vangorda Creek and the Pelly River.

3.2.4 Groundwater Quantity

The purpose of this section is to describe the existing baseline hydrogeological conditions at the Faro and Vangorda/Grum Sites to form a baseline for the environmental impact assessment of mine closure. The existing baseline conditions prior to mine closure activities are defined as those that exist presently, recognizing that significant impacts have occurred to groundwater quantity (and quality) as a result of historical mine operations and on-going maintenance activities. Groundwater flow data collected between 2005 and 2008 are considered to reflect baseline groundwater flow (quantity) conditions.

Hydraulic conductivity (permeability or K) is a measure of the ease of water movement through a specific soil or rock. A summary of the available hydraulic conductivity results for the defined units found in the Faro Site are summarized in Table 3.2-1. The S-cluster well area and ETA area are two of the most highly contaminated areas on-site, where Zone II Outwash Area is reported to be moderately impacted. Zone II Outwash Area and the S-cluster area are providing loading to NFRC, where the ETA area is providing loading to the Rose Creek Valley Aquifer. The ultimate receiving environment to the summation of these areas is downgradient of the Cross Valley Dam.

The following describes the hydrostratigraphy and groundwater level trends at studied areas of the Faro Site.

Faro Site

S-Cluster Wells

Hydraulic conductivity testing was completed in all 2005 monitoring wells with the exception of SRK05-06, which was dry. The original S-cluster wells were also tested. Tests were completed as standard slug tests or as "mini-pumping" tests. Results varied from approximately 1 x 10^{-4} to 4 x 10^{-7} m/s. Based on the geology and results of hydraulic testing, four hydrostratigraphic units are defined for the S-cluster area (SRK, 2006a) (Figure 3.2-4):

Shallow Aquifer Unit: Characterized by sand and gravel. Hydraulic conductivity is approximately 3 x 10^{-5} m/s. High water levels in this zone suggest that this shallow aquifer is perched.

Low Permeability Unit: Underlying the shallow aquifer unit consisting predominantly of fine-grained materials. This unit represents a confining layer for the underlying deep aquifer. The unit appears to be laterally continuous, though likely inter-fingers with coarser grain materials. Grain size analyses completed on samples from surface exposures of these materials, taken from a test pit program in 2004, suggest hydraulic conductivity values are in the range of 2 x10^{-7} to 3x10^{-7} m/s.

Deep Aquifer Unit: Includes deeper sand and gravel materials overlying bedrock, as well as the weathered upper bedrock profile. Thickness varies across the site from <1 m to approximately 10 m. In some areas, such as SRK05-SP5 and SRK05-SP6, the deep aquifer unit may consist predominantly of weathered bedrock with only a minor component of unconsolidated material. Hydraulic conductivity ranges from 1 x 10^{-4} to 9 x 10^{-6} m/s.

Bedrock: The bedrock in the S-cluster area consists of schist of the Mt. Mye Formation. Bedrock is defined as calcareous schist to calcareous silicate. In the area of the S-cluster, bedrock has a phyllitic texture and has been called phyllite in the drill logs. No significant fractures or structures have been identified, but drilling generally did not continue far into bedrock and the drilling method precludes recovery of continuous core. Hydraulic testing was not carried out in this unit; however, the hydraulic conductivity of the bedrock is expected to be lower than the overlying aquifer units.

Water level trends from measurements from 2004 to 2008 for the S-Cluster area are presented in Figure 3.2-5. Groundwater levels in most of the wells showed no pronounced response to seasonal variation. Slightly higher readings can be observed in most of the wells around October/November while slightly lower levels are observed during the summer month readings. Well SRK05-SP-4A showed pronounced differences in water level measurements: consistently higher readings in May/June and lower readings in the summer months. This could be due to SRK05-SP-4A having a faster response to snowmelt and precipitation than the other wells. SRK05-SP-4A is completed at the top of bedrock which normally contains fractured and broken rock that is capable of transmitting groundwater flow quickly but has a much lower porosity than unconsolidated sediments. There is no observed trend in groundwater elevation over time for the S-Cluster wells, implying groundwater levels are near constant over the measurement period.

Zone II Outwash Area

The backfilled Zone II Pit (pit was filled with waste rock) intercepts both shallow and deeper groundwater flow (Figure 3.2-6). The presence of substantial faulting in the southern area of the Main Pit indicates the possibility of subsurface flow of water from the Main Pit into the Zone II Pit. Annual monitoring of volumes dewatered from the Zone II Pit, as reported in annual environmental reports, indicates that Zone II Pit dewatering rates did not increase substantially with an increase in the water level in the Main Pit. Therefore, groundwater inflows into the Zone II Pit do not appear to be directly proportional to Main Pit water levels. The groundwater inflows into the Zone II Pit were estimated at 13 L/s during mine operations (Robertson GeoConsultants Inc., 1996).

A drilling program was carried-out in the Zone II Outwash Area (Figure 3.2-6). This field investigation included the installation of one 6-inch diameter pumping well (PW3), two conventional monitoring wells (P05-04 and BH05-01), and two shallow drive points installed along the banks of the NFRC (SRK, 2007a).

The general soil profile in the vicinity of PW3 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 K);
- 3.5 – 6.7 m Sand and gravel with cobbles, (highest K);
- 6.7 – 7.9 m Sand and gravel cemented; and
- 7.9 – 9.1 m Sand and gravel with cobbles, (highest K).

A 24 hour constant rate pumping test was conducted at pumping well, PW3. An average hydraulic conductivity of 6.3 x 10^{-4} m/s was calculated for the pumping well. This is similar to the hydraulic conductivity estimated for the same type of glacio-fluvial sediments in the Rose Creek aquifer.

Observed groundwater levels suggest that groundwater flow in the NFRC aquifer is in a southwesterly direction; i.e., aligned with the general direction of the NFRC valley (SRK, 2007a). Water level trends from measurements from 2004 to 2008 in the Zone II Outwash Area are presented in Figure 3.2-7. Groundwater levels in most of the wells showed no pronounced seasonal variation.

Emergency Tailings Area (ETA)

Hydraulic testing during the 2005 ETA field program consisted of packer injection tests completed in wells during drilling and a 24-hour pump test. Based on geologic data, hydraulic testing results and hydrology data, the ETA is interpreted to have three hydrostratigraphic units. A summary of ETA hydrostratigraphy follows (SRK, 2006b):

Tailings: Silt to gravel size tailings up to 6.5 meters thick, thinning up-valley and towards the valley sides, with coarser, gravel-size, waste rock interbeds. Tailings may represent a partial confining layer to the primary aquifer. Coarse waste rock interbeds may represent preferential pathways within the tailings. Hydraulic conductivity of the tailings is unknown, but is interpreted to be lower than the primary aquifer unit.

Primary Aquifer: Sand to gravel size alluvium is interpreted to be deposits of historic Faro Creek, with sandy till or gravelly-silt till in up-valley sections of the ETA and along valley walls. The primary aquifer includes weathered bedrock where present. Alluvium thickness varies between 2-6 meters near the mine access road, but is uncertain up-valley. Average transmissivity is estimated to be 67 m^2/day (hydraulic conductivity = 2 x 10^{-4} m/s); average storativity is estimated to be 0.014.

Bedrock: The phyllitic bedrock is a relatively minor aquifer unit. Intermittent discrete fracturing is present but with no known preferred orientation. Average hydraulic conductivity is 4.3x10^{-8} m/s with more permeable zones up to 1.1 x 10^{-7} m/s.

In localized areas of the ETA, groundwater is observed to discharge to surface (groundwater spring) and join surface flow in the former Faro Creek channel (Figure 3.2-8). Review of vertical hydraulic gradients and stream flow data suggests that the former Faro Creek channel gains significant flow from groundwater along its length. The available data suggests that ground and surface water interaction occurs in the upper reaches of the former Faro Creek channel, below surface sampling station X23 (adjacent well P96-8). Faro Creek does not appear to gain significantly from upward groundwater discharge emanating from bedrock below the mine access road.

Water level measurements and trends in the ETA are presented in Figure 3.2-9 covering a period from 2004 to 2007. Most of the water levels showed fast response to snowmelt, peaking in May or June. Water levels in well P96-8A/B show a slower response to snowmelt than the other wells. There is no long term rising or declining trend in groundwater levels over time for the ETA wells.

Cross Valley Dam

Water level measurements and trends in wells within the Cross Valley Dam area are presented in Figure 3.2-10, covering a period from 2001 to 2008. Water levels in wells near the Cross-Valley Dam are expected to be highly influenced by the water level of the pond behind the dam maintaining near constant water levels. For most of the wells, no specific trends are observed for groundwater levels. There are no long term rising or declining trends in groundwater levels in the Cross Valley Dam wells.

Conceptual Model for Groundwater Flow at the Faro Site

A conceptual groundwater flow map for the Rose Creek Tailings Impoundment was constructed using available groundwater level data, surface water features elevations and topography (Figure 3.2-11). All groundwater piezometers do not have surveyed high resolution elevations, and therefore, the constructed piezometric surface is only an approximation of general groundwater flow. Figure 3.2-11 is not intended to be used for construction design purposes.

The piezometric surface in Figure 3.2-11 represents the water table surface present mainly in the overburden (including the tailings) within the Rose Creek valley. Groundwater flow is generally from high elevation areas to lower elevation areas in the valley.

Therefore, high elevation areas on both sides of the Rose Creek valley are considered to be recharge areas for the valley aquifer. Groundwater flow is directed downward from these recharge areas. Seepage from the

ETA area is expected to flow towards the tailings facilities. Groundwater leaving the Faro mine site and upgradient areas joins the Rose Creek Valley aquifer and flows westward down the Rose Creek Valley under the tailings impoundment and the Cross Valley Pond.

South of the tailings impoundment, the Rose Creek Diversion Channel has been constructed along the valley wall. This diversion channel increases infiltration and increases groundwater flow into the tailings and the overlying ponds. Groundwater within the tailings is expected to be a mixture of upstream groundwater and surface water from the within the Rose Creek Tailings Impoundment and seepage from the Rose Creek Diversion Channel.

Vangorda and Grum Dump Area

As of 2007, there has not been any hydrogeologic testing to provide estimates of the hydraulic conductivity for the stratigraphic units in the Grum/Vangorda Area. Based on geology from available drill holes, four hydrostratigraphic units are defined for the Grum area (Figure 3.2-12):

Surficial aquifer: gravelly fine to coarse sand with variable organics. Present at ground surface in vicinity of SRK05-5C and Grum Creek. Thickness varies from two to six meters.

Till: clayey to sandy silt with trace gravel. Present in available drill holes, ranging in thickness from 2.5 to over eight meters and in depth from just below ground surface to a maximum of approximately 15 meters. This unit acts as a confining unit for the deep aquifer.

Deep Aquifer: fine to coarse sand with gravel and underlying weathered bedrock. This deep aquifer was encountered at well SRK04-5 and well P96-9 with thickness ranging between six to seven meters.

Bedrock: chlorite schist to phyllite. Depths range from approximately two meters to approximately 20 meters below ground surface with an assumed lower hydraulic conductivity than the overlying units.

Water level measurements and trends in the Vangorda/Grum area are presented in Figure 3.2-13. Low hydraulic conductivity in the sediments of the Vangorda area (due to the low permeability of the local till deposits) results in minor seasonal change to groundwater levels (wells V37, V34 and P2001-02A&B) (Figure 3.2-13). There is minimal seasonal variation in groundwater level in well SRK05-08. Well SRK05-09 near Vangorda Creek, shows greater seasonal variations with high groundwater levels in the fall and lower groundwater levels in the spring. There is an apparent long term trend of decreasing groundwater levels over time. Well V35 at the edge of the rock dump has high groundwater levels in the late spring and low groundwater levels in the fall.

3.2.5 Groundwater Quality

3.2.5.1 Overview

In order to conduct the environmental impact assessment of the mine closure and remediation plan, baseline groundwater quality must be defined and documented. This section contains a summary of available information for the Faro and Vangorda/Grum Sites. The baseline period for groundwater quality is based on data collected between 2005 and 2007.

Groundwater impacts observed presently near the mine facilities may be indicators of potential future impacts on downstream surface water receptors, as impacted groundwater slowly moves through the subsurface to discharge points along creek channels. This baseline compilation focuses mainly on current conditions (2005-2007) at monitoring locations in known impacted areas, and provides historical time trends (1994-2007) in Appendices B3 and B4. Groundwater quality data from these impacted areas provides information on future impacts on groundwater and/or surface water receptors.

Groundwater quality data for the 2005-2007 baseline period includes regularly monitored wells on the Faro and Vangorda/Grum Sites. The Mine site groundwater wells were divided into groups by areas to facilitate discussion of groundwater quality data. Both the Faro and the Vangorda/Grum Sites wells are discussed using the following areas as outlined in Figure 3.2-15.

- Upgradient
- Mine Footprint
- Downgradient

Within the mine footprint area for Faro, there are further sub-groupings of wells as indicated below (see Figure 3.2-2).

- Rose Creek Tailing Facility:
  - Second Impoundment
  - Intermediate Impoundment
  - Toe of Intermediate Dam

- Faro Rock Dumps along the North Fork of Rose Creek (NFRC):
  - S-cluster
  - Zone II Outwash Area
  - Northeast Rock Dump and Intermediate Rock Dumps

- Former Faro Creek channel below the Faro Rock Dumps:
  - Emergency Tailings Area

A summary of the groups used to organize wells within the baseline report is provided in Table 3.2-2 along with supporting rationale for including this grouping. Most wells within the areas listed in Table 3.2-2 were installed for the purpose of investigating potential or existing impacts to groundwater at key locations, where mitigation measures may be effective. Each area contains a baseline groundwater summary table of relevant statistics giving a ‘snapshot’ of current groundwater quality conditions at that location.

There have been a number of well installation programs at different times over the mine life. Therefore, the monitoring wells discussed here have varying periods of record. Historic data temporal trends can be viewed in appendices B3 and B4, while more recent data (2005-2007) is used for establishing baseline conditions for the environmental assessment, recognizing that groundwater quality is changing and evolving as a result of on-going geochemical processes within impacted areas.

3.2.5.2 Historical Profile

The major historical monitoring well installation programs are summarized below:

1996 Groundwater Monitoring Well Installation – Robertson GeoConsultants Inc.

A series of groundwater monitoring wells were installed in 1996 by Robertson GeoConsultants Inc., primarily intended to replace some of the 1981 wells that had become inoperable or destroyed but that were referenced in the Water Licence. These wells include X21-96 A/B/C, X24-96 A/B/C/D and X25-96 A/B. Wells X24 and X25 are located at the toe of the Intermediate Dam and station X21 is located near the north toe of the Second Impoundment Dam.

2001 Groundwater Monitoring Well Installation – Gartner Lee Limited

In 2001, a comprehensive hydrogeological and geochemical investigation of the Rose Creek Tailings Facility was conducted by Gartner Lee Limited. The purpose of the study was to update the characterization of the hydrogeological system and geochemical state of the tailings. As part of the investigation, twenty two groundwater monitoring wells at eleven locations (P01-01 through P01-11) were installed within tailings, at the toe of the Intermediated Dam and downgradient of the Cross Valley Dam. These wells were installed to enhance the monitoring of groundwater quality. Several of these wells became damaged and were decommissioned in 2005 (Robertson GeoConsultants Inc., 2005).

2003 Rose Creek Tailings Impoundment Area Multilevel Well Installation – Gartner Lee Limited

In 2003, Gartner Lee Limited installed a series of groundwater monitoring wells as part of a follow up to the 2001 hydrogeological investigation. Sonic drilling technology was used to obtain detailed stratigraphic information through the complete soil horizon through the tailings and down to the bedrock interface at many locations. As part of this program, 76 additional groundwater monitoring points were installed at nine locations (P03-01 through P03-09) within each of the impoundments and downgradient of the Cross Valley Dam. The monitoring points are completed both within the tailings and in the underlying native sediments.

2004 and 2005 Monitoring Well Installation – SRK Consulting

SRK was retained by Deloitte and Touche to carry out additional field investigations to characterize local groundwater conditions and to assess options to intercept any Acid Rock Drainage (ARD) impacted seepage for collection and treatment. The groundwater investigation and seepage collection assessment targeted three specific areas: (i) Emergency Tailings Area (old Faro Creek valley), (ii) NFRC, and (iii) the Grum Creek areas. These areas were identified during initial review and planning stages as the areas with highest priority for seepage interception.

2005 Pumping/Monitoring Well Installation and Pumping Test Analysis – Robertson GeoConsultants Inc.

Robertson GeoConsultants Inc. installed one 6-inch diameter pumping well (PW3) and two conventional monitoring wells (BH05-01 and P05-04) within the Zone II Outwash Area to use for hydraulic testing of shallow overburden sediments. Two additional 6-inch pumping wells (PW1 and PW2) and two conventional monitoring wells (MW1 and MW2) were installed at the base of the Cross Valley Pond and used to assess seepage interception capacity and efficiency.

2007 Town of Faro Water Wells Investigation – Gartner Lee Limited

A focussed sampling and analysis program was conducted to evaluate the interaction between the Town of Faro water supply wells and the adjacent surface water in Vangorda Creek (GLL, 2007). Although this was not a well installation program, the study utilized several observation wells and the Faro water supply wells located at the mouth of Vangorda Creek where it meets the Pelly River (Figure 3.2-14).

3.2.5.3 Groundwater Quality Classification

Groundwater quality records are classified as ranging from non-impacted to adversely impacted for all well data within the baseline groundwater quality data set. This baseline water quality classification identifies five impact levels for groundwater quality within wells (Table 3.2-3). Groundwater wells were first classified based on mean sulphate concentration observed over the baseline time period (2005-2007). The next step of the well classification was to sort the groundwater quality data by mean zinc concentration ranges (averaged over the same time period as for sulphate). Although sulphate is a good initial indicator of impact from ARD and metal leaching processes because it is a conservative element, a zinc screening provides a further source of information for metals undergoing some degree of attenuation.

The range of mean sulphate and mean zinc values used for this classification are presented in Table 3.2-3. The 'Non-Impacted' mean sulphate concentration range was selected based on water quality at TH86-17, while the 'Adversely Impacted' sulphate concentration range was selected based on water quality observed in the ETA and S-cluster areas. The ranges selected for the slightly, moderately, and highly impacted well groupings were based on similar mean sulphate concentration values. The zinc concentration ranges adopted are based on the Metal Mining Effluent Regulation (MMER); the regulated limit for mean monthly zinc concentration for discharge to surface water is 0.5 mg/L (Canada Gazette, 2006). In the classification scheme used within the baseline report, the upper limit of the "slightly impacted" groundwater group is the mean monthly MMER limit for zinc. The upper limit of the non-impacted well grouping is defined as one order of magnitude less than this MMER limit. Conversely, the upper limit for the moderately impacted grouping is one order of magnitude higher than this MMER limit. Finally, the upper limit for the highly impacted grouping is two orders of magnitude higher than this MMER limit.

The results of the well classification are graphically presented using colour coding of monitoring well symbols on Figures 3.2-16 and 3.2-17. The groupings based on the groundwater quality classification for each area of interest are presented in multiple tables for all parameter of interest in the next section. Each well grouping is compared to Yukon Government Contaminated Sites Regulations (CSR), Schedule 3 Generic Groundwater Quality Standards for protection of Aquatic Life (Yukon Environment, 2002). These generic standards assume 1:10 dilution for groundwater entering surface water. For each well grouping table containing exceedances, shading gives a visual indication of the extent of impact (for example Table 3.2-7).

3.2.5.4 Faro Mine Site

Upgradient Areas

Figure 3.2-15 shows the upgradient area of the Rose Creek Tailings Facility. Groundwater well TH86-17 is the only well physically upgradient (approximately 450 m) of the Rose Creek tailings facility (Table 3.2-4). The well is screened at approximately 15 metres below ground surface (mbgs) and is the only true

background well on-site and is thus representative of "non-impacted" conditions. Groundwater sulphate concentrations at this well range from 13.6 to 16.6 mg/L and zinc concentrations range from 0.0123 to 0.0156 mg/L. The groundwater chemistry of TH86-17 was used as a basis for designating other groundwater wells outside the mine footprint area and deep below the Rose Creek tailings facility as 'non-impacted'.

Representative groundwater wells within the original impoundment have either been decommissioned, are inoperable, or do not require sampling; and hence are not listed within the construction or summary of groundwater chemistry tables in this report. Details regarding these conditions are outlined in Robertson GeoConsultants Inc., 2007. Table 3.2-5 summarizes groundwater quality upstream of the Rose Creek tailings facility based on data from monitoring well TH86-17.

Mine Footprint Areas

Emergency Tailings Area (ETA)

The ETA is located between the Faro Mill and the Rose Creek Tailings Facility, and overlaps with a section of the old Faro Creek channel. Drainage from the waste rock dumps and tailings placed in the old Faro Creek channel are leading to contamination of groundwater in this area, and are also contributing significant contaminant load to the tailings impoundment and underlying aquifer. Table 3.2-6 lists relevant information for all groundwater monitoring wells in the area used in the baseline assessment. Two groundwater monitoring wells were installed in 1996 along the base of the Faro rock dumps, followed by three new wells installed by SRK in 2004 and seven new monitoring wells in 2005, all within the footprint of the ETA tailings impoundment, however many of these wells are not routinely monitored. Table 3.2-7 provides a statistical summary of the ETA groundwater quality.

Groundwater within this area is highly to adversely impacted. Highly impacted groundwater is shown at well SRK05-ETA-BR2, and is representative of bedrock groundwater flow. Sulphate and zinc concentrations at this well ranged from 1270 – 1410 mg/L and 4.06 – 15.3 mg/L, respectively through 2005 to 2007.

Adversely impacted groundwater conditions are represented by wells P96-8B, SRK04-3A/B and SRK05-ETA-BR1, and vary in depth from 7-12 mbgs. Sulphate and zinc concentrations from 2005 through 2007 ranged from 3220 – 18500 mg/L and 173 – 754 mg/L, respectively.

The Emergency Tailings Area contains some of the most contaminated groundwater at the Faro Mine Complex, and represents a major source of contaminant loading the Rose Creek Valley aquifer, and potentially Rose Creek. Seepage from the ETA area is now collected immediately downstream of the mine access road.

S-Cluster Area

This area is located at the toe of the Faro waste rock dumps, south of the haul road and immediately adjacent to the North Fork of Rose Creek (NFRC). Wells in this area were installed to monitor impacts to groundwater from the upgradient rock dumps and to evaluate the potential for impact on NFRC. Table 3.2-8 lists relevant information for all groundwater monitoring wells in the area used in the baseline assessment.

Groundwater monitoring in this area started in 1989 with the installation of three nested standpipe piezometers ("S" wells), followed by (P96-7) installed in 1996 (Robertson GeoConsultants Inc., 1996) and 6 nested piezometers ("SRK05-SP" series) and several drive point piezometers installed in 2005. Table 3.2-9 presents a statistical summary of S-Cluster Area baseline groundwater quality.

Groundwater quality within the S-cluster zone varies from slightly to adversely impacted. Slightly impacted groundwater is represented by groundwater wells SRK05-SP-1B and SRK05-SP-2. Sulphate and zinc concentrations for these wells over the past three years (2005-2007) ranged from 33.7 to 276 mg/L and 0.105 to 0.278 mg/L, respectively. The depths of these wells are generally representative of the deeper groundwater system ranging between 11.0 mbgs (SRK05-SP-2) and 12.3 mbgs (SRK05-SP-1B). Well SRK05-SP-2 contains the lowest sulphate and zinc concentrations of all the wells in the S-cluster area and is located southeast of the other wells, adjacent to the NFRC. Despite being the shallowest well of the slightly impacted group, it is screened in alluvium/bedrock.

Moderately impacted groundwater is characterized by groundwater wells P96-7, S1B, SRK05-SP-1A, SRK05-SP-3A/B, SRK05-SP-4A. Sulphate concentrations range from 173 to 1,910 mg/L and zinc concentrations from 0.0078 to 3.5 mg/L. These wells vary substantially in depth with SRK05-SP-3A at 21.9 mbgs and S1B at 4.3 mbgs.

Highly impacted groundwater is present in monitoring well S2B, and is representative of the shallow groundwater system at 6.7 mbgs. S2B has also shown significant zinc concentration increases and is screened in till at 6.7 mbgs.

Adversely impacted groundwater is characterized by groundwater wells S1A, S2A, S3, SRK05-SP-4B and SRK05-SP-5. These wells can generally be characterized as the shallow groundwater system with depths ranging from 3.5 mbgs (SRK04-SP-4B) to 12.5 mbgs (SRK05-SP-5). Monitoring well SRK04-SP-4B is the shallowest well within the S-cluster area, and also contains the highest zinc concentration reaching 447 mg/L in October 2007. Zinc concentrations in S1A, S2A, and S3 have increased in a similar trend since 2003. Both S1A and S2A are bedrock wells at 12.2 mbgs where S3 is screened in till at 5.6 mbgs.

Groundwater impact at the S-cluster area varies significantly both spatially and with depth. The shallow groundwater system is generally characterized as being adversely impacted; however, highly impacted groundwater extends down to bedrock in some areas. Sulphate and zinc concentrations (in addition to other trace metals such as manganese) have shown substantial concentration increases since 2001.

All of the impacted wells in the S-cluster area are in close proximity to the NFRC (Figure 3.2-4). This area was targeted for increased monitoring frequency in order to support future remediation plans.

Zone II Outwash Area

The layout of the Faro waste rock dumps and the relevant monitoring wells in the Zone II Outwash Area are presented in Figure 3.2-6. Most of the groundwater monitoring wells in the outwash area are located at the toe of the waste rock dump. Other monitoring wells are located along the toe of the Northeast and the

Intermediate Dumps. Table 3.2-10 lists information of groundwater monitoring wells relevant to the baseline assessment, located in the Zone II Outwash Area.

Available groundwater quality data in the Zone II Outwash Area characterizes groundwater as moderately impacted. These wells include BH1, BH4, BH6, and P05-04. Sulphate and zinc concentrations range from 41.4 mg/L to 261 mg/L and 0.615 mg/L to 7.66 mg/L, respectively. These wells are completed in the shallow groundwater system with depths ranging from 2.4 mbgs (BH4) to 6.34 mbgs (P05-04). Groundwater flow is in a southwesterly direction, in alignment with the NFRC valley.

Groundwater wells closest to NFRC are BH4 and BH6. All wells within the Zone II Outwash Area are categorized as 'moderately impacted' and pose a potential threat to the creek.

Table 3.2-11 summarizes groundwater quality in the Zone II Outwash Area.

Northeast and Intermediate Rock Dumps

Figure 3.2-6 shows the monitoring wells located along the toe of the Northeast Dump and the Intermediate Dump. Table 3.2-12 lists groundwater monitoring wells in the area used in the baseline assessment. Wells in the area were installed in 1994 by SRK and in 1996 by Robertson GeoConsultants Inc.

Table 3.2-13 summarizes groundwater quality in the vicinity of the Northeast and Intermediate Faro Rock Dumps. Groundwater quality at the toe of the Northeast Dump is characterized as both slightly and moderately impacted. Low impacted wells include BH12A/B and BH13A/B, with sulphate and zinc concentrations ranging between 133 mg/L to 623 mg/L and 0.008 mg/L to 0.683 mg/L, respectively. Well depths range between 3.05 mbgs (BH12A) and 8.23 mbgs (BH12B and BH13B). The low impact wells are located furthest north along the perimeter of the Northeast rock dump. It is likely that the waste rock upgradient of this area is less reactive and contributes lower contaminant concentrations in seepage to these downgradient wells. In addition, the North Fork Rose Creek lies just to the north of BH13 and may be lowering concentrations by dilution through seepage.

Moderately impacted groundwater is characterized by BH14 which is located south of the Northeast rock dump. Sulphate and zinc concentrations in BH14A (6.25 mbgs) and BH14B (9.3 mbgs) range between 1,550 mg/L to 2,040 mg/L and 0.019 to 0.59 mg/L, respectively. Both of these wells are screened in shallow bedrock.

Moderately impacted groundwater is characterized by BH14 which is located south of the Northeast rock dump. Sulphate and zinc concentrations in BH14A (6.25 mbgs) and BH14B (9.3 mbgs) ranged between 1,550 mg/L to 2,040 mg/L and 0.019 to 0.59 mg/L, respectively. Both of these wells are screened in shallow bedrock.

Well P96-6 is located about 30 m northeast of the S-cluster wells. Thus, the similarity of groundwater quality in a few wells in the S-cluster area and in P96-6 is not unexpected. It was suggested by Robertson GeoConsultants Inc. that the groundwater quality in P96-6 may be a combination of highly impacted

groundwater seeping from the intermediate dump diluted by background quality groundwater recharged by the NFRC (Robertson GeoConsultants Inc., 2007).

In addition, the sediments encountered at depth in P96-6 are similar to those observed in the nearby Zone II Outwash Area. It is possible that they form part of a continuous "alluvial aquifer" along the NFRC and impacted groundwater from the Zone II Outwash Area is influencing water quality at P96-6.

Second Impoundment

Table 3.2-14 lists pertinent information on groundwater monitoring wells used in establishing baseline conditions in the Second Impoundment, a section of the Rose Creek Tailings Impoundment. Groundwater monitoring in the Second Impoundment commenced in 2001 with the installation of two nested piezometers (P01-07A/B/C/D/E and P01-9A/B/C/D). These wells were decommissioned in 2005 due to concerns about their integrity (Robertson GeoConsultants Inc., 2007). In 2003, six multilevel monitoring wells were installed within the footprint of the Second Impoundment. The following multilevel wells are important for establishing baseline conditions in this area: P03-01, P03-02, P03-04, P03-05 and P03-06.

Groundwater conditions in the Second Impoundment include all five impacted groundwater designations from adverse to non-impacted conditions, as shown in Table 3.2-15. Wells screened in the tailings range in depth from 7.77 mbgs (P03-01-09) to 13.72 mbgs (P03-04-08). These well points are P03-01 (points 08, 09), P03-02 (07, 08, 09), P03-04 (points 08, 09), P03-05 (06, 07, 08) and P03-06-06. Sulphate and zinc concentrations within wells screened in the tailings of the second impoundment vary from 1270 mg/L to 58,100 mg/L and 0.0054 mg/L to 4,040 mg/L respectively. Generally, sulphate and zinc concentrations decrease with increasing depth of the well. Appendix B1.4 shows the temporal depth profile of sulphate, magnesium, zinc, alkalinity, pH, iron and manganese for the multilevel piezometers P03-01 to P03-09 which are located throughout the second (P03-01 to P03-06) and intermediate impoundments (P03-08), and at the toe of the Cross Valley Dam (P03-09).

The groundwater quality in the aquifer beneath the tailings of the Second Impoundment is being affected by loadings of SO4, Mg, Zn and Na from upstream areas, i.e., original impoundment and possibly ETA. Higher concentrations of ARD is observed in groundwater in the northern portion of the Rose Creek Valley Aquifer and is likely due to waste rock drainage from the Faro waste rock dumps via the old Faro Creek channel and also from vertical dispersion along the groundwater flow path.

ARD is also observed at depth within the aquifer below the tailings. Multilevel well P03-03-02 gives a clear indication of this with over one hundred times the SO4 concentration and ten thousand times the Zn concentration as compared to P03-01-01 (Appendix B1.3). The high concentrations detected are thought to be the result of an upgradient leaky well, P01-09. This well was decommissioned in October 2001, while the May 2007 sampling event at P03-03 yielded lower SO4 and Zn concentrations (Appendix B4).

This increase of ARD products in the aquifer below the tailings of the second impoundment may indicate that the neutralizing capacity of the aquifer along groundwater flow paths is being exhausted. This suggests a potential for future increases in metal and sulphate concentrations.

Intermediate Impoundment

Table 3.2-16 lists information for groundwater monitoring wells located in the Intermediate Impoundment, which are relevant for establishing baseline conditions. Wells X21A/B/C were first installed in 1981. These wells were destroyed during mine operation and later replaced with wells at a similar location in 1996 (Robertson GeoConsultants Inc., 1996). In 2001, additional piezometers (P01-05A/B and P01-06) were installed (Gartner Lee Limited, 2002) and subsequently decommissioned in October 2005 due to well integrity concerns (Robertson GeoConsultants Inc., 2007). In 2003, one multilevel monitoring well (P03-08) was installed within the footprint of the Intermediate Impoundment with monitoring points extending down into the aquifer beneath the tailings.

A summary of groundwater quality at the Intermediate Impoundment is provided in Table 3.2-17. The Intermediate Impoundment is characterized by non-impacted to adversely impacted groundwater conditions. However, the wells screened in tailings at multilevel P03-08 contain uncharacteristically low metal concentrations. Surface water ponding nearby P03-08 (infiltrating to the measurement points) in addition to groundwater recharge from nearby Rose Creek are thought to be contributing factors to the low metal concentrations at this location.

Groundwater within the intermediate impoundment is monitored by multilevel well P03-08 and X21A/B (Figure 3.2-2). Monitoring points in the tailings include X21A-96 and P03-08-06/07/08. Sulphate and zinc concentrations reached a maximum of 18,500 mg/L and 104 mg/L, respectively. Tailings thickness at P03-08-06 extends down to 20.12 mbgs. Moderately impacted groundwater is present in P03-08-05/06/07 and X21B-96; slightly impacted groundwater in P03-08-02/03/08; and non-impacted conditions are present in the deep aquifer well, P03-08-01 at 32.61 mbgs.

Toe of Intermediate Dam

Table 3.2-18 provides specification for groundwater monitoring wells located in the Intermediate Impoundment, which are relevant for establishing baseline conditions. Wells X24A/B/C/D and X25A/B were first installed in the area in 1987. These wells were replaced in 1996 when the dam level was raised (Robertson GeoConsultants Inc., 1996). In 2001, additional wells P01-03 and P01- 04A/B were installed to complement the existing monitoring wells at X24 and X25 (Gartner Lee Limited, 2002). Wells X24A/B/C were not sampled in recent years because of problems with integrity and sand heaving.

Groundwater at the toe of the Intermediate Dam is characterized by moderate to non-impacted conditions. Moderately impacted groundwater is characterized by groundwater wells P01-03 and X24D-96. These wells have a wide range in depth from 9.3 to 28.34 mbgs. Sulphate and zinc concentrations reach 1,930 mg/L and 0.335 mg/L, respectively. Slightly impacted groundwater includes P01-04A, and X25A/B-96.

Non-impacted groundwater is represented by well P01-04B, which is located furthest south along the reach of the dam and is also the deepest well (52.5 mbgs) in the area. Groundwater quality at the Toe of the Intermediate Dam is summarized in Table 3.2-19.

Downgradient Areas

Toe of Cross Valley Dam

Table 3.2-20 lists the wells located along the toe of the Cross Valley Dam. Water quality from these wells represents conditions immediately downgradient of the Cross Valley Dam and consequently, downgradient of major sources of contamination from mining footprint areas. Groundwater monitoring started in 2001 along the toe of the Cross Valley Dam at wells P01-02A/B and P01-11. Multilevel wells P03-09 and P05-01 were installed in the center of the valley in 2003 and 2005 respectively. Two single piezometers (P05-02 and P05-03) were installed in 2006 as part of a study to design a seepage interception system in this area (Robertson GeoConsultants Inc., 2007).

Groundwater at the Toe of the Cross Valley Dam is characterized by moderately impacted and slightly impacted groundwater. Table 3.2-21 summarizes baseline groundwater quality along this reach. Groundwater quality improves from north to south along the reach of the dam.

Moderate impacts to groundwater are represented by groundwater wells P01-11, P05-01-02 through P05-01-06, and P05-02. Sulphate concentrations reached 1130 mg/L while the zinc maximum concentration was 0.45 mg/L. The greatest range in depth among these multilevel wells is seen at P05-01 where depths range from 3.35 to 19.82 mbgs. This interval is uniformly stratified, and as a result there is a high consistency in groundwater chemistry results.

Slight impacts to groundwater are observed in the southern toe of the Cross Valley Dam (consistent with observations upgradient at the toe of the Intermediate Dam). These wells include P01-02A/B, P03-09 (all points 01 through 09), P05-01-01, and P05-03. These wells cover a depth range of 7.62 mbgs (P03-09-09 and P05-03) to 35.05 mbgs at P03-09-01.

Downgradient of Cross Valley Dam

Table 3.2-22 lists groundwater monitoring wells located downgradient of the Cross Valley Dam that are relevant to establishing baseline conditions. Wells X16A/B, X17A/B and X18A/B were installed downstream of the Cross Valley Dam in 1981. In 2001, another set of nested monitoring wells (P01-01A/B) were installed in the north side of the valley.

Table 3.2-23 summarizes groundwater quality downgradient of the Cross Valley Dam. Slightly impacted and non-impacted groundwater are the designations describing this area. Slight impacts are represented by P01-01A/B, X17B and X18A/B. Sulphate and zinc concentrations in these wells ranged between 39.5 and 673 mg/L and <0.005 and 0.149 mg/L, respectively. These wells generally represent the deep groundwater system with depths ranging from 10.6 to 34.9 mbgs (X18A and P01-01B, respectively).

Non-impacted groundwater wells include X16A/B, located furthest downgradient from the Rose Creek Tailings impoundment, and X17A. At monitoring location X-17, 300m downsream of the Cross Valley Dam, the deeper piezometer X-17B (25 mbgs) is slightly impacted, whereas the shallower piezometer X-17A (6.2 mbgs) is non-impacted.

Shallow groundwater is likely cleaner due to the addition via seepage of dilute surface water from the Rose Creek Diversion channel. Distinct seasonal variations are seen at X17B with highest concentrations observed in the spring. This may be the result of increased contributions of deep groundwater upwelling from underlying bedrock and/or basal till (Robertson GeoConsultants Inc., 2007), or might indicate that tailings impacted groundwater is passing below the Cross Valley Dam through the deep groundwater system.

3.2.5.5 Grum/Vangorda Mine Site

Figure 3.2-12 shows the general layout of the Grum/Vangorda mine site and the groundwater monitoring wells used for this baseline assessment. The Grum site comprises the Grum Pit, Grum rock dump (with a sulphide cell) and the overburden stockpile. The Vangorda site comprises the Vangorda Pit (with the in-pit rock dumps) and the Vangorda rock dump. The area is drained by Vangorda Creek, which runs between both mine sites and flows toward the Pelly River. Groundwater monitoring wells are located along the toe of both the Grum and Vangorda rock dumps.

As with the Faro site, the Vangorda/Grum site was divided into separate areas to facilitate discussion of groundwater quality data (Figure 3.2-15)

Upgradient Areas

Upgradient Areas within the Vangorda/Grum Site are not currently monitored, as there have not been any wells installed to assess background concentrates outside of the mine impacted areas.

Mine Footprint Areas

Grum Rock Dump Area

Table 3.2-24 lists information for the monitoring wells located at the toe of the Grum waste rock dumps (Figure 3.2-12) used in the baseline assessment.

Vangorda Rock Dump Area

Table 3.2-26 lists information for the monitoring wells used in the baseline assessment at the Vangorda site (Figure 3.2-12).

Groundwater chemistry around the toe of the Vangorda waste rock dumps is summarized in Table 3.2-27. Similar to the Grum Mine Site, the groundwater quality at the Vangorda Mine Site is also characterized as either slightly or moderately impacted. Most of the groundwater however is slightly impacted with only one well (V35) representative of moderately impacted conditions.

Sulphate and zinc concentrations in slightly impacted groundwater at the Grum Mine Site range from 42.5 to 693 mg/L and from 0.004 to 0.047 mg/L, respectively. Sulphate concentrations have remained very steady in all slightly impacted wells at the Vangorda site, where seasonal changes are not observed to have an effect on the wells. The largest change in sulphate concentration over the last three years for slightly impacted groundwater was observed at well V36 with a net sulphate change of 184 mg/L (509 mg/L recorded in May

2005 and 693 mg/L recorded in May 2007). This can be partly explained by the low permeability screened units in this area where freshet conditions do not impose a dilution effect through well screens.

Well V35 represents the only moderately impacted groundwater well at the Vangorda site. This well is located on the south-side of the Vangorda rock dumps with a depth of 15.95 mbgs and is screened in alluvium. Sulphate and zinc concentrations range from 495 mg/L to 1,680 mg/L and from <0.005 to 0.113 mg/L, respectively.

Water quality in the Vangorda/Grum Site show evidence of ARD impacts along the toe of the waste rock dumps. Most of the wells located close to the toe of the waste rock dump are clearly impacted. However, groundwater travel times to the Vangorda Creek are significantly less than at the Grum waste area. This is a result of a thick till deposit present at the Vangorda area compared to the alluvial sediments in drainage channels at Grum (Robertson GeoConsultants Inc., 2007).

Figure 3.2-17 summarizes the impact level in the Grum/Vangorda Site area. The same criteria are used for classifying the level of impact in Figure 3.2-17 as presented in Table 3.2-3. The impact on groundwater in wells in the Grum/Vangorda area is low to moderate. As Figure 3.2-17 shows, the highest level of impact at the toe of the Vangorda and Grum waste rock dumps is moderate (550 to 4,500 mg/L sulphate and 0.01 to 300 mg/L zinc). It is also evident from Figure 3.2-17 that groundwater wells at the toe of the Vangorda rock dump show less impact (low: 40 to 600 mg/L sulphate and 0.005 to 15 mg/L zinc) compared to the wells at the toe of the Grum rock dump which show moderate impact.

Downgradient Areas

Town of Faro and Lower Vangorda Creek

The location of the Town of Faro drinking water supply wells and nearby observation wells is presented in Figure 3.2-14. These wells provide baseline information for groundwater within the Vangorda Creek and Pelly River alluvial sediments. This location is significant as the Town water supply wells receive a portion of their water from Vangorda Creek recharge (GLL, 2007).

The Anvil Range water license QZ03-059 contains a condition requiring an investigation of the potential influence of Vangorda Creek on the Town of Faro water supply. In response to this water license condition, Gartner Lee recently completed a report on the town of Faro water wells (GLL, 2007). This study indicated that Vangorda Creek contributes to the recharge of the Town of Faro water supply aquifer. The study concluded that the Town of Faro water supply is consistently of very good quality. Further, the Gartner Lee report noted that metal concentrations measured in Vangorda Creek throughout the study period were well below Canadian Drinking Water Quality Guidelines and therefore posed minimal risks to the Town of Faro water supply (GLL, 2007).

Continued routine monitoring of Vangorda Creek was recommended in the Gartner Lee Ltd. (2007) report because of the observed hydraulic connection between Vangorda Creek and the Town of Faro water supply aquifer. It was also observed during the study that concentrations of two compounds – nitrate and chloride – were elevated in the Vangorda Creek samples compared to samples obtained in the Pelly River. All

measurements of these compounds were well below the respective Canadian Drinking Water Quality Guidelines (CDWQG). The source of these elevated concentrations (natural or anthropogenic) could not be determined owing to the lack of data from historical monitoring throughout Vangorda Creek.

A focused sampling and analysis program was initiated in spring 2007 to investigate the elevated nitrate and chloride concentrations observed in lower Vangorda Creek. Key findings from the study show there are no mining-related sources of chlorides to Vangorda Creek; elevated levels of nitrate concentrations in Vangorda Creek, relative to the Pelly River, may be related to mining activities and land use. The low nitrate concentrations observed downstream of the Anvil Range site pose minimal risks to the Town of Faro water supply (GLL, 2007).

3.2.5.6 Groundwater Quality Temporal Trends

The groundwater quality within the Faro Mine Complex was recently reviewed and summarized by Robertson GeoConsultants Incl (2007). Figure 3.2-18 presents the temporal trends of water quality in the different mine site areas within the Faro and Grum/Vangorda Sites. The temporal trends for zinc, sulphate and pH shown in Figure 3.2-18 reflects some of the following conclusions on the current baseline status of groundwater quality in both mine sites.

Faro Mine Site

Mine Footprint

Groundwater quality in the underlying Rose Creek aquifer has significantly deteriorated in the last three years in areas downgradient of the Rose Creek Tailings Facility. This deterioration has occurred not only within the footprint area of the tailings impoundments but also further downstream at the Intermediate and Cross Valley Dams. The increase of sulphate, magnesium, iron, zinc and manganese concentrations deep in the aquifer are of concern particularly in the northern part of the aquifer. Seepage from the tailings and Emergency Tailings Area are affecting the entire depth of the sedimentary aquifer as evident in the time trends of monitoring wells P03-06, X21B, X24D.

The attenuation capacity of the aquifer soils/sediments beneath the tailings is being exhausted. Wells screened below the tailings at shallow aquifer depths indicate significant increases in zinc concentration (e.g., 22 mg/L at NA11). Other recent increases in zinc concentrations in many parts of the Rose Creek aquifer may be explained by the diminishing attenuation capacity in aquifer material.

Over the last five years the quality of groundwater in the S-cluster rock dump area has deteriorated dramatically. This deterioration was marked by rapid increase in dissolved zinc concentrations (increased by as much as 100 mg/L from Sep. 2005 to June 2007) in selected wells (e.g., S1A, S2B, S3). All affected wells are in vicinity of North Fork Rose Creek (NFRC) indicating that there is a potential for significant increases in zinc concentrations along this reach of Rose Creek.

A moderate impact on groundwater in the relatively highly permeable alluvial sediments of the NFRC valley was observed based on a 2005 study of the Zone II Outwash Area at the toe of the Faro waste rock dumps.

Downgradient

Recent increases in zinc concentrations in groundwater downgradient from the Northeast Dump (at BH14A/B) were observed in 2006. Increases in sulphate, magnesium and alkalinity concentrations preceded the increase in zinc concentrations. Geochemical characterization work has identified sulphide-rich waste rock in this portion of the Northeast Dumps and it is possible that groundwater quality will continue to deteriorate in this area with sulphate and eventually zinc concentrations reaching similar concentrations as currently observed in the ETA and S-cluster areas. Sulphate rich rocks in the Northeast Dump were the likely source of increase of zinc, sulphate, magnesium and alkalinity in the groundwater in this area. It is likely that this area will eventually have similar contamination levels to the Faro Creek and S-cluster areas.

Vangorda/Grum Site

Mine Footprint

Effects of seepage from the Grum rock dump are limited to shallow depths since deep wells installed in 2004 in the area do not show increased metal concentrations.

Low permeability of sediments and till at Vangorda area allow for a delayed impact of waste rock seepage on groundwater in contrast to other impacted areas of the mine. However, there was a recent increase in sulphate, magnesium and zinc concentrations in one of the wells (V35) at the southwest corner of the Vangorda rock dump.

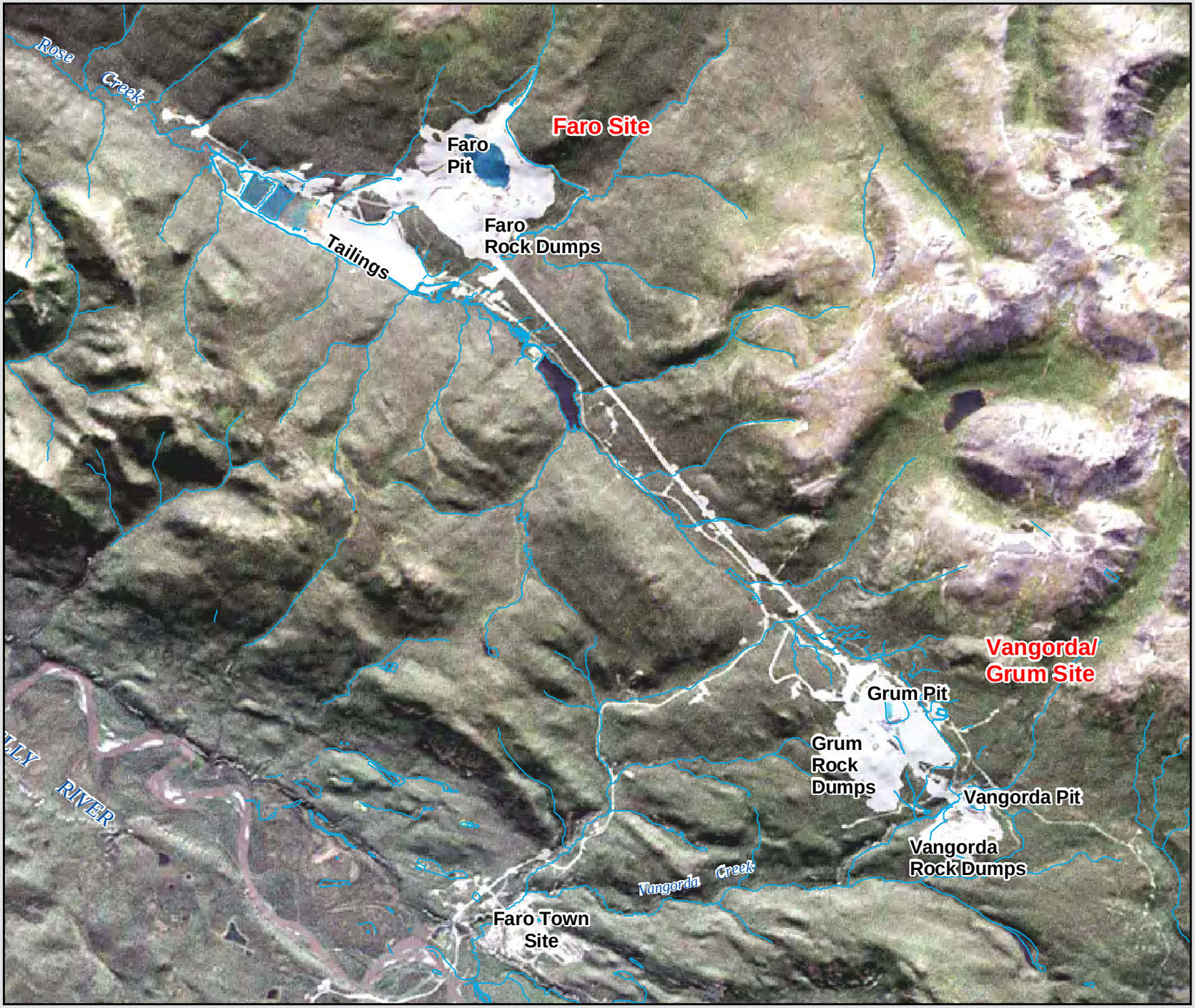
Downgradient

Observed trends of groundwater quality downgradient of the Grum Rock Dump confirm previous interpretations that suggested seepage from the Grum rock dump is the cause of a gradual increase in SO4, Mg, and to a lesser extent Zn concentration (zinc and other metals are being attenuated) in the shallow groundwater draining toward Vangorda Creek.

Town of Faro and Lower Vangorda Creek

Vangorda Creek recharges the town of Faro water supply aquifer. It was observed that concentrations of nitrate and chloride were elevated in the Vangorda Creek samples compared to samples obtained in the Pelly River. However, concentrations of these compounds were well below the CDWQG. A focused sampling and analysis program in 2007 showed there are no mining-related sources of chlorides to Vangorda Creek. The low nitrate concentrations observed downstream of the Anvil Range site pose negligible risks to the Town of Faro water supply (GLL, 2007).

Groundwater quality in this area shows significant spatial variation, both by location and with depth, indicating heterogeneous subsurface conditions. Furthermore, groundwater quality in this area has deteriorated over the last five years (Appendix B1.3 includes historical water quality plots).



Legend

Watercourse

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.

N
W E
S

0 1 2

Kilometers

1:100,000

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation

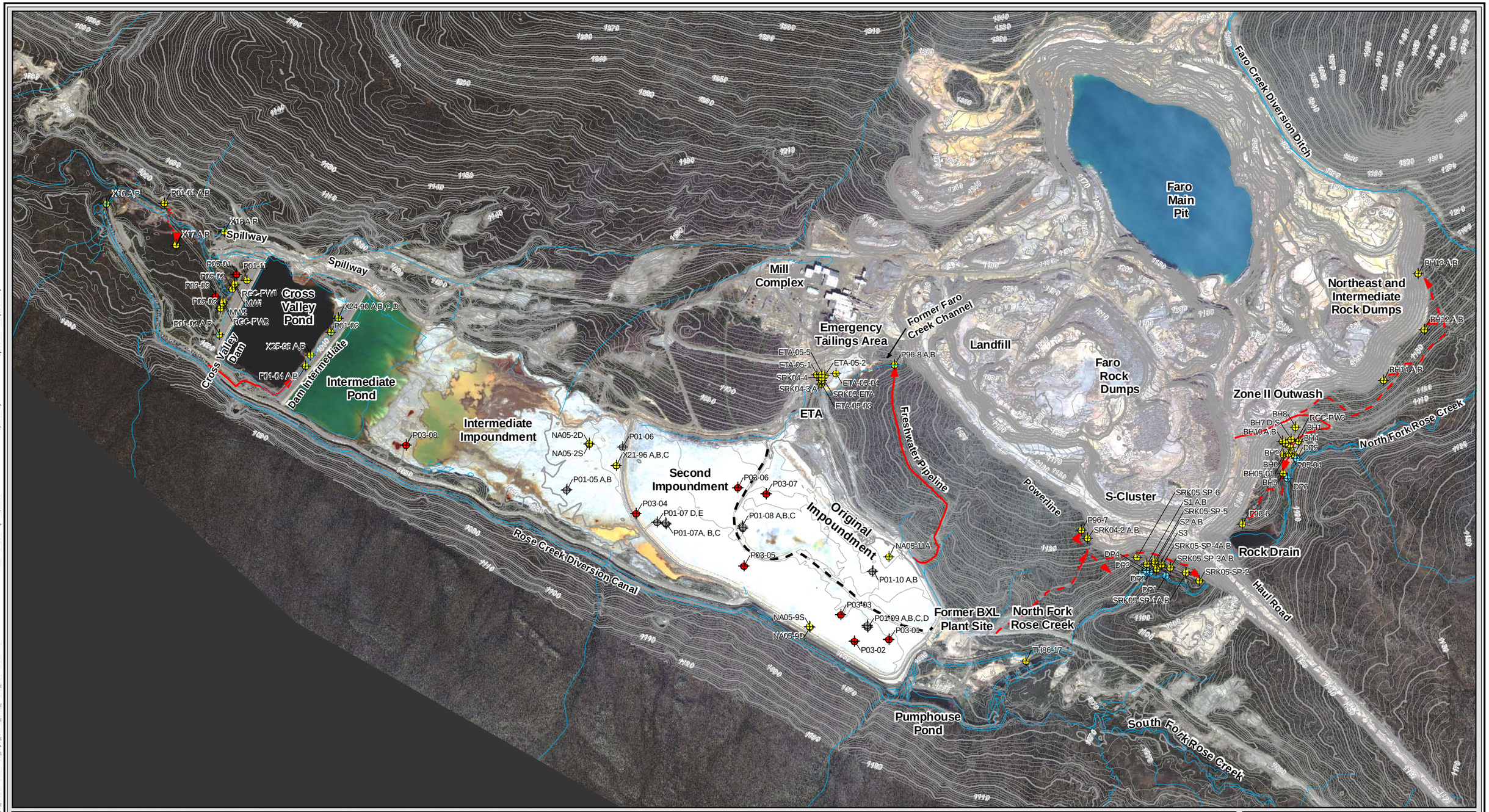
Faro Mine Complex
Faro, Yukon

March 2009

AECOM

Figure 3.2-1

File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GW\By1_Baseline\107403_By1_3-2-1_FaroComplex_09cMar31.mxd Date Revised: April 1, 2009 Prepared by: MM Project: 107403 (80642-1)



Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009.

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N
W E
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0 250 500
Meters

1:17,500
UTM Zone 8N, NAD 83

Legend

Wells
- Drive Points
- Conventional Wells
- Multilevel Wells
- Decommissioned Wells

Well Access Routes
- Foot
- ATV
- Truck

- Impoundment (original)
- Watercourse

Contours
- Index Contours (10m)
- Intermediate

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

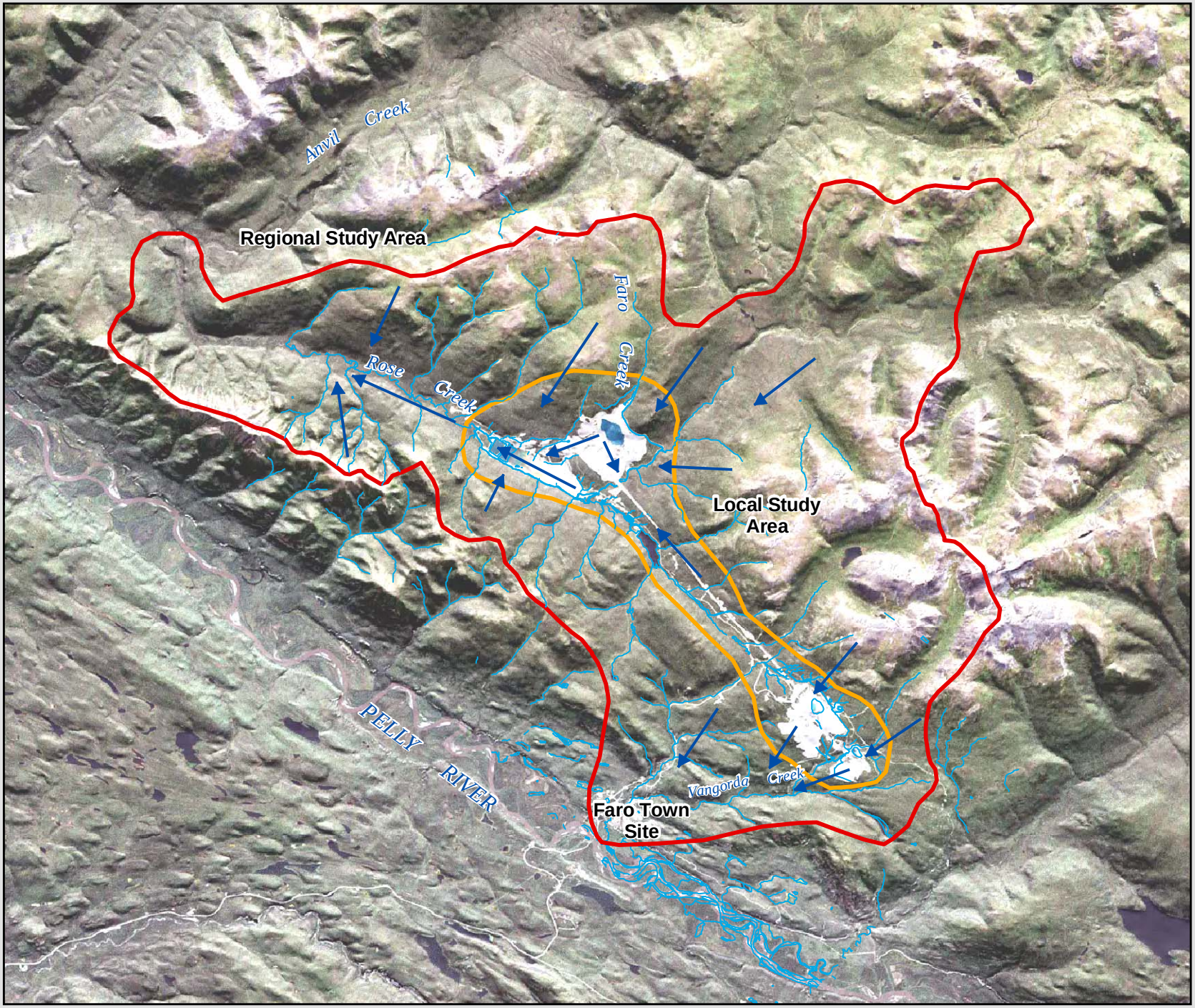
Detailed Location of the Faro Site and Existing Wells

March 2009

AECOM

Figure 3.2-2

Project: 107403 (80642-1)
Prepared by: MM
Date Revised: April 1, 2009
File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy1_Baseline\107403_By1_3-2-2_Site_Wells_09oMar31.mxd



Legend

- Watercourse
- Regional Study Area
- Local Study Area
- Inferred Groundwater Flow Direction

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.

N
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Kilometers

1:200,000

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

Local and Regional Study Areas for the Faro Mine Complex

March 2009

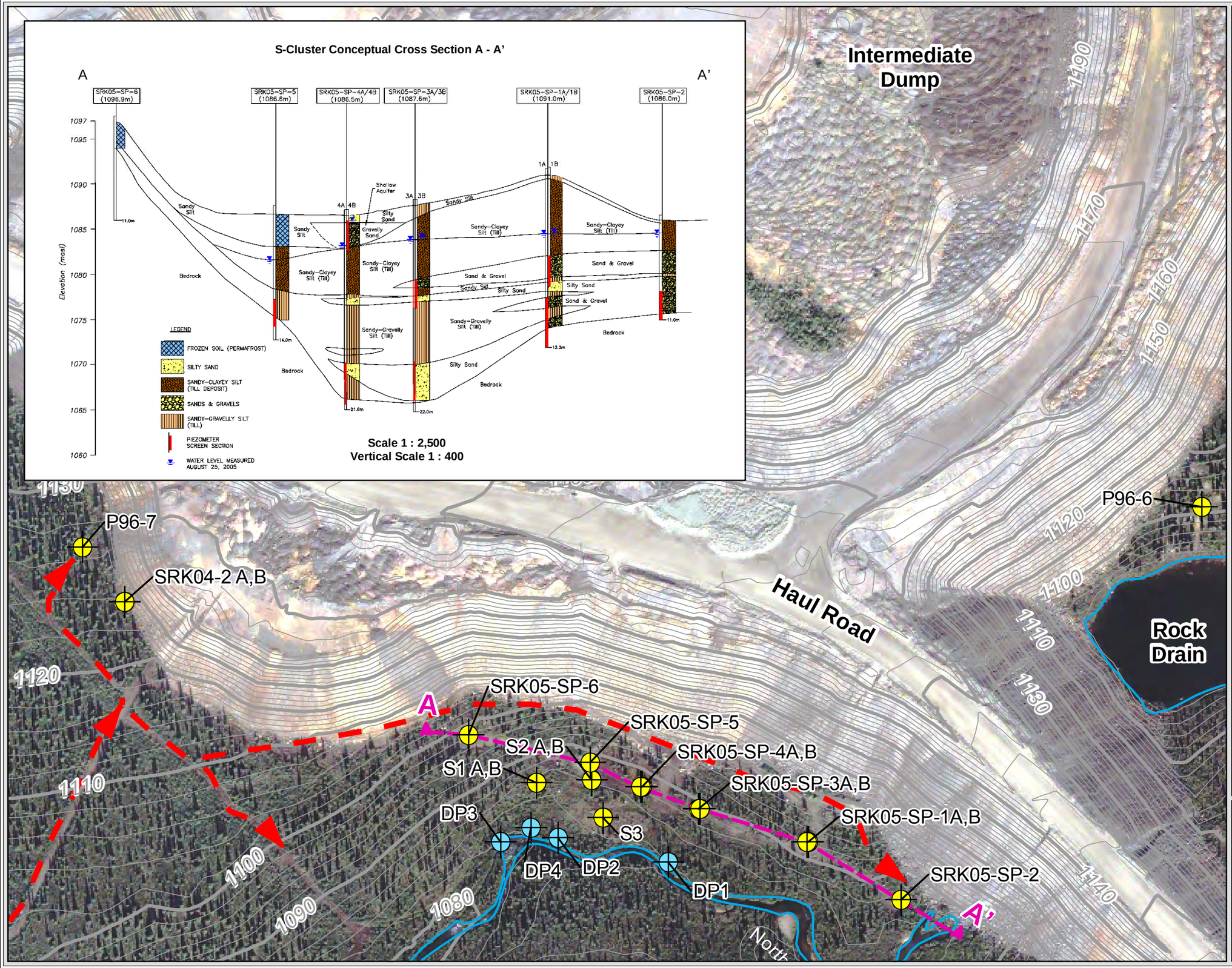
AECOM

Figure 3.2-3

File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GW\By1_Baseline\107403_By1_3-2-3_LocReg_09cMar31.mxd Date Revised: April 1, 2009 Prepared by: MM Project: 107403 (80642-1)

S-Cluster Conceptual Cross Section A - A'

Scale 1 : 2,500
Vertical Scale 1 : 400



Legend

Wells

- Drive Points
- Conventional Wells
- Multilevel Wells
- Decommissioned Wells
- Section Line A-A'
- Impoundment (original)
- Watercourse

Well Access Routes

- Foot
- ATV
- Truck

Contours

- Index Contours (10m)
- Intermediate

Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009. Cross-Section: Extracted from Figure 4 of the report, "Anvil Range Mining Complex 2005 Seepage Investigation at the S-Cluster Area Below the Faro Waste Rock Dump", prepared for Deloitte & Touche, Inc., by SRK Consulting, as issued in November 2006.

N W E S

0 25 50
Meters

1:2,500

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

S-Cluster Area and Stratigraphy

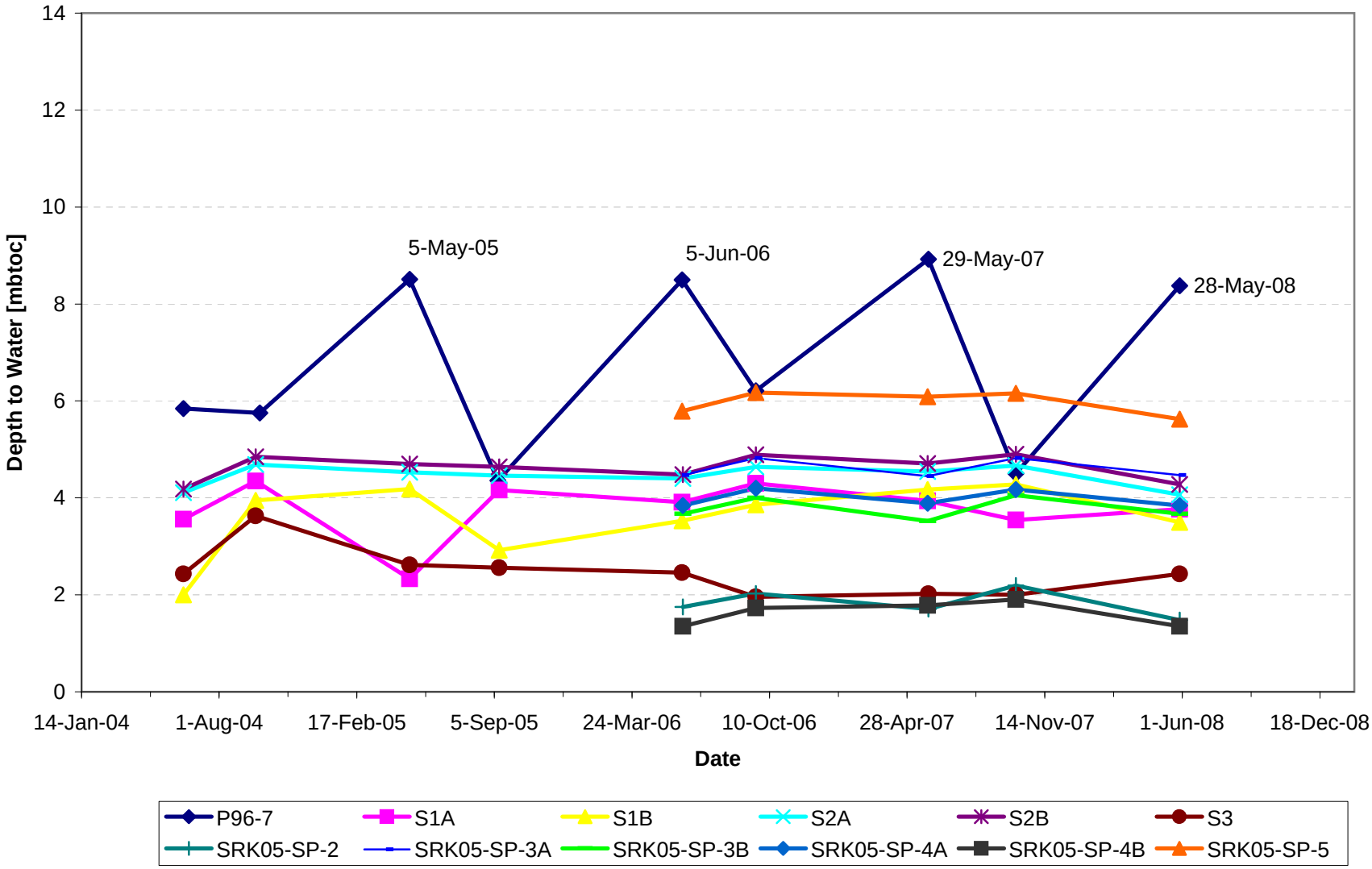
March, 2009

AECOM

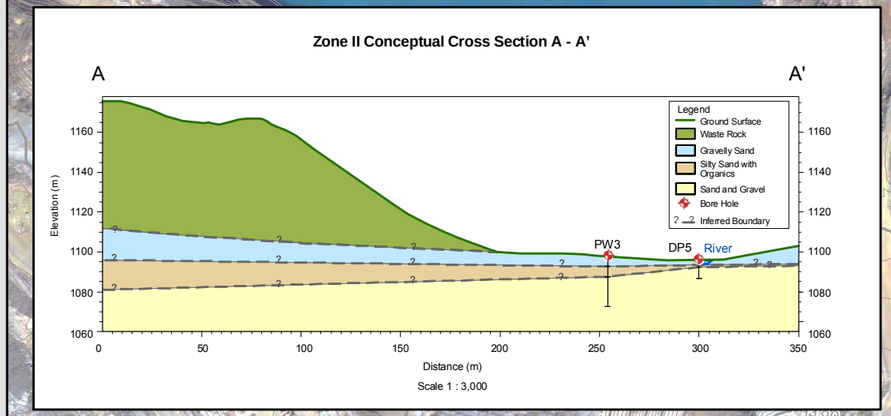
Figure 3.2-4

Project: 107403 (80642-1)
Prepared by: MM
Date Revised: April 1, 2009
File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy1_Baseline\107403_By1_3-2-4_S-Cluster_09cMar31.mxd

Figure 3.2-5 Water Level Trends in Wells within the S-Cluster Area



AECOM



Northeast Dump

Faro Rock Dumps

Intermediate Dump

ZONE II PIT AREA

Haul Road

North Fork Rose Creek

BH13 A,B

BH12 A,B

BH14 A,B

BH8

BH7 D,S

BH1

BH10 A,B

BH2

BH05-01

RGC-PW3

P05-04

BH6

BH4

DP5

BH5

DP6

P96-6

A

A'

Legend

Wells

- Drive Points
- Conventional Wells
- Multilevel Wells
- Decommissioned Wells
- Section Line A-A'
- Impoundment (original)
- Watercourse

Well Access Routes

- Foot
- ATV
- Truck

Contours

- Index Contours (10m)
- Intermediate

Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009. Cross-Section: Extracted from Figure 4 of the report, "Anvil Range Mining Complex 2005 Seepage Investigation at the S-Cluster Area Below the Faro Waste Rock Dump", prepared for Deloitte & Touche, Inc., by SRK Consulting, as issued in November 2006.

N W E S

0 50 100
Meters

1:5,000

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

Zone II Outwash Area and Stratigraphy

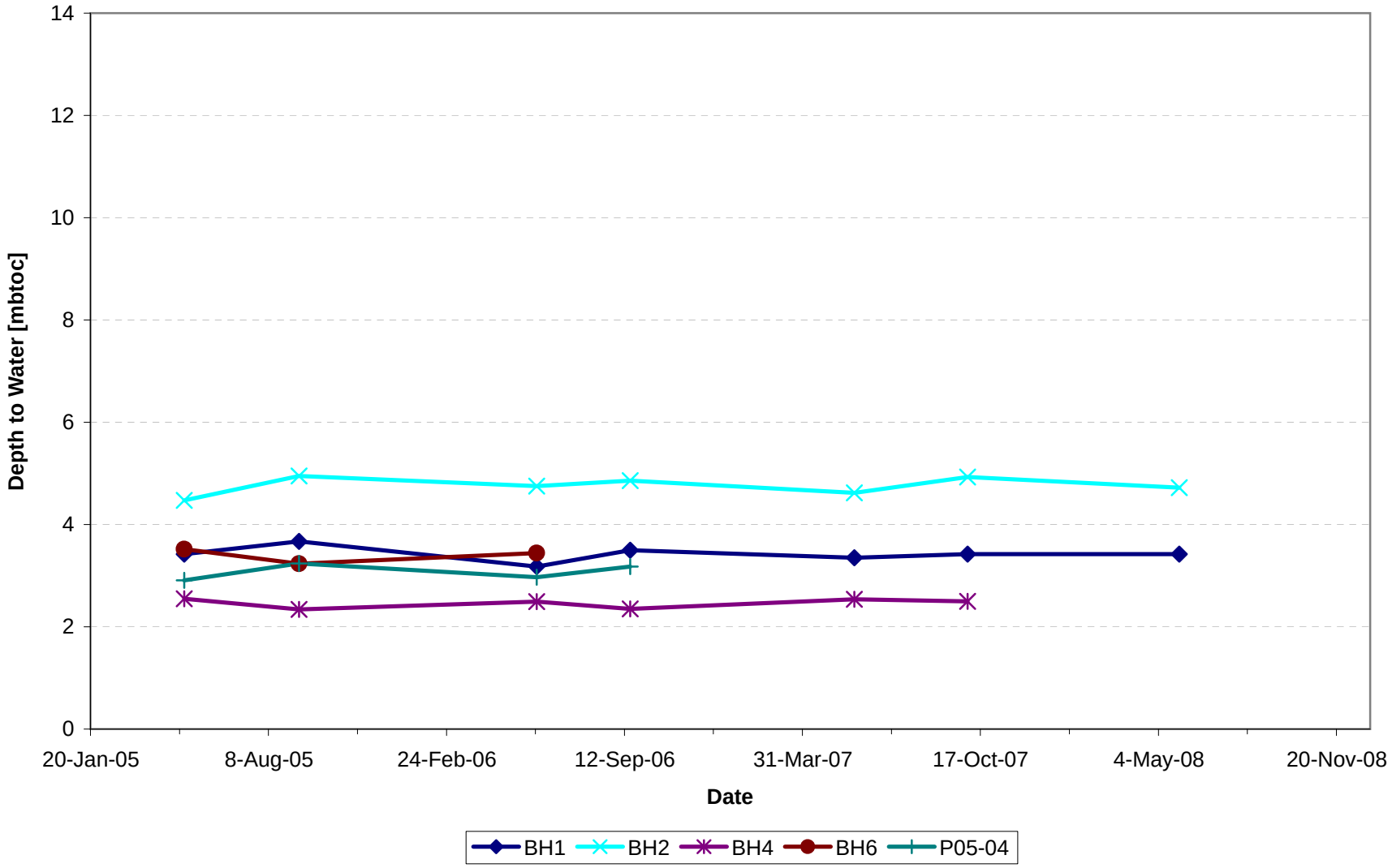
March, 2009

AECOM

Figure 3.2-6

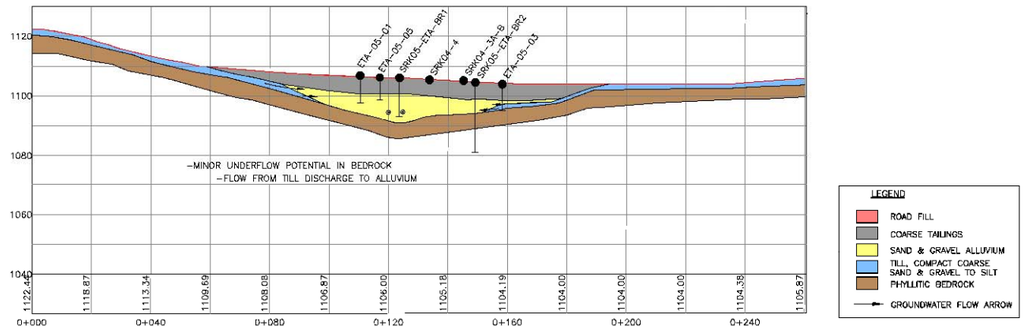
Project: 107403 (80642-1)
Prepared by: MM
Date Revised: April 1, 2009
File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GW\By1_Baseline\107403_By1_3-2-6_Zone2_09oMar31.mxd

Figure 3.2-7 Water Level Trends in Wells within the Zone II Area



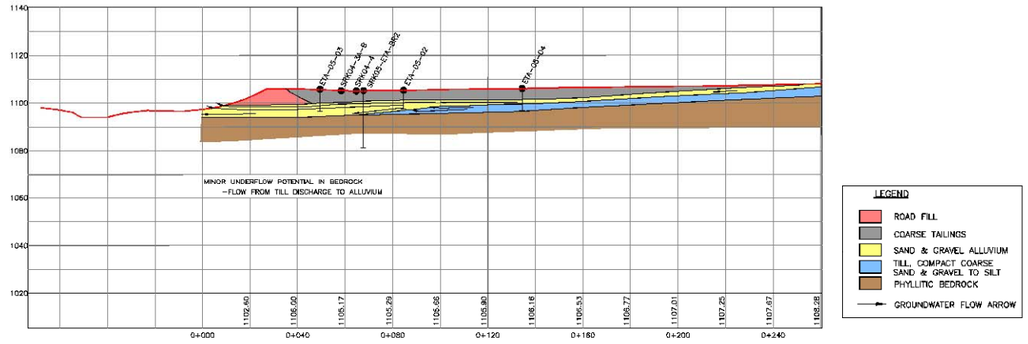
AECOM

ETA Conceptual Cross Section A - A'



Scale 1 : 2,000

ETA Conceptual Cross Section B - B'



Scale 1 : 2,500

Mill Complex

Emergency Tailings Area

SRK05-ETA

ETA-05-5

ETA-05-1

ETA-05-4

SRK04-4

ETA-05-2

SRK05-ETA

ETA-05-3

SRK04-3A,3B

P96-8A,8B

A

A'

B

B'

Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009. Cross-Section: Extracted from Figures 4 & 5 of the draft report,"2005 Seepage Investigation at the Emergency Tailings Area", prepared for D & T Inc. by SRK Consulting, as issued in May 2006.

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N W E S

0 50 100
Meters

1:3,000
UTM Zone 8N, NAD 83

Legend

Wells
- Drive Points
- Conventional Wells
- Multilevel Wells
- Decommissioned Wells

Well Access Routes
- Foot
- ATV
- Truck
- Section Line

- Impoundment (original)
- Watercourse

Contours
- Index Contours (10m)
- Intermediate

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

ETA and Stratigraphy

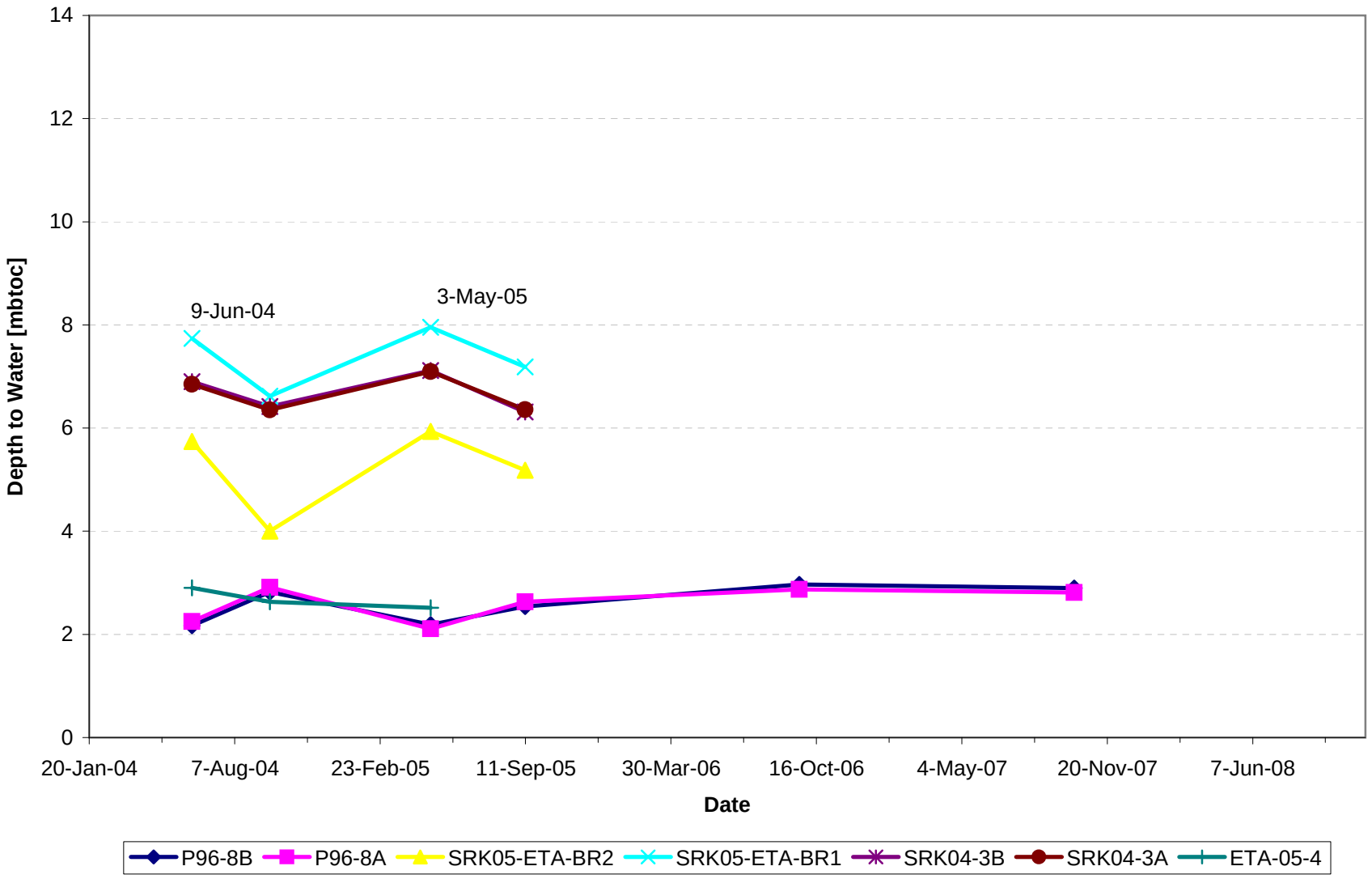
March 2009

AECOM

Figure 3.2-8

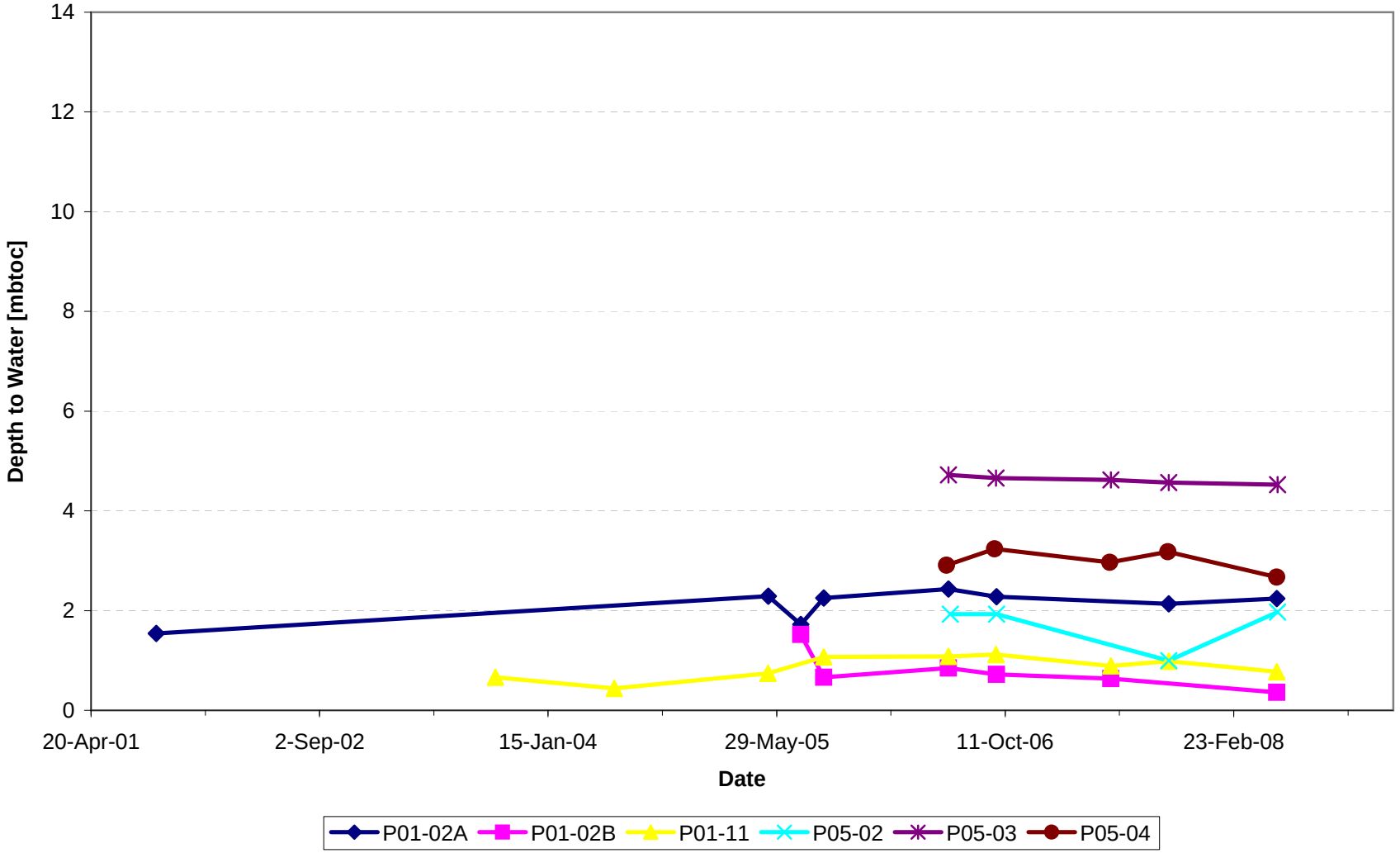
Project: 107403 (80642-1)
Prepared by: MM
Date Revised: April 1, 2009
File Location: E:\GIS\GIS_proj\Y2008\107403_Faro_GWBy1_Baseline\107403_By1_3-2-8_ETA_Strat_09cMar31.mxd

Figure 3.2-9 Water Level Trends in Wells within the ETA

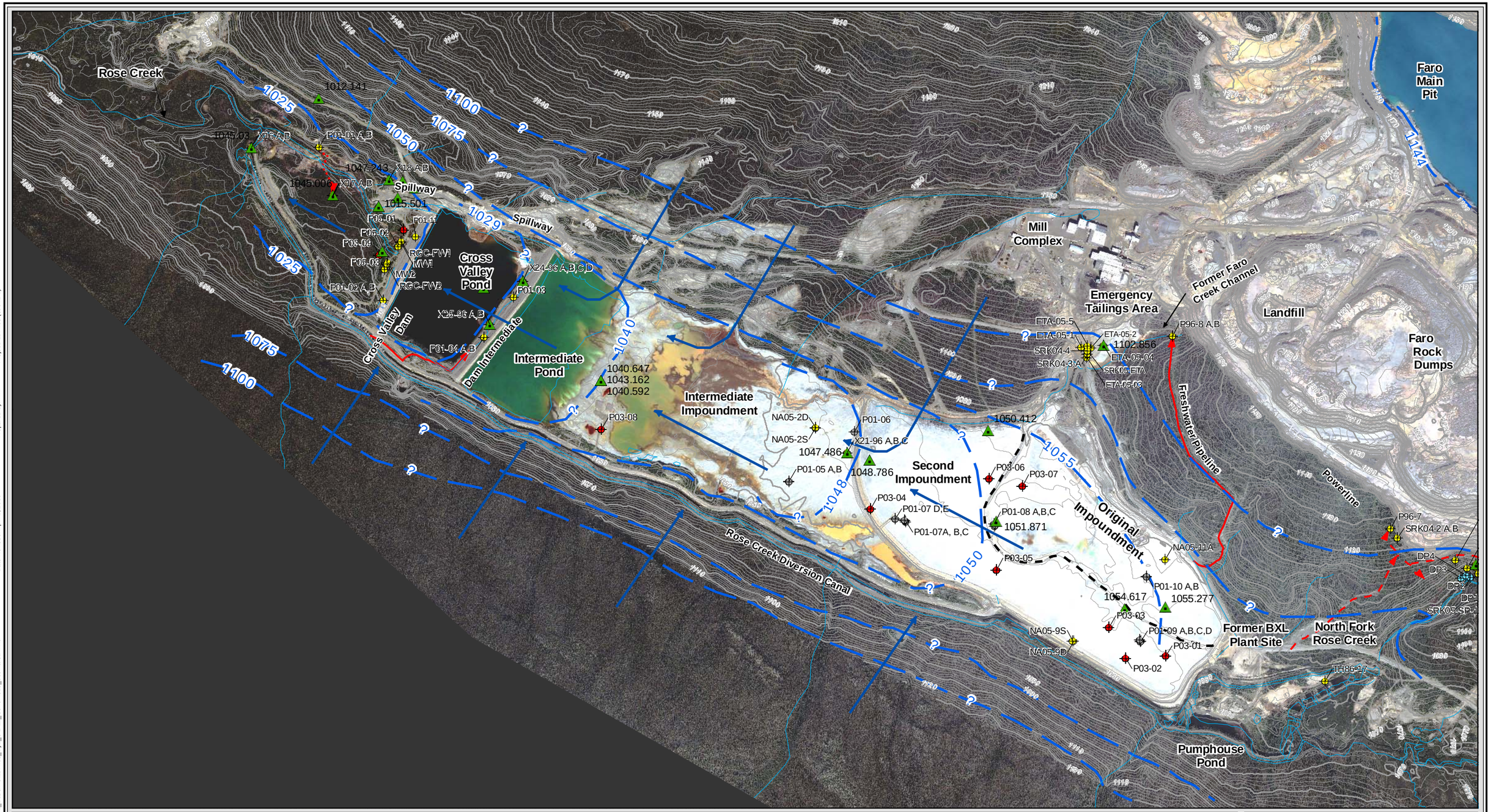


AECOM

Figure 3.2-10 Water Level Trends in Wells Downgradient of the Cross Valley Dam



AECOM



Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009.

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N
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Meters

1:15,000
UTM Zone 8N, NAD 83

Legend

Wells
- Drive Points
- Conventional Wells
- Multilevel Wells
- Decommissioned Wells

1100 Approximate Water Table Elevation [mASL]
Impoundment (original)

Contours
- Index Contours (10m)
- Intermediate

Approximate Water Table Spot Elevation [mASL]
Groundwater Flow Direction
Watercourse

Well Access Routes
- Foot
- ATV
- Truck

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

Conceptual Approximation of Piezometric Surface at the Faro Site, June 2008

March 2009

AECOM

Figure 3.2-11

Date Revised: April 1, 2009
Prepared by: MM
Project: 107403 (80642-1)
File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy1_Baseline\107403_By1_3-2-11_ConcPiezo_09cMar31.mxd

Legend

Wells

- Drive Points
- Conventional Wells
- Multilevel Wells
- Decommissioned Wells
- Section Line A-A'
- Impoundment (original)
- Watercourse

Well Access Routes

- Foot
- ATV
- Truck

Contours

- Index Contours (10m)
- Intermediate

Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009. Cross-Section: Extracted from Figure 2 of the report, "Anvil Range Mining Complex 2005 Seepage Investigation at the Grum Dump Area", prepared for Deloitte & Touche, Inc., by SRK Consulting, as issued in January 2007.

N W E S

0 100 200
Meters

1:7,500

UTM Zone 8N, NAD 83

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

Grum/Vangorda Area and Stratigraphy

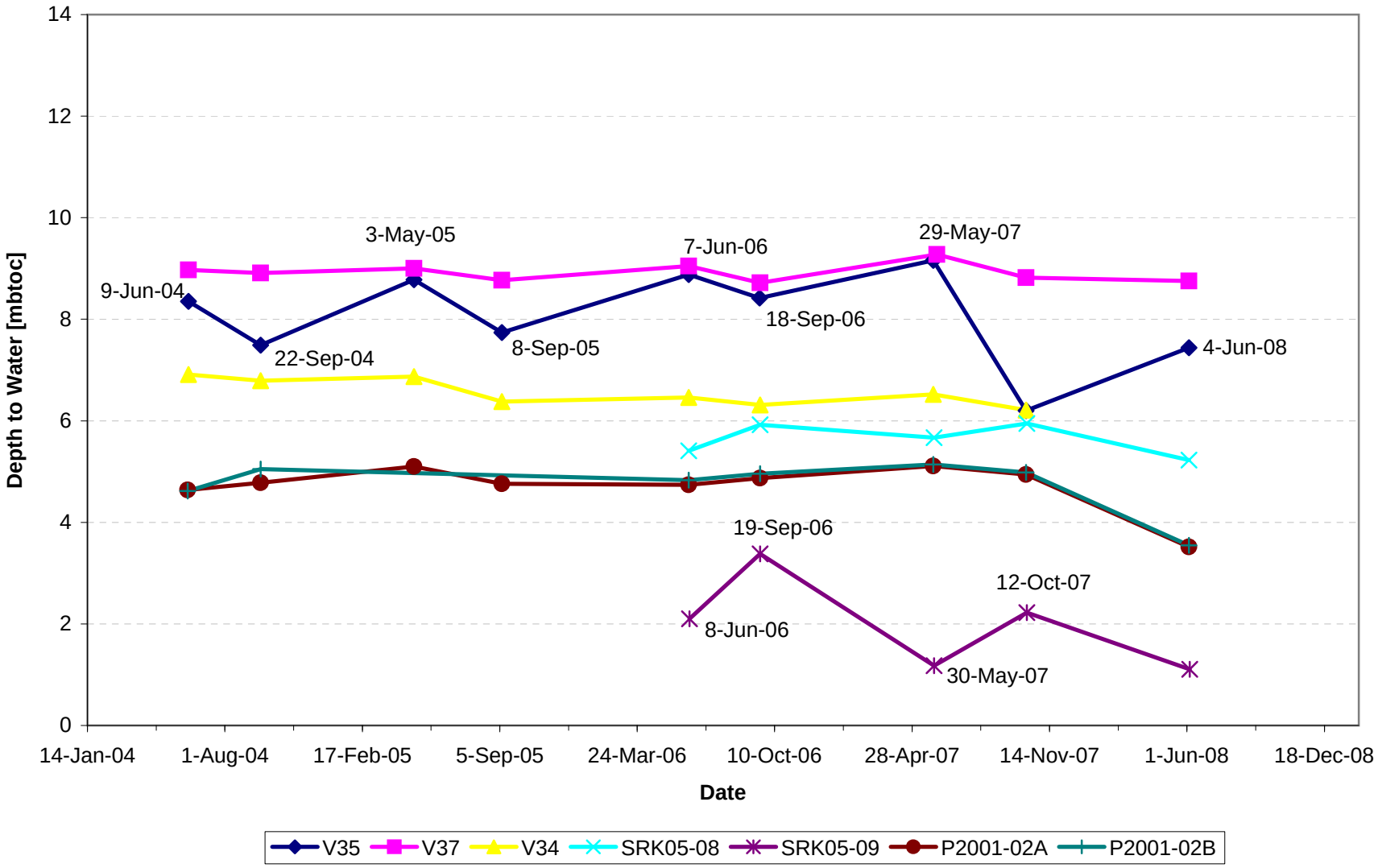
March, 2009

AECOM

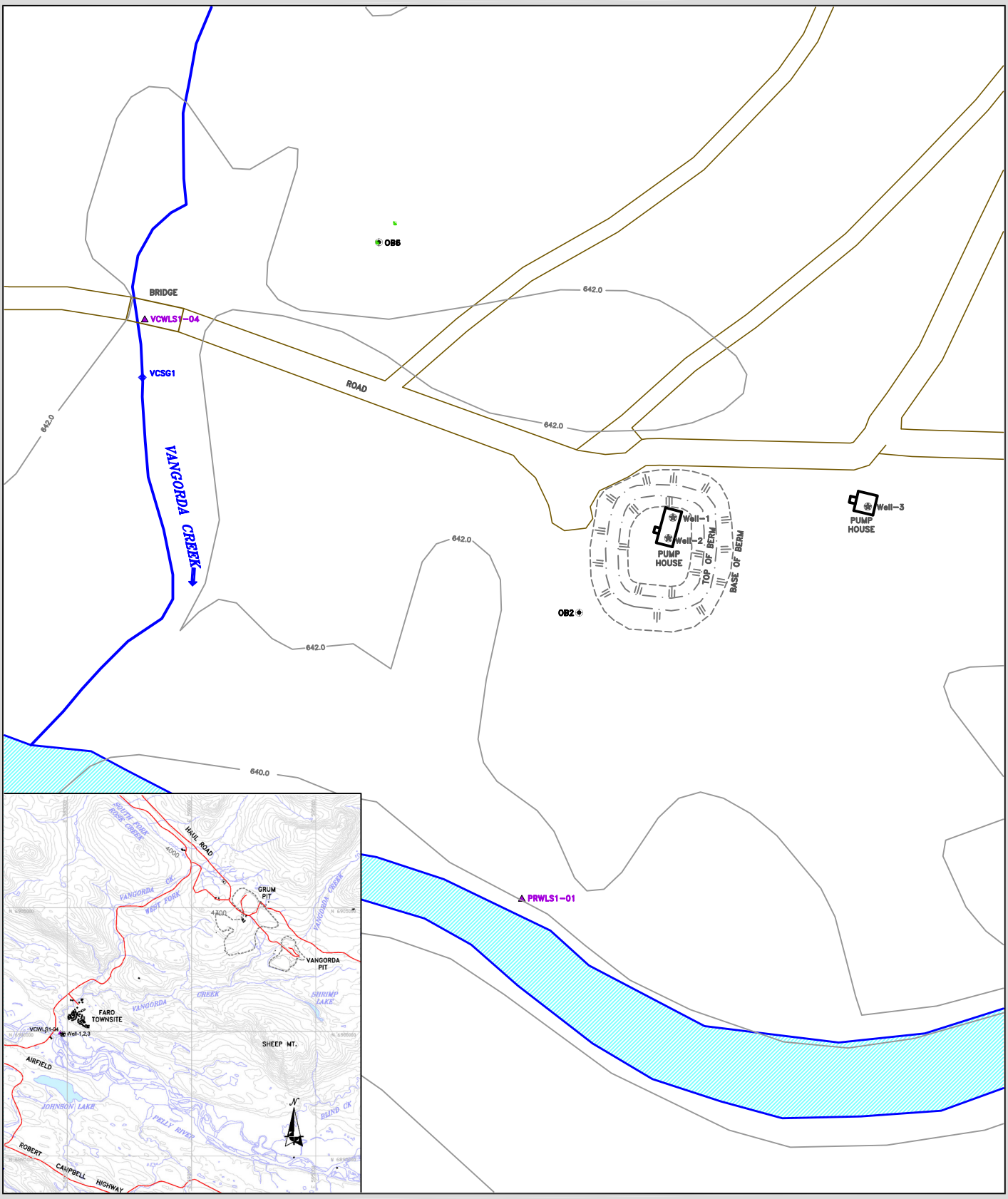
Figure 3.2-12

Project: 107403 (80642-1)
Prepared by: MM
Date Revised: April 1, 2009
File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GW\By1_Baseline\107403_By1_3-2-12_GrumVang_09eMar31.mxd

Figure 3.2-13 Water Level Trends in Wells Downgradient of the Grum/Vangorda Site



AECOM



Digital copy of 1:50,000 topographic maps supplied by SRK Consulting.
Survey conducted in summer 2004 by Yukon Engineering Services.

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0 5 10 20 30 40 m

1 : 1000
UTM Zone 8N, NAD83

File Name: 107403_By1_Fig3-2-14_WaterSupply_09dMar31.dwg
Reviewed by: FKP Prepared by: MM
Date Issued: March, 2009 Project Number: 107403 (80642-1)

Legend

OB6	Observation Well 2" or 6" diameter
Well-2	Town of Faro Water Supply Well
	Abandoned Well

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Closure and Reclamation

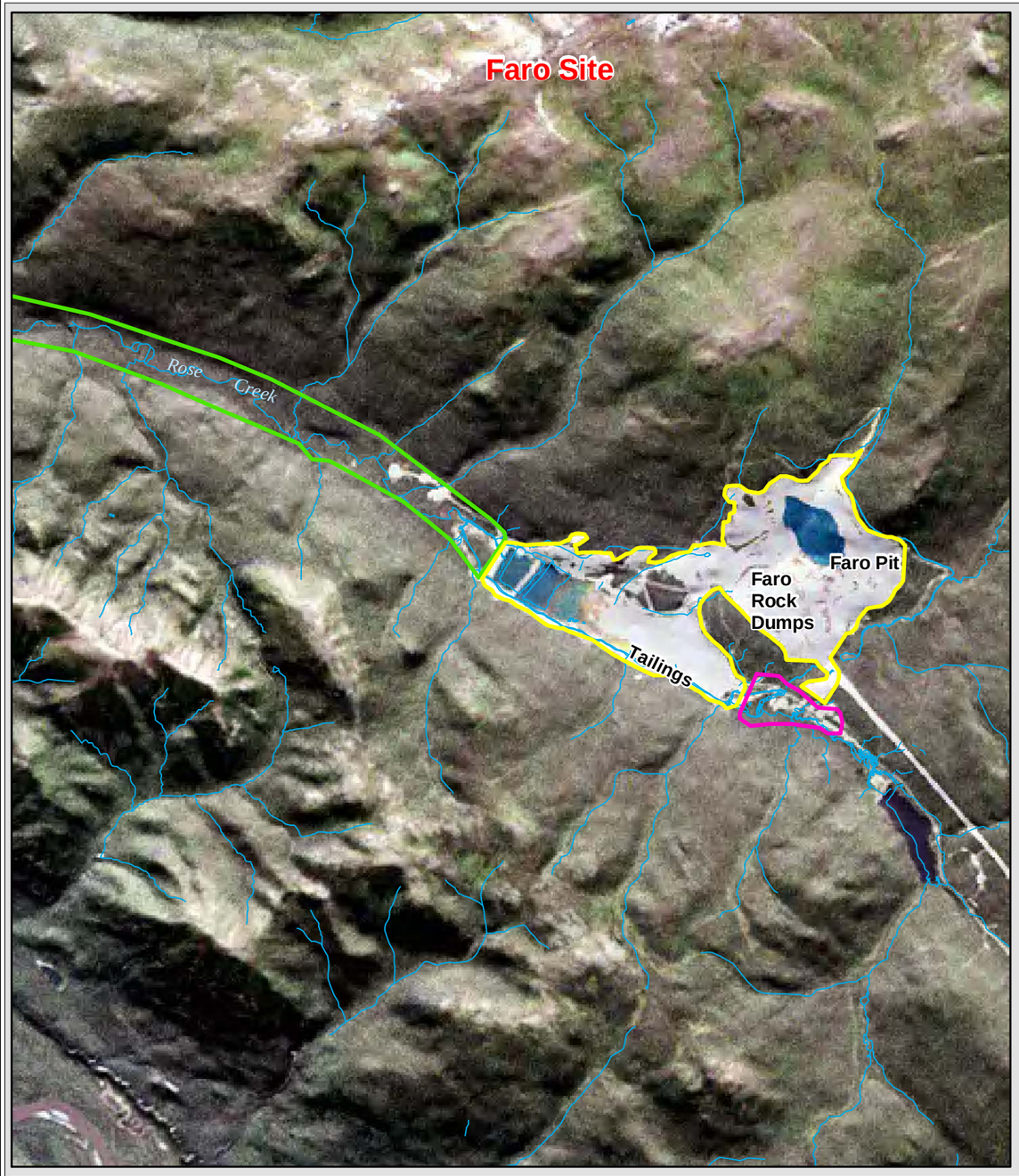
Town of Faro Water Supply and Observation Well Site Plan

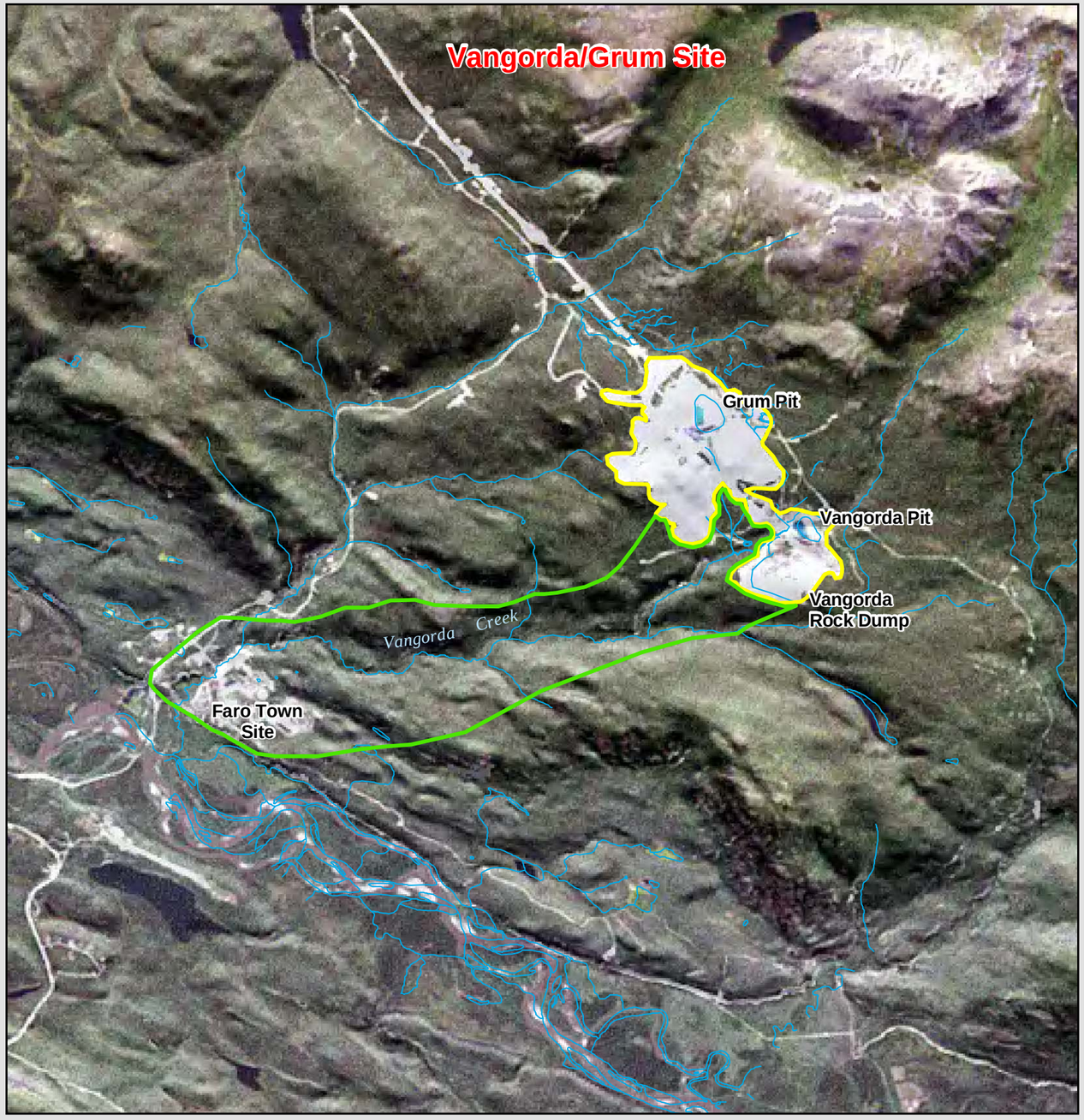
March, 2009

AECOM

Figure 3.2-14

Date Plotted: April 2, 2009 File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GW\By1_Baseline\107403_By1_Fig3-2-14_WaterSupply_09dMar31.dwg





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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N
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Kilometers

1:75,000

UTM Zone 8N, NAD 83

Legend

- Mine Footprint Areas
- Upgradient Areas
- Downgradient Areas
- Watercourse

Faro Mine Closure
Fermeture de la mine Faro

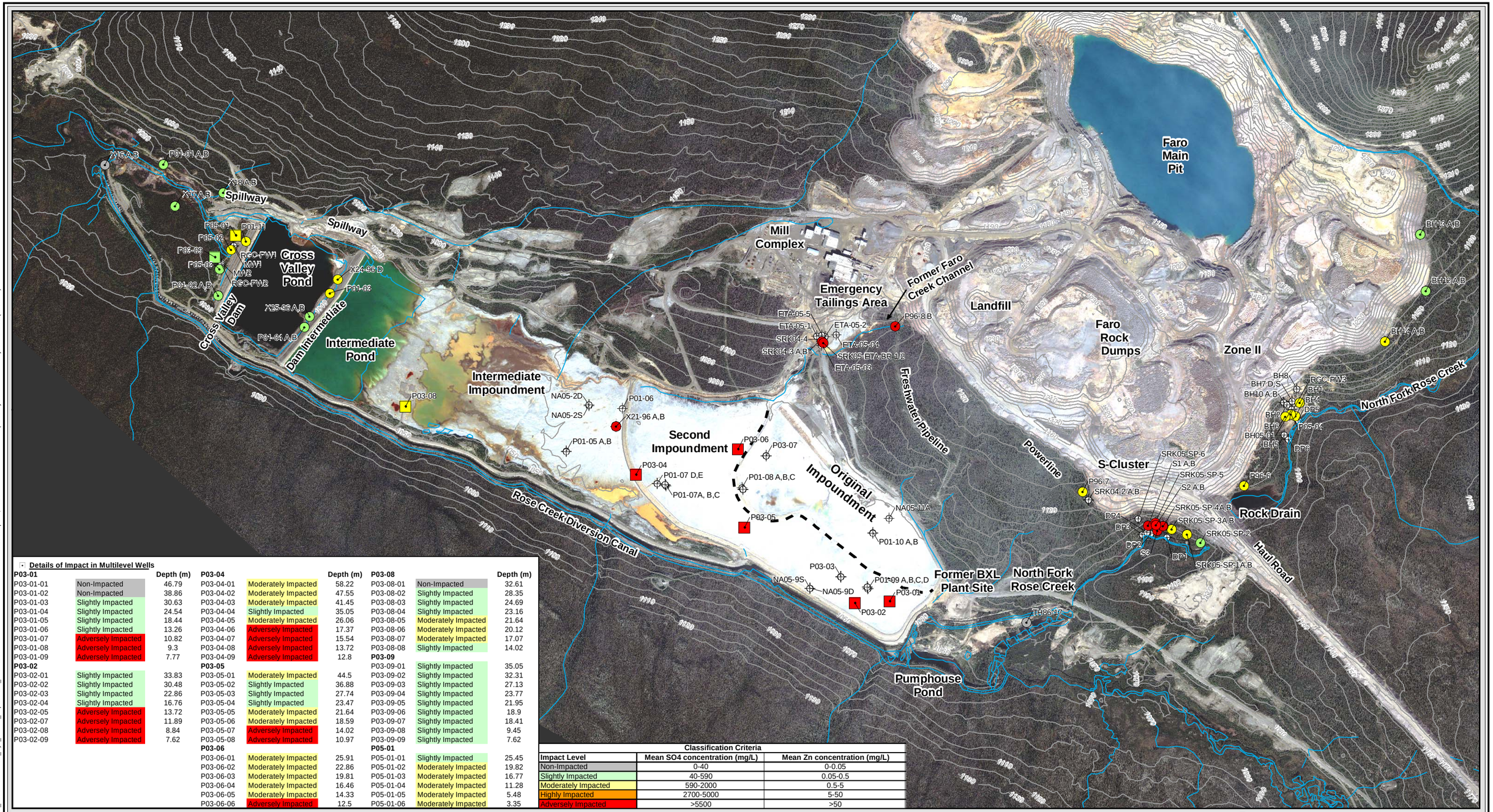
Faro Mine Complex Upgradient, Downgradient and Mine Footprint Areas

March 2009

AECOM

Figure 3.2-15

File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy1_Baseline\107403_By1_3.2-15_UpDownFP_09cMar31.mxd
Date Revised: April 1, 2009
Prepared by: MM
Project: 107403 (80642-1)



Details of Impact in Multilevel Wells

P03-01		Depth (m)	P03-04		Depth (m)	P03-08		Depth (m)
P03-01-01	Non-Impacted	46.79	P03-04-01	Moderately Impacted	58.22	P03-08-01	Non-Impacted	32.61
P03-01-02	Non-Impacted	38.86	P03-04-02	Moderately Impacted	47.55	P03-08-02	Slightly Impacted	28.35
P03-01-03	Slightly Impacted	30.63	P03-04-03	Moderately Impacted	41.45	P03-08-03	Slightly Impacted	24.69
P03-01-04	Slightly Impacted	24.54	P03-04-04	Slightly Impacted	35.05	P03-08-04	Slightly Impacted	23.16
P03-01-05	Slightly Impacted	18.44	P03-04-05	Moderately Impacted	26.06	P03-08-05	Moderately Impacted	21.64
P03-01-06	Slightly Impacted	13.26	P03-04-06	Adversely Impacted	17.37	P03-08-06	Moderately Impacted	20.12
P03-01-07	Adversely Impacted	10.82	P03-04-07	Adversely Impacted	15.54	P03-08-07	Moderately Impacted	17.07
P03-01-08	Adversely Impacted	9.3	P03-04-08	Adversely Impacted	13.72	P03-08-08	Slightly Impacted	14.02
P03-01-09	Adversely Impacted	7.77	P03-04-09	Adversely Impacted	12.8	**P03-09**		
P03-02			**P03-05**			P03-09-01	Slightly Impacted	35.05
P03-02-01	Slightly Impacted	33.83	P03-05-01	Moderately Impacted	44.5	P03-09-02	Slightly Impacted	32.31
P03-02-02	Slightly Impacted	30.48	P03-05-02	Slightly Impacted	36.88	P03-09-03	Slightly Impacted	27.13
P03-02-03	Slightly Impacted	22.86	P03-05-03	Slightly Impacted	27.74	P03-09-04	Slightly Impacted	23.77
P03-02-04	Slightly Impacted	16.76	P03-05-04	Slightly Impacted	23.47	P03-09-05	Slightly Impacted	21.95
P03-02-05	Adversely Impacted	13.72	P03-05-05	Moderately Impacted	21.64	P03-09-06	Slightly Impacted	18.9
P03-02-07	Adversely Impacted	11.89	P03-05-06	Moderately Impacted	18.59	P03-09-07	Slightly Impacted	18.41
P03-02-08	Adversely Impacted	8.84	P03-05-07	Adversely Impacted	14.02	P03-09-08	Slightly Impacted	9.45
P03-02-09	Adversely Impacted	7.62	P03-05-08	Adversely Impacted	10.97	P03-09-09	Slightly Impacted	7.62
			P03-06			**P05-01**		
			P03-06-01	Moderately Impacted	25.91	P05-01-01	Slightly Impacted	25.45
			P03-06-02	Moderately Impacted	22.86	P05-01-02	Moderately Impacted	19.82
			P03-06-03	Moderately Impacted	19.81	P05-01-03	Moderately Impacted	16.77
			P03-06-04	Moderately Impacted	16.46	P05-01-04	Moderately Impacted	11.28
			P03-06-05	Moderately Impacted	14.33	P05-01-05	Moderately Impacted	5.48
			P03-06-06	Adversely Impacted	12.5	P05-01-06	Moderately Impacted	3.35

Classification Criteria		
Impact Level	**Mean SO4 concentration (mg/L)**	**Mean Zn concentration (mg/L)**
Non-Impacted	0-40	0-0.05
Slightly Impacted	40-590	0.05-0.5
Moderately Impacted	590-2000	0.5-5
Highly Impacted	2700-5000	5-50
Adversely Impacted	>5500	>50

Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009.

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N W E S

0 250 500
Meters

1:17,500
UTM Zone 8N, NAD 83

Legend

Monitor Symbols

- Monitor Location: Not Enough Data to be Included
- Monitor Location Data Used in this Assessment
- Multi-level Monitor Location Data Used in this Assessment (See details in table above)

Impact Levels

- Non-Impacted: Below Detection to Low Levels of Zinc, Metals and Sulphate Concentrations
- Slightly Impacted: Low Levels of Zinc, Metals and Sulphate Concentrations
- Moderately Impacted: Moderate Levels of Zinc, Metals and Sulphate Concentrations
- Highly Impacted: High Levels of Zinc, Metals and Sulphate Concentrations
- Adversely Impacted: Very High Levels of Zinc, Metals and Sulphate Concentrations (Screened in Tailings)

Watercourse
Impoundment (original)

Contours
Index Contours (10m)
Intermediate

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

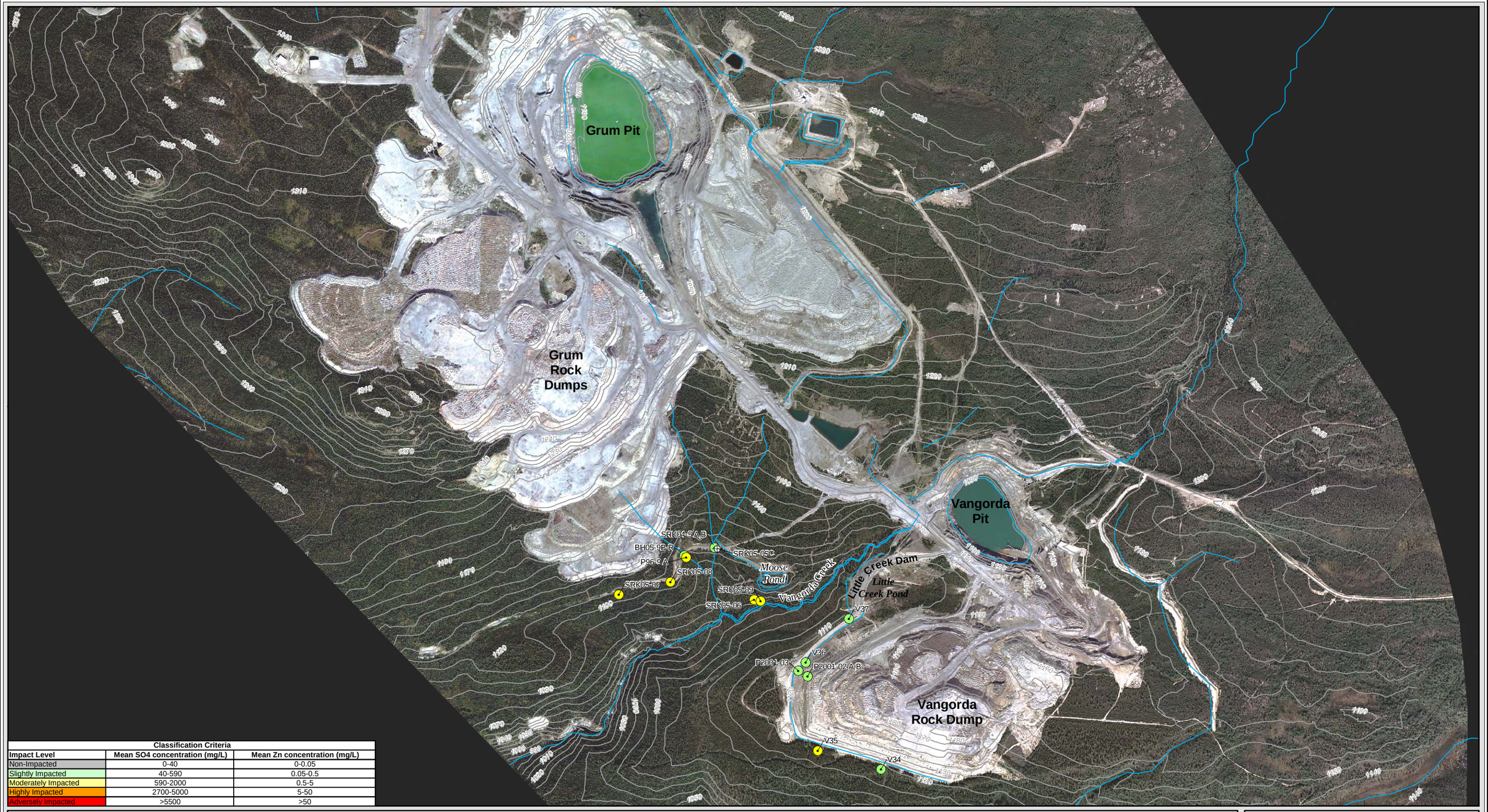
Level of Impact on Groundwater in Monitoring Wells at the Faro Site Based on Zinc Sulphate Concentrations

March 2009

AECOM

Figure 3.2-16

Project: 107403 (80642-1) Prepared by: MM Date Revised: April 1, 2009
File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy1_Baseline\107403_By1_3-2-16_ImpactFaro_09cMar31.mxd



Classification Criteria		
Impact Level	**Mean SO4 concentration (mg/L)**	**Mean Zn concentration (mg/L)**
Non-Impacted	0-40	0-0.05
Slightly Impacted	40-590	0.05-0.5
Moderately Impacted	590-2000	0.5-5
Highly Impacted	2700-5000	5-50
Adversely Impacted	>5500	>50

Imagery from SRK Consulting, flown August 19, 2008.
Well locations and other features, SRK Consulting and AECOM, 2008/2009.

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N W E S

0 250 500
Meters

1:15,000

UTM Zone 8N, NAD 83

Legend

Monitor Symbols

- Monitor Location: Not Enough Data to be Included
- Monitor Location Data Used in this Assessment

Impact Levels

- Non-Impacted: Below Detection to Low Levels of Zinc, Metals and Sulphate Concentrations
- Slightly Impacted: Low Levels of Zinc, Metals and Sulphate Concentrations
- Moderately Impacted: Moderate Levels of Zinc, Metals and Sulphate Concentrations
- Highly Impacted: High Levels of Zinc, Metals and Sulphate Concentrations
- Adversely Impacted: Very High Levels of Zinc, Metals and Sulphate Concentrations (Screened in Tailings)

- Watercourse
- Impoundment (original)

Contours

- Index Contours (10m)
- Intermediate

Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Reclamation Project

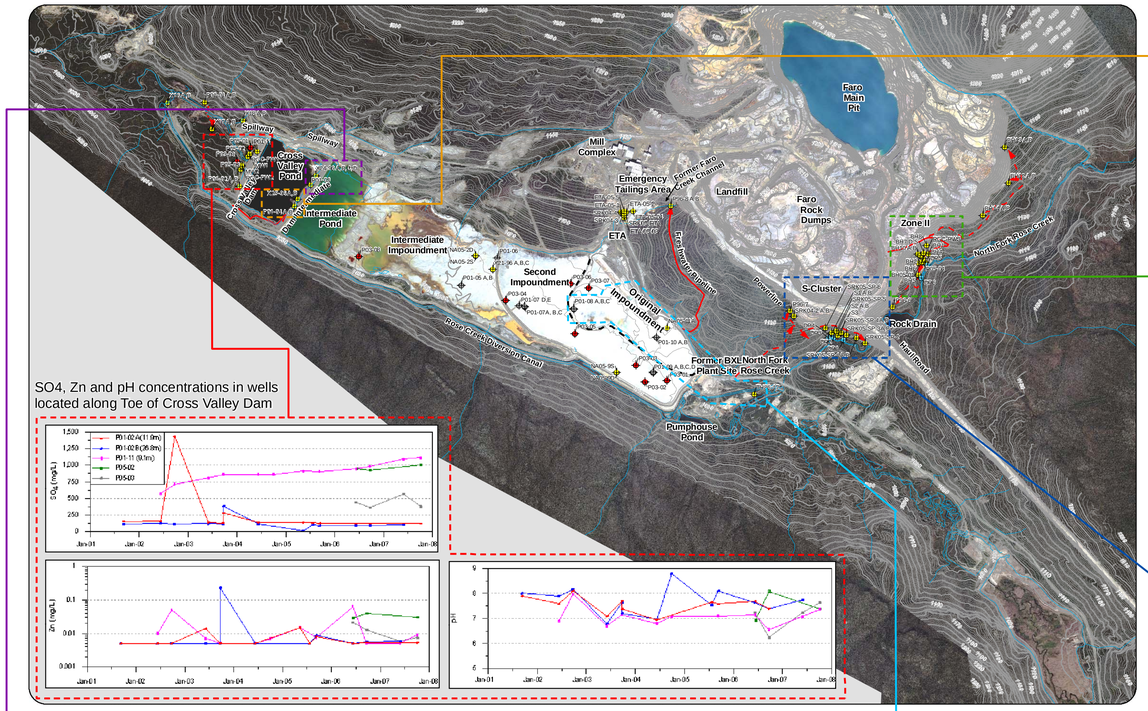
Level of Impact on Groundwater in Monitoring Wells at the Vangorda/Grum Site Based on Zinc Sulphate Concentrations

March 2009

AECOM

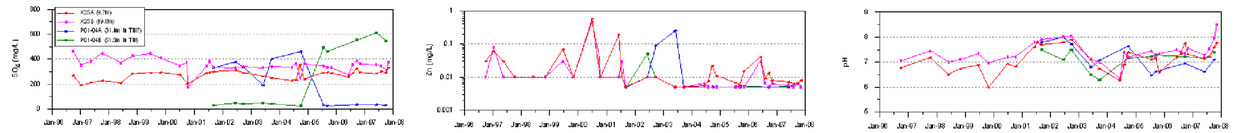
Figure 3.2-17

File Location: E:\GIS\GIS_proj\Y2009\107403_Faro_GWBy1_Baseline\107403_By1_3-2-17_Impact\Vang_09cMar31.mxd Prepared by: MM Project: 107403 (80642-1) Date Revised: April 1, 2009

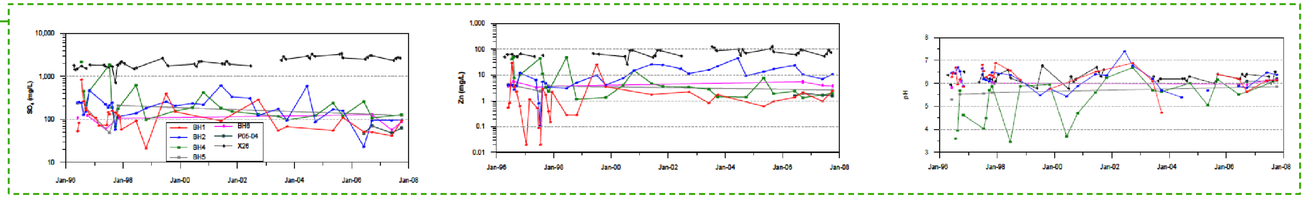


SO4, Zn and pH concentrations in wells located along Toe of Cross Valley Dam

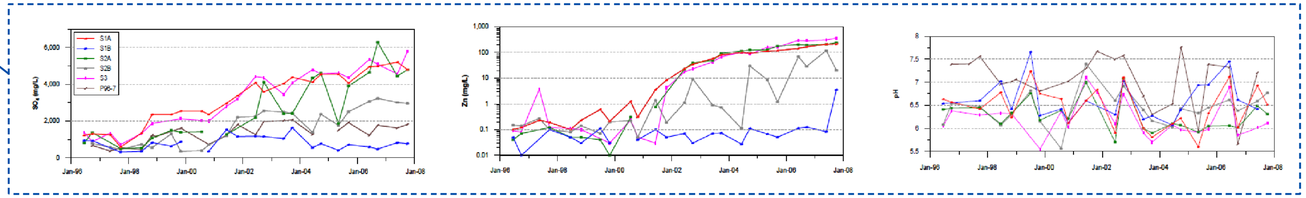
SO4, Zn and pH concentrations in wells located south of Intermediate Dam



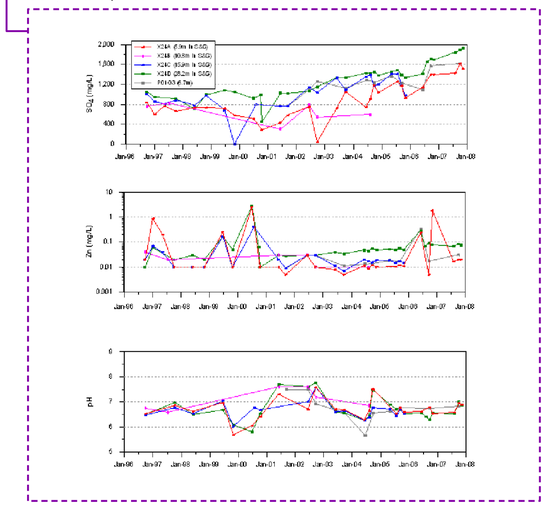
SO4, Zn and pH concentrations in wells located in Zone II



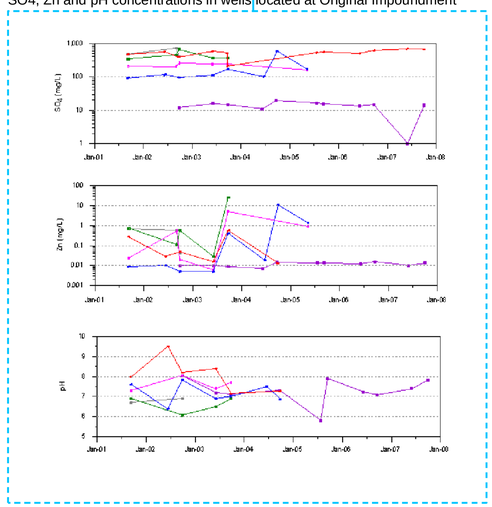
SO4, Zn and pH concentrations in wells located in the S-Cluster



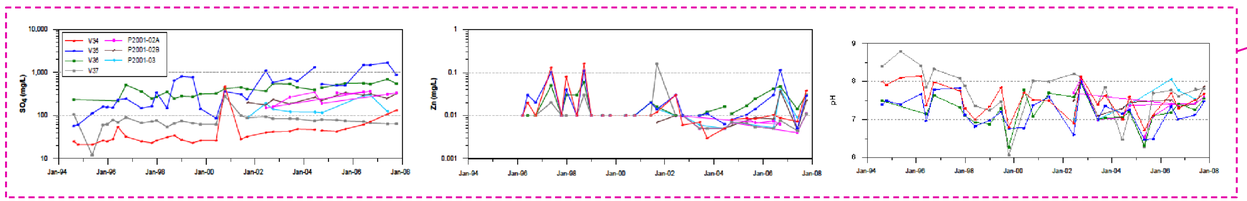
SO4, Zn and pH concentrations in wells located north of Intermediate Dam

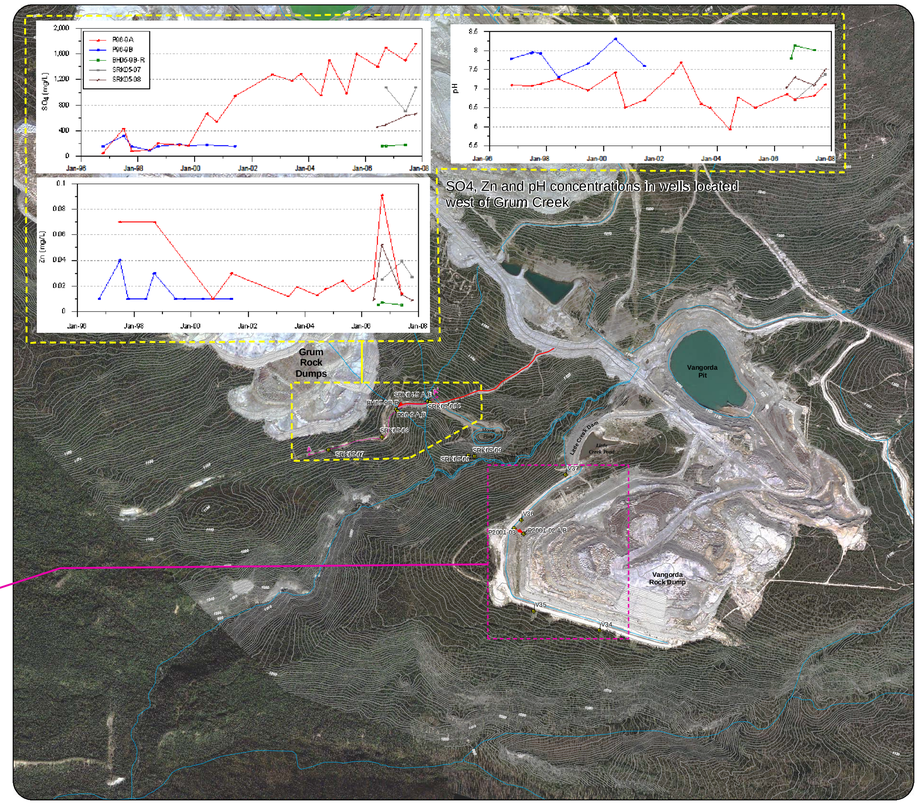


SO4, Zn and pH concentrations in wells located at Original Impoundment



SO4, Zn and pH concentrations in wells located downgradient of Vangorda Rock Dump





Legend

Wells
- Drive Points
- Conventional Wells
- Multilevel Wells
- Decommissioned Wells
- Watercourse

Well Access Routes
- Foot
- ATV
- Truck

Contours
- Index Contours (10m)
- Intermediate

N W E S

Imagery from Orthoshop, Calgary, AB, November 2003. Prepared for SRK Consulting. Based on August 2003 aerial photography. Graphs and all other data, AECOM 2009.

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Faro Mine Closure
Fermeture de la mine Faro

Faro Mine Complex Closure and Remediation Project

Compilation of Temporal Trends of Groundwater Quality: pH, Sulphate and Zinc Concentrations in the Faro and Vangorda/Grum Sites

March 2009

AECOM

Figure 3.2-18

Table 3.2-1. Summary of Hydraulic Conductivity Values

Location	Hydraulic Conductivity (m/s)
S-Cluster Wells (SRK 2006a)	
Shallow Aquifer Unit	$3x10^{-5}$
Low Conductivity Unit	$2x10^{-7}$ to $3x10^{-7}$
Deep Aquifer Unit	$1x10^{-4}$ to $9x10^{-6}$
Bedrock	unknown; anticipated to be lower than overlying aquifer units
Zone II Outwash Area Wells (SRK 2007a)	
Sand and Gravel	$1x10^{-6}$ to $6.3x10^{-4}$
Emergency Tailings Area (SRK 2006b)	
Tailings	unknown; lower than gravel aquifer unit
Primary Aquifer	$2x10^{-4}$
Bedrock	$1.1x10^{-7}$ to $4.3x10^{-8}$

Table 3.2-2. Summary of Relevant Areas for Baseline Groundwater Quality Data

Areas	Rationale for inclusion in the specified Area
Faro Site	
Background:	
Upstream of Rose Creek Tailings Facility and Mine facilities	Background groundwater in upgradient area. Includes deep wells underlying the tailings that have not been impacted by mine wastes.
Mine Footprint:	
Rose Creek Tailings Impoundment	Impacted groundwater in the tailings or in the aquifer underlying the tailings. Potential future Rose Creek Impact.
Emergency Tailings Area (Internal)	Impacted groundwater contributing significant load to Rose Creek Valley aquifer, with future potential to impact Rose Creek.
Northeast and Intermediate Rock Dumps (Internal)	Impacted shallow groundwater down slope at toe of Rock Dumps. Potential future North Fork Rose Creek Impact.
Zone II Outwash Area (Internal)	Impacted shallow groundwater down slope at toe of waste rock in-filled Zone II Pit. Potential future Rose Creek Impact.
S-Cluster Area (Internal)	Impacted shallow groundwater down slope at toe of Rock Dumps. Potential future Rose Creek Impact.
Downgradient:	
Downgradient/Downstream of the Cross Valley Dam (External)	Groundwater downgradient of all currently proposed closure activities. Represents baseline conditions for groundwater leaving the local study area.
Vangorda/Grum Site	
Background:	
Upstream areas	No groundwater data available
Mine Footprint:	
Waste rock areas for Vangorda/Grum pits as well as shallow overburden area immediately downgradient of waste rock.	Impacted shallow groundwater down slope at toe of Rock Dumps. Potential future Vangorda Creek Impact. This area is either underneath or lies in direct path downgradient of waste rock seepage. Groundwater in the area could impact Vangorda Creek.
Downgradient:	
Downgradient of Grum and Vangorda Rock Dumps	Un-impacted wells located further downgradient of toe of the rock dumps represent current baseline conditions downgradient of the source zones (i.e., the rock dumps).
Faro Town Site Water Wells (External)	This location is at the confluence of Vangorda Creek and the Pelly River. Well pumping may induce some recharge from Vangorda Creek. Residents of Faro have expressed concern about potential contamination in the past.

Table 3.2-3. Summary of Criteria Used for Classification of Impact on Groundwater for the Baseline Period (2005-2007)

Impact Level	Mean SO4 Concentration mg/L	Mean Zn Concentration mg/L
Non-Impacted	0-40	0-0.05
Slightly Impacted (Low)	40-590	0.05-0.5
Moderately Impacted	590-2000	0.5-5
Highly Impacted	2700-5000	5-50
Adversely Impacted	>5500	>50

Table 3.2-4. Monitoring Wells Upgradient of the Rose Creek Tailings Facility

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Upstream RC Tailings Facility							
TH86-17	6912478	583957	1.04	~15	No data	1986	No data

Table 3.2-5. Baseline Groundwater Quality at TH86-17

		Physical Parameters					Dissolved Metals													
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Upstream RC Tailings Facility																			
Non-Impacted	N	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Mean	79.3	548	98	7.17	15.0	0.00002	0.0057	0.0004	26.10	0.00002	0.00019	0.0004	0.001	0.241	0.005	0.0019	0.0004	0.014
	Median	74.4	171	98	7.2	14.7	0.00001	0.0051	0.00025	25	0.000018	0.0002	0.0005	0.0005	0.206	0.01	0.003	0.00025	0.0136
	Minimum	73.8	166	91	5.81	13.6	< 0.00002	0.0051	< 0.0005	23.4	< 0.000017	< 0.0003	< 0.0005	< 0.001	0.07	0.00436	< 0.001	< 0.0005	0.0123
	Maximum	88.1	2060	105	7.9	16.6	< 0.00005	< 0.01	< 0.001	30.6	< 0.00005	< 0.0005	< 0.001	0.0013	0.477	< 0.01	< 0.005	< 0.001	0.0156
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)		**-**	**-**		**1000**	**0.015** [A1]	**-**	**0.050**	**-**	**0.0005** [A2]	**0.009**	**0.01** [B1] **- 0.09** [B2]	**0.04** [A3]	**-**	**-**	**0.65** [A4]	**0.05** [A5]	**0.15** [A6]	

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6)
B2: Standard is specific to chromium (+3)
Exceeds CSR.

Table 3.2-6. Monitoring Wells in the Emergency Tailings Area

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Emergency Tailings Area								
Adversely Impacted	P96-8B	6913898	583328	0.7	5.5	8.52	1996	Alluvium
	SRK04-3A	6913824	582977	0.56	10.4	11.9	2004	Tailings /Alluvium
	SRK04-3B	6913824	582977	0.65	5.5	7	2004	Alluvium / BR
	SRK05-ETA-BR1	6913846	582972	0.66	9	12	2005	Alluvium
Highly Impacted	SRK05-ETA-BR2	6913825	582987	0.64	14.6	18.9	2005	BR (schist)

Table 3.2-7. Emergency Tailings Area Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Emergency Tailings Area																			
Adversely Impacted	N	16	16	2	15	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	Mean	85	7317	3925	5.77	6940	0.00111	1.973	0.027	423	0.0345	0.5889	0.0461	0.0484	1557.0	70.51	0.8421	0.0527	409.5
	Median	80	6575	3925	5.80	5625	0.001	1.095	0.025	423	0.0224	0.5480	0.05	0.05	778.00	69.25	0.7650	0.025	371.5
	Minimum	< 2	4190	3770	4.13	3220	< 0.001	< 0.25	< 0.025	390	< 0.00085	0.268	< 0.025	< 0.05	< 0.06	49	0.5	< 0.025	173
	Maximum	214	15100	4080	7.05	18500	< 0.005	6.3	< 0.1	456	0.13	1.69	< 0.2	< 0.2	7700	90.7	1.4	0.335	754
Highly Impacted	N	4	4		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Mean	119	2070		7.05	1330	0.00008	0.017	0.001	402	0.0001	0.0154	0.0025	0.0025	30.13	3.27	0.0225	0.0019	9.71
	Median	119	2185		6.97	1320	0.00005	0.0125	0.00125	401	0.0000677	0.01535	0.0025	0.0025	31.35	3.04	0.0215	0.00125	9.74
	Minimum	112	1660		6.82	1270	< 0.0001	< 0.025	< 0.0025	360	< 0.000085	0.0075	< 0.005	< 0.005	12.9	1.85	0.0128	< 0.0025	4.06
	Maximum	128	2250		7.43	1410	0.00016	0.031	< 0.0025	444	0.000132	0.0235	< 0.005	< 0.005	44.9	5.14	0.0342	0.0037	15.3
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)				**-**	**-**	**1000**	**0.015** [A1]	**-**	**0.050**	**-**	**0.0006** [A2]	**0.009**	**0.01** [B1] **-0.09** [B2]	**0.09** [A3]	**-**	**-**	**1.5** [A4]	**0.16** [A5]	**2.4** [A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6)
B2: Standard is specific to chromium (+3)
Exceeds CSR.

Table 3.2-8. Monitoring Wells in the S-Cluster Area

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
S-cluster Area								
Adversely Impacted	S1A	6912942	584539	1.34	9.2	12.2	1989	BR (phyllite)
	S2A	6912944	584577	1.44	9.2	12.2	1989	BR (phyllite)
	S3	6912918	584585	1.12	2.6	5.6	1989	Till
	SRK05-SP-4B	6912939	584611	0.76	0.6	3.5	2005	Overburden
	SRK05-SP-5	6912956	584576	0.91	9.4	12.5	2005	Overburden / BR
Highly Impacted	S2B	6912944	584577	1.77	3.7	6.7	1989	Till
Moderately Impacted	P96-7	6913105	584225	0.68	6.26	9.24	1996	Overburden / BR
	S1B	6912942	584539	1.16	1.3	4.3	1989	Till
	SRK05-SP-1A	6912901	584727	0.54	13.7	19.2	2005	Overburden / BR
	SRK05-SP-3A	6912924	584651	0.85	17.4	21.9	2005	Overburden
	SRK05-SP-3B	6912924	584652	0.66	8.3	11.4	2005	Overburden
	SRK05-SP-4A	6912939	584612	0.69	16.5	21.0	2005	Overburden / BR
Slightly Impacted	SRK05-SP-1B	6912901	584726	0.66	9.0	12.3	2005	Overburden
	SRK05-SP-2	6912861	584791	0.44	7.9	11.0	2005	Alluvium / BR

Table 3.2-9. S-Cluster Area Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
S-Cluster Wells																			
Adversely Impacted	N	22	19	6	21	22	22	22	22	22	22	22	22	22	22	22	22	22	22
	Mean	211	5787	4295	6.11	4611	0.00084	0.327	0.019	518.0	0.0242	0.0233	0.0282	0.0316	1.18	85.42	1.7800	0.0192	234.73
	Median	214	5930	4385	6.05	4690	0.001	0.25	0.025	504	0.01825	0.0183	0.025	0.025	0.431	80.85	1.7250	0.025	211.50
	Minimum	171	4340	3760	5.6	1860	< 0.0004	< 0.1	< 0.01	372	< 0.0025	0.018	< 0.02	< 0.02	< 0.06	45.2	1	< 0.01	113
	Maximum	252	6800	4700	6.93	6280	< 0.0025	2.69	< 0.05	609	0.0916	0.041	< 0.1	< 0.1	5.59	132	2.97	< 0.05	447
Highly Impacted	N	6	5	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Mean	118	4080	1985	6.52	2757	0.00020	0.081	0.005	692.3	0.0033	0.0137	0.0067	0.0075	122.10	25.94	0.2915	0.0046	36.27
	Median	137	4330	1985	6.52	2985	0.0002	0.05	0.005	670.5	0.00167	0.0122	0.0075	0.0075	109	23.35	0.1865	0.005	24.75
	Minimum	16	3370	1880	6.33	1760	< 0.0002	< 0.05	< 0.005	501	< 0.0005	0.0053	< 0.005	< 0.01	71	8.55	< 0.05	< 0.005	1.19
	Maximum	199	4640	2090	6.77	3230	< 0.0005	0.26	< 0.01	927	0.00932	0.0273	< 0.02	< 0.02	193	55.2	0.754	< 0.01	89.9
Moderately Impacted	N	24	22	4	18	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Mean	231	1510	1281	6.40	729	0.00006	0.044	0.002	256.2	0.0002	0.0044	0.0020	0.0023	10.70	0.79	0.0159	0.0014	0.68
	Median	254	1250	1298	6.04	466	0.00005	0.027	0.0023	169.5	0.000083	0.00316	0.00125	0.0025	1.257	0.87	0.0132	0.00125	0.75
	Minimum	26	723	447	5.66	173	< 0.00004	< 0.01	< 0.001	123	< 0.000034	< 0.0015	< 0.002	< 0.002	< 0.03	< 0.003	< 0.005	< 0.001	0.0078
	Maximum	332	2940	2080	7.45	1910	< 0.0005	0.168	< 0.01	605	0.000784	0.0262	< 0.01	< 0.01	50.1	2.92	0.0535	< 0.01	3.5
Slightly Impacted	N	6	6		4	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Mean	222	647		6.27	144	0.00002	0.013	0.005	98.4	0.0002	0.0032	0.0008	0.0008	4.84	0.84	0.0078	0.0004	0.19
	Median	176	642		6.22	131	0.000015	0.0137	0.003225	97.75	0.0001335	0.00309	0.00075	0.00075	3.87	0.86	0.0073	0.000375	0.17
	Minimum	129	270		6.1	34	< 0.00002	< 0.01	< 0.0005	44.4	0.000093	0.00209	< 0.001	< 0.001	< 0.03	0.722	0.0034	< 0.0005	0.105
	Maximum	365	1050		6.52	276	< 0.00004	0.0206	0.0113	155	0.000312	0.00486	< 0.002	< 0.002	12.8	0.93	0.0145	< 0.001	0.278
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)				**-**	**-**	**1000**	**0.015** [A1]	**-**	**0.050**	**-**	**0.0006** [A2]	**0.009**	**0.01** [B1] **-** **0.09** [B2]	**0.09** [A3]	**-**	**-**	**1.5** [A4]	**0.16** [A5]	**1.65-2.4** [A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-10. Monitoring Wells in the Zone II Outwash Area

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Zone II Outwash Area								
Moderately Impacted	BH1	6913532	585267	0.07	No data	No data	1992	N/A
	BH4	6913467	585247	0.7	No data	No data	1992	N/A
	BH6	6913466	585198	0.75	4.72	6.25	1994	Alluvium
	P05-04	6913475	585224	0.66	2.19	6.34	2005	Alluvium

Table 3.2-11. Monitoring Wells in the Zone II Outwash Area

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Zone II Outwash Area								
Moderately Impacted	BH1	6913532	585267	0.07	No data	No data	1992	N/A
	BH4	6913467	585247	0.7	No data	No data	1992	N/A
	BH6	6913466	585198	0.75	4.72	6.25	1994	Alluvium
	P05-04	6913475	585224	0.66	2.19	6.34	2005	Alluvium

Table 3.2-12. Zone II Outwash Area Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Zone II Outwash Area																			
Moderately Impacted	N	17	15	4	16	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Mean	130	404	270	5.98	101	0.00002	0.6993	0.0003	63.85	0.00397	0.01366	0.0005	0.015	1.055	0.468	0.0197	0.0014	2.474
	Median	136	406	280	6.1	88	0.00001	0.0652	0.00025	63.3	0.00322	0.004	0.0005	0.0044	0.015	0.23	0.013	0.00078	1.94
	Minimum	22	329	225	5.05	41	< 0.00002	0.0341	< 0.0005	48	0.00128	< 0.0003	< 0.0005	< 0.001	< 0.03	0.00196	< 0.005	< 0.0005	0.615
	Maximum	165	509	295	6.4	261	< 0.0001	9.22	< 0.002	85.9	0.0131	0.0603	< 0.001	0.182	8.36	1.94	0.068	0.00401	7.66
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)				-	-	**1000**	**0.015** [A1]	-	**0.050**	-	**0.0006** [A2]	**0.009**	**0.01** [B1]**-0.09** [B2]	**0.009** [A3]	-	-	**1.5** [A4]	**0.16** [A5]	**1.65** [A6]

N: number of samples used for calculations.
A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.
B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-13. Monitoring Wells at the Toe of Northeast Dumps and Intermediate Dump

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Toe of Northeast Dumps								
Moderately Impacted	BH14A	6913826	585676	0.12	4.72	6.25	1994	BR (weathered)
	BH14B	6913826	585676	0.78	7.77	9.3	1994	BR (quartz/diorite)
Slightly Impacted	BH12A	6914068	585871	2.38	1.53	3.05	1994	BR (weathered)
	BH12B	6914068	585871	2.43	6.1	8.23	1994	BR (phyllite/schist)
	BH13A	6914339	585844	0.75	2.29	3.81	1994	Aquifer
	BH13B	6914339	585844	0.54	6.71	8.23	1994	BR (phyllite/schist)
Toe of Intermediate Dumps								
Moderately Impacted	P96-6	6913133	584999	0.7	18.07	20.12	1996	Alluvium

Table 3.2-14. Baseline Groundwater Quality at Northeast and Intermediate Faro Rock Dumps

Parameter		Physical Parameters				Dissolved Metals													
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Toe of NE Dumps (NFRC)																			
Moderately Impacted	N	9	8	3	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	Mean	379	3398	2280	6.84	1787	0.00013	0.0522	0.0025	562.67	0.00018	0.00139	0.003	0.004	0.017	0.003	0.0083	0.0028	0.263
	Median	358	3455	2320	7.0	1760	0.0001	0.025	0.0025	568	0.000136	0.0015	0.0025	0.005	0.015	0.00	0.005	0.0025	0.224
	Minimum	312	2870	2060	6.16	1550	< 0.0001	< 0.025	< 0.0025	506	0.000105	< 0.0015	< 0.0025	< 0.005	< 0.03	< 0.0015	< 0.005	< 0.0025	0.019
	Maximum	441	3790	2460	7.22	2040	< 0.0005	0.27	< 0.01	612	< 0.0005	< 0.005	< 0.01	< 0.01	< 0.06	< 0.02	< 0.05	< 0.01	0.59
Slightly Impacted	N	16	16	7	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	Mean	169	1221	559	7.22	344	0.00004	0.0331	0.0010	167.71	0.00027	0.00069	0.001	0.003	0.185	0.038	0.0102	0.0011	0.181
	Median	187	1025	520	7.3	311	0.00005	0.01	0.001	137.0	0.000226	0.0005	0.00075	0.00215	0.015	0.00	0.009	0.001	0.169
	Minimum	92	528	362	6.11	133	< 0.00002	< 0.01	0.00055	45.3	0.000067	< 0.0006	< 0.001	0.0019	< 0.03	0.0018	0.0011	< 0.001	0.008
	Maximum	230	2550	742	7.82	623	< 0.0002	0.201	< 0.005	408	0.00095	< 0.003	< 0.01	< 0.01	2.24	0.43	0.031	< 0.005	0.683
Toe of Intermediate Dumps																			
Moderately Impacted	N	5	4	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Mean	339	1026	640	6.22	277	0.00003	0.0206	0.0008	162.80	0.00021	0.00043	0.001	0.001	0.042	0.042	0.0155	0.0008	0.567
	Median	341	997	640	6.2	268	0.00002	0.005	0.0005	169	0.00022	0.0003	0.001	0.001	0.044	0.03	0.018	0.0005	0.727
	Minimum	271	900	640	5.24	264	< 0.00004	< 0.01	< 0.001	138	0.000085	< 0.0006	< 0.001	< 0.002	< 0.03	0.0022	0.0077	< 0.001	0.219
	Maximum	432	1210	640	6.78	298	< 0.0001	0.078	< 0.0025	185	0.000334	< 0.0015	< 0.005	< 0.005	0.068	0.092	0.0225	< 0.0025	0.84
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)				**-**	**-**	**1000**	**0.015** [A1]	**-**	**0.050**	**-**	**0.0006** [A2]	**0.009**	**0.01** [B1]**-0.09** [B2]	**0.09** [A3]	**-**	**-**	**1.5** [A4]	**0.16** [A5]	**2.4** [A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-15. Monitoring Wells in the Second Impoundment

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Second Impoundment								
Non-Impacted	P03-01-01	6912580	583301	*0.526*	46.48	46.79	2003	Alluvium
	P03-01-02	6912580	583301	*0.526*	38.56	38.86	2003	Alluvium
Slightly Impacted	P03-01-03	6912580	583301	*0.526*	30.33	30.63	2003	Alluvium
	P03-01-05	6912580	583301	*0.526*	18.14	18.44	2003	Alluvium
	P03-02-01	6912572	583135	*0.692*	33.53	33.83	2003	Alluvium
	P03-02-02	6912572	583135	*0.692*	30.18	30.48	2003	Alluvium
	P03-02-03	6912572	583135	*0.692*	22.56	22.86	2003	Alluvium
	P03-04-04	6913186	582085	*0.777*	34.75	35.05	2003	Alluvium
	P03-05-02	6912934	582605	*0.843*	36.58	36.88	2003	Alluvium
	P03-05-03	6912934	582605	*0.843*	27.43	27.74	2003	Alluvium
	P03-05-04	6912934	582605	*0.843*	23.16	23.47	2003	Alluvium
Moderately Impacted	P03-01-04	6912580	583301	*0.526*	24.23	24.54	2003	Alluvium
	P03-01-06	6912580	583301	*0.526*	12.95	13.26	2003	Alluvium
	P03-02-04	6912572	583135	*0.692*	16.46	16.76	2003	Alluvium
	P03-04-01	6913186	582085	*0.777*	57.91	58.22	2003	Alluvium
	P03-04-02	6913186	582085	*0.777*	47.24	47.55	2003	Alluvium
	P03-04-03	6913186	582085	*0.777*	41.15	41.45	2003	Alluvium
	P03-04-05	6913186	582085	*0.777*	25.76	26.06	2003	Alluvium
	P03-05-01	6912934	582605	*0.843*	44.20	44.50	2003	Alluvium
	P03-05-05	6912934	582605	*0.843*	21.34	21.64	2003	Tailings
	P03-05-06	6912934	582605	*0.843*	18.29	18.59	2003	Tailings
	P03-06-01	6913309	582573	*0.867*	25.60	25.91	2003	Alluvium
	P03-06-02	6913309	582573	*0.867*	22.56	22.86	2003	Alluvium
	P03-06-03	6913309	582573	*0.867*	19.51	19.81	2003	Alluvium
	P03-06-04	6913309	582573	*0.867*	16.15	16.46	2003	Alluvium
Highly Impacted	P03-06-05	6913309	582573	*0.867*	14.02	14.33	2003	Alluvium
Adversely Impacted	P03-01-07	6912580	583301	*0.526*	10.52	10.82	2003	Alluvium
	P03-01-08	6912580	583301	*0.526*	8.99	9.30	2003	Tailings
	P03-01-09	6912580	583301	*0.526*	7.47	7.77	2003	Tailings
	P03-02-05	6912572	583135	*0.692*	13.41	13.72	2003	Alluvium
	P03-02-07	6912572	583135	*0.692*	11.58	11.89	2003	Tailings
	P03-02-08	6912572	583135	*0.692*	8.53	8.84	2003	Tailings
	P03-02-09	6912572	583135	*0.692*	7.32	7.62	2003	Tailings
	P03-04-06	6913186	582085	*0.777*	17.07	17.37	2003	Alluvium
	P03-04-07	6913186	582085	*0.777*	15.24	15.54	2003	Alluvium
	P03-04-08	6913186	582085	*0.777*	13.41	13.72	2003	Tailings
	P03-04-09	6913186	582085	*0.777*	12.50	12.80	2003	Tailings
	P03-05-07	6912934	582605	*0.843*	13.72	14.02	2003	Tailings
	P03-05-08	6912934	582605	*0.843*	10.67	10.97	2003	Tailings
	P03-06-06	6913309	582573	*0.867*	12.19	12.50	2003	Tailings

Table 3.2-16. Second Impoundment Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Second Impoundment																			
Adversely Impacted	N	83	83	30	77	83	84	84	84	84	84	84	84	84	84	84	84	84	84
	Mean	19	11112	2181	5.95	13589	0.00274	0.794	0.061	385.6	0.0027	0.0482	0.0572	0.0742	6295.8	56.95	0.2270	0.3628	419.23
	Median	13	8230	2060	6.13	7790	0.001	0.25	0.025	399.5	0.00085	0.015	0.025	0.025	3385	30.90	0.1065	0.025	4.28
	Minimum	< 1	3810	783	3.26	3840	< 0.0001	< 0.02	< 0.002	94.3	< 0.0001	< 0.001	< 0.001	< 0.002	238	13.7	< 0.01	0.0099	0.0065
	Maximum	129	35600	4390	7.56	58100	< 0.1	17.8	< 2	573	< 0.1	0.792	< 1	< 1	27100	391	< 5	5.9	4040
Highly Impacted	N	6	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Mean	19	2130	1281	6.68	1330	0.00049	0.122	0.014	128.2	0.0005	0.0295	0.0076	0.0118	253.00	36.18	0.1355	0.0132	66.20
	Median	18.9	1820	1281	6.64	1109	0.000075	0.01875	0.0072	124	0.0000675	0.01525	0.00375	0.00375	234	28.00	0.0582	0.00375	38.50
	Minimum	< 1	1180	452	6.52	613	< 0.0001	< 0.02	0.0059	81.1	< 0.000085	0.0019	< 0.001	< 0.002	180	8.46	< 0.01	< 0.0025	4.49
	Maximum	32	3730	2110	6.91	2740	< 0.005	< 1	< 0.1	168	< 0.005	0.078	< 0.05	< 0.1	353	82.2	0.54	< 0.1	242
Moderately Impacted	N	89	89	32	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89
	Mean	119	1534	723	6.64	865	0.00015	0.034	0.005	220.6	0.0018	0.0631	0.0028	0.0036	39.85	19.44	0.1029	0.0242	0.95
	Median	120	1520	744	6.67	835	0.0001	0.025	0.0025	234	0.00025	0.0273	0.0025	0.0025	5.88	17.70	0.053	0.0025	0.079
	Minimum	11.3	187	169	2.13	49	< 0.00002	0.0065	< 0.0005	22.6	< 0.000034	< 0.0005	< 0.0005	< 0.001	< 0.03	0.0685	< 0.002	< 0.0005	< 0.005
	Maximum	286	4370	1160	8.07	2990	< 0.01	0.617	< 0.2	464	0.0289	0.619	< 0.02	0.0298	271	80.1	0.903	1.94	6.66
Slightly Impacted	N	59	59	22	56	59	59	59	59	59	59	59	59	59	59	59	59	59	59
	Mean	136	695	365	6.95	245	0.00013	0.016	0.004	107.4	0.0002	0.0042	0.0013	0.0015	1.81	4.79	0.0084	0.0015	0.01
	Median	138	724	424	6.97	327	0.000025	0.0093	0.00051	127.00	0.00004	0.00189	0.0005	0.001	0.229	0.69	0.0025	0.0005	0.0074
	Minimum	12.5	250	136	6.01	30	< 0.00002	< 0.005	< 0.0005	38.7	< 0.000017	< 0.0003	< 0.0005	< 0.001	< 0.03	0.00066	< 0.001	< 0.0005	< 0.005
	Maximum	234	1410	794	7.77	702	< 0.01	< 0.2	< 0.2	234	< 0.01	0.0659	< 0.01	< 0.01	7.98	30.5	0.107	< 0.05	0.18

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Non-Impacted	N	12	12	4	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	Mean	200	398	209	7.26	27	0.00002	0.004	0.004	65.6	0.00002	0.0015	0.0004	0.0005	2.37	0.61	0.0017	0.0004	0.005
	Median	207	404	212	7.29	24	0.0000175	0.005	0.0024	65.35	0.000022	0.00061	0.000375	0.0005	2.286	0.44	0.00205	0.0005	0.0025
	Minimum	148	327	190	6.43	11	< 0.00002	< 0.005	0.00098	58	< 0.000017	< 0.0003	< 0.0005	< 0.001	0.201	0.134	< 0.001	< 0.0005	< 0.005
	Maximum	233	444	221	7.67	49	< 0.00005	< 0.01	0.00905	76.1	< 0.00005	0.00638	< 0.001	< 0.001	5.02	1.42	< 0.005	< 0.001	0.0114
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)				**-**	**-**	**1000**	**0.015** [A1]	**-**	**0.050**	**-**	**0.0005-0.0006** [A2]	**0.009**	**0.01** [B1]**-0.09** [B2]	**0.06-0.09** [A3]	**-**	**-**	**1.1-1.5** [A4]	**0.06-0.16** [A5]	**0.9-2.4** [A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-17. Monitoring Wells in the Intermediate Impoundment

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Intermediate Impoundment								
Adversely Impacted	X21A-96	6913417	581989	0.69	2.43	8.53	1996	Tailings
Moderately Impacted	P03-08-05	6913514	580980	*0.878*	21.34	21.64	2003	Alluvium
	P03-08-06	6913514	580980	*0.878*	19.81	20.12	2003	Tailings
	P03-08-07	6913514	580980	*0.878*	16.76	17.07	2003	Tailings
	X21B-96	6913417	581989	0.74	11.64	14.69	1996	Alluvium
Slightly Impacted	P03-08-02	6913514	580980	*0.878*	28.04	28.35	2003	Alluvium
	P03-08-03	6913514	580980	*0.878*	24.38	24.69	2003	Alluvium
	P03-08-04	6913514	580980	*0.878*	22.86	23.16	2003	Alluvium
	P03-08-08	6913514	580980	*0.878*	13.72	14.02	2003	Tailings
Non-Impacted	P03-08-01	6913514	580980	*0.878*	32.31	32.61	2003	Alluvium

Table 3.2-18. Intermediate Impoundment Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Intermediate Impoundment																			
Adversely Impacted	N	6	6	2	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Mean	23	8937	2904	6.22	10758	0.00102	0.2208	0.0226	281	0.00096	0.01922	0.024	0.031	3868.5	300.20	0.0842	0.0374	47.21
	Median	18	10725	2904	6.3	12850	0.001	0.25	0.025	348	0.00085	0.015	0.01875	0.0375	4145	385	0.05	0.0375	48.10
	Minimum	13	2830	977	5.89	1760	< 0.0002	< 0.05	0.0053	101	< 0.00017	0.0142	< 0.005	< 0.01	502	30.4	< 0.01	0.0054	0.837
	Maximum	54	13800	4830	6.5	18500	< 0.005	< 1	< 0.1	389	< 0.005	< 0.05	< 0.1	< 0.1	7110	481	< 0.5	< 0.1	104
Moderately Impacted	N	29	26	13	27	29	30	30	30	30	30	30	30	30	30	30	30	30	30
	Mean	144	1964	1017	7.16	1038	0.00041	0.0320	0.0101	299.5	0.00042	0.00539	0.002	0.003	39.361	7.040	0.0102	0.0086	0.384
	Median	165	2145	1040	7.1	1070	0.00005	0.025	0.00275	298.5	0.000085	0.00305	0.0025	0.0025	37.150	5.92	0.007	0.00485	0.0166
	Minimum	20	1220	602	6.44	476	< 0.00004	< 0.01	< 0.001	137	< 0.000034	< 0.0015	< 0.002	< 0.002	< 0.03	0.296	< 0.002	< 0.001	< 0.005
	Maximum	288	2410	1300	8.68	1490	< 0.01	< 0.2	< 0.2	497	< 0.01	0.0342	< 0.01	< 0.01	192	29.9	< 0.05	< 0.05	6.07
Slightly Impacted	N	41	37	20	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
	Mean	257	831	450	7.26	213	0.00040	0.0197	0.0089	118	0.00049	0.00105	0.001	0.003	9.373	3.783	0.0148	0.0046	0.013
	Median	282	720	402	7.2	142	0.00002	0.01	0.001	110	0.000122	0.00066	0.001	0.0025	0.087	3.88	0.019	0.00125	0.008
	Minimum	110	479	91	6.35	61	< 0.00002	< 0.005	< 0.0005	16.9	<0.000017	< 0.0003	< 0.0005	< 0.001	< 0.03	0.0313	< 0.001	< 0.0005	< 0.005
	Maximum	326	1570	889	8.98	620	< 0.01	< 0.2	< 0.2	253	< 0.01	< 0.01	< 0.01	< 0.01	39.8	7.52	< 0.05	< 0.05	0.148
Non-Impacted	N	6	5	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Mean	261	505	312	7.45	35	0.00002	0.0038	0.0003	73.15	0.00002	0.00018	0.0004	0.001	0.070	0.056	0.0023	0.0003	0.005
	Median	262	490	312	7.4	34	0.00001	0.00375	0.00025	76.0	0.0000225	0.00015	0.0005	0.0005	0.057	0.05	0.002	0.00025	0.005
	Minimum	250	477	307	6.93	21	< 0.00002	< 0.005	< 0.0005	63.5	< 0.000017	< 0.0003	< 0.0005	< 0.001	< 0.03	0.0326	0.0019	< 0.0005	< 0.005
	Maximum	275	548	316	8.09	54	< 0.00005	< 0.01	< 0.001	81.6	< 0.00005	< 0.0005	< 0.001	< 0.001	0.171	0.112	< 0.005	< 0.001	< 0.01
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)				**-**	**-**	**1000**	**0.0005 -0.015 [B]**	**-**	**0.050**	**-**	**0.0005 -0.0007[B]**	**0.009**	**0.01 [B1]- 0.09 [B2]**	**0.04 -0.09 [B]**	**-**	**-**	**0.65 -1.5 [B]**	**0.05 -0.16 [B]**	**0.15 -2.4 [B]**

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-19. Monitoring Wells at the toe of the Intermediate Dam

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Intermediate Dam								
Moderately Impacted	P01-03	6914056	580617	0.3	7.78	9.3	2001	Alluvium
	X24D-96	6914124	580655	0.7	26.84	28.34	1996	Alluvium
Slightly Impacted	P01-04A	6913893	580496	0.31	31.7	33.22	2001	Alluvium
	X25A-96	6913945	580519	0.68	7.44	8.97	1996	Alluvium
	X25B-96	6913945	580519	0.63	17.7	19.17	1996	Alluvium
Non-Impacted	P01-04B	6913893	580496	0.3	51.0	52.5	2001	Till

Table 3.2-20. Toe of Intermediate Dam Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Toe of Intermediate Dam																			
Moderately Impacted	N	16	16	8	15	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	Mean	367	2766	1781	6.67	1542	0.00046	0.0517	0.0095	518.63	0.00246	0.04865	0.004	0.005	0.083	45.506	0.1594	0.0048	0.086
	Median	362	2710	1760	6.7	1530	0.000125	0.0375	0.0025	519	0.00252	0.04935	0.005	0.005	0.015	47.55	0.155	0.0025	0.062
	Minimum	315	2340	1540	6.29	1090	< 0.0002	< 0.05	< 0.005	445	0.00113	0.0282	< 0.0025	< 0.005	< 0.03	35.7	0.091	< 0.005	0.0172
	Maximum	406	3240	2060	7	1930	< 0.01	0.227	< 0.2	593	< 0.01	0.0793	< 0.02	< 0.02	0.277	53.6	0.243	< 0.05	0.335
Slightly Impacted	N	27	27	12	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Mean	268	1104	566	7.39	360	0.00041	0.0175	0.0084	175.59	0.00049	0.00242	0.001	0.002	1.194	2.444	0.0065	0.0027	0.008
	Median	269	1080	542	7.3	334	0.00005	0.01	0.001	168.0	0.00005	0.00075	0.001	0.0025	0.616	1.39	0.005	0.001	0.006
	Minimum	229	927	481	6.6	260	< 0.00004	< 0.01	< 0.001	137	< 0.000034	< 0.0006	< 0.001	< 0.002	< 0.03	0.157	< 0.002	< 0.001	< 0.005
	Maximum	317	1510	808	8.48	613	< 0.01	< 0.2	< 0.2	276	< 0.01	< 0.01	< 0.01	< 0.01	5.3	6.09	< 0.05	< 0.05	0.041
Non-Impacted	N	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Mean	664	1142	548	6.75	32	0.00036	0.0095	0.0010	128	0.00006	0.00051	0.001	0.001	0.647	0.2356	0.0037	0.0010	0.003
	Median	643	1090	548	6.6	32	0.00036	0.01	0.001	126	0.00005	0.0005	0.0005	0.001	0.61	0.229	0.005	0.001	0.0025
	Minimum	582	1000	481	6.48	26	0.00027	< 0.01	< 0.001	114	0.000066	< 0.0006	< 0.001	< 0.002	0.505	0.208	< 0.002	< 0.001	< 0.005
	Maximum	746	1290	615	7.09	34	0.00044	< 0.025	< 0.0025	152	< 0.0001	< 0.0015	< 0.005	< 0.005	0.815	0.27	< 0.01	< 0.0025	0.0065
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)					**-**	**1000**	**-**	**0.015** [A1]	**0.050**	**-**	**0.0006** [A2]	**0.009**	**0.01** [B1] **- 0.09** [B2]	**0.09** [A3]	**-**	**-**	**1.5** [A4]	**0.16** [A5]	**2.4** [A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-21. Monitoring Wells at the Toe of the Cross Valley Dam

Groundwater Impact level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Toe of Cross Valley Dam								
Moderately Impacted	P01-11	6914306	580214	0.55	9.15	10.67	2001	Alluvium
	P05-01-02	6914335	580165	*0.671*	19.67	19.82	2005	Alluvium
	P05-01-03	6914335	580165	*0.671*	16.62	16.77	2005	Alluvium
	P05-01-04	6914335	580165	*0.671*	11.13	11.28	2005	Alluvium
	P05-01-05	6914335	580165	*0.671*	5.33	5.48	2005	Alluvium
	P05-01-06	6914335	580165	*0.671*	3.20	3.35	2005	Alluvium
	P05-02	6914265	580143	0.98	1.83	4.88	2005	Alluvium
Slightly Impacted	P01-02A	6914044	580081	0.59	12.37	13.89	2001	Alluvium
	P01-02B	6914044	580081	1.57	26.21	27.7	2001	Till
	P03-09-01	6914229	580065	*0.689*	34.75	35.05	2003	Alluvium
	P03-09-02	6914229	580065	*0.689*	32.00	32.31	2003	Alluvium
	P03-09-03	6914229	580065	*0.689*	26.82	27.13	2003	Alluvium
	P03-09-04	6914229	580065	*0.689*	23.47	23.77	2003	Alluvium
	P03-09-05	6914229	580065	*0.689*	21.64	21.95	2003	Alluvium
	P03-09-06	6914229	580065	*0.689*	18.59	18.90	2003	Alluvium
	P03-09-07	6914229	580065	*0.689*	13.11	18.41	2003	Alluvium
	P03-09-08	6914229	580065	*0.689*	9.14	9.45	2003	Alluvium
	P03-09-09	6914229	580065	*0.689*	7.32	7.62	2003	Alluvium
	P05-01-01	6914335	580165	*0.671*	25.15	25.45	2005	Till / BR
	P05-03	6914171	580088	0.84	3.44	7.62	2005	Alluvium

Table 3.2-22. Toe of Cross Valley Dam Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Toe of Cross Valley Dam																			
Moderately Impacted	N	25	25	2	24	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	Mean	295	2028	1140	6.93	972	0.00006	0.0200	0.0085	370.72	0.00011	0.00398	0.002	0.002	13.307	15.880	0.0058	0.0013	0.033
	Median	290	2030	1140	6.9	965	0.00005	0.0125	0.00125	361	0.0000425	0.0027	0.0025	0.0025	14.6	15.80	0.005	0.00125	0.009
	Minimum	242	1780	1110	6.24	831	< 0.0001	< 0.02	< 0.0025	305	< 0.000085	< 0.0015	< 0.001	< 0.002	< 0.03	12.3	< 0.005	< 0.002	< 0.005
	Maximum	343	2300	1170	8.09	1130	< 0.00025	0.189	0.0318	434	0.00132	0.0104	< 0.005	< 0.005	27.3	19.4	< 0.025	< 0.005	0.445
Slightly Impacted	N	101	101	43	99	101	101	101	101	101	101	101	101	101	101	101	101	101	101
	Mean	278	1165	637	7.20	382	0.00029	0.0169	0.0061	184.26	0.00037	0.00203	0.001	0.002	1.430	4.877	0.0078	0.0022	0.006
	Median	274	1210	640	7.2	388	0.000025	0.01	0.001	185	0.000105	0.00139	0.001	0.001	0.077	6.01	0.008	0.001	0.006
	Minimum	175	495	266	6.24	92	< 0.00002	< 0.005	0.00063	63.9	< 0.000017	< 0.0003	< 0.0005	< 0.001	< 0.03	0.137	< 0.001	< 0.0005	< 0.005
	Maximum	497	1910	954	8.27	717	< 0.01	< 0.2	< 0.2	287	< 0.01	< 0.01	< 0.01	0.0343	7.2	10.3	< 0.05	< 0.05	0.034
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)				**-**	**-**	**1000**	**0.015[B]**	**-**	**0.050**	**-**	**0.0007[B]**	**0.009**	**0.01[B1]- 0.09[B2]**	**0.09[B]**	**-**	**-**	**1.5[B]**	**0.11-0.16[B]**	**1.65-2.4[B]**

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-23. Monitoring Wells Downgradient of the Cross Valley Dam

Groundwater Impact Levels	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Downgradient of Cross Valley Dam								
Non-Impacted	X16A	6914672	579538	0.5	3.0	6.0	1981	Alluvium
	X16B	6914672	579538	0.1	20.0	34.0	1981	Alluvium
	X17A	6914475	579874	0.62	4.5	6.2	1981	Alluvium
Slightly Impacted	P01-01A	6914675	579819	0.74	19.8	21.36	2001	Alluvium
	P01-01B	6914675	579819	0.65	33.35	34.9	2001	Alluvium
	X17B	6914475	579874	1.16	17.0	25.0	1981	Alluvium
	X18A	6914539	580105	0.63	8.8	10.6	1981	Alluvium
	X18B	6914539	580105	0.59	16.6	22.8	1981	Alluvium

Table 3.2-24. Downgradient of the Cross Valley Dam Baseline Groundwater Quality

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Downgradient Cross Valley Dam																			
Slightly Impacted	N	29	29	10	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
	Mean	271	1184	638	7.46	416	0.00005	0.0163	0.0027	198.26	0.00017	0.00062	0.002	0.002	0.964	1.433	0.0055	0.0011	0.024
	Median	255	1310	642	7.4	505	0.00005	0.0125	0.00125	203.0	0.00005	0.00075	0.00125	0.0025	0.721	1.14	0.005	0.00125	0.010
	Minimum	230	530	359	6.85	39	< 0.00002	< 0.005	< 0.0005	75.8	< 0.000017	< 0.0003	< 0.0005	< 0.001	< 0.03	0.089	< 0.001	< 0.0005	< 0.005
	Maximum	454	1560	831	8.55	673	< 0.00025	0.143	0.0108	289	0.000598	< 0.0025	< 0.005	< 0.005	3.48	4.72	< 0.025	< 0.005	0.149
Non-Impacted	N	18	18	6	17	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Mean	203	401	232	7.67	29	0.00002	0.0055	0.0004	66.12	0.00004	0.00020	0.0004	0.001	0.026	0.005	0.0014	0.0004	0.009
	Median	206	399	240	7.6	26	0.000015	0.005	0.000375	65.2	0.000025	0.0002	0.0005	0.0005	0.015	0.005	0.001	0.000375	0.008
	Minimum	136	276	181	6.98	20	< 0.00002	< 0.005	< 0.0005	49.9	< 0.000017	< 0.0003	< 0.0005	< 0.001	< 0.03	< 0.0003	< 0.001	< 0.0005	< 0.005
	Maximum	289	572	298	8.43	63	< 0.00005	0.0185	< 0.001	103	0.000102	< 0.0006	< 0.002	< 0.002	0.175	0.0202	< 0.005	< 0.001	0.0312
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)			**-**	**-**	**-**	**1000**	**0.015** [A1]	**-**	**0.050**	**-**	**0.0006** [A2]	**0.009**	**0.01** [B1] **- 0.09** [B2]	**0.08- 0.09** [A3]	**-**	**-**	**1.5** [A4]	**0.06- 0.16** [A5]	**0.9- 2.4** [A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-25. Monitoring Wells Downgradient of Grum Rock Dump

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Grum WRD Area								
Slightly Impacted	BH05-9B-R	6903172	592747	1.06	15.50	18.60	2005	Overburden/BR
	SRK04-5A	6903205	592871	0.76	22.7	23.7	2004	BR (weathered)
	SRK04-5B	6903205	592871	0.78	13.7	14.7	2004	Overburden
Moderately Impacted	P96-9A	6903165	592753	0.84	4.96	9.45	1996	Overburden
	SRK05-06	6902991	593032	0.73	0.7	2.7	2005	Overburden
	SRK05-07	6903011	592477	0.75	0.75	5.8	2005	Overburden/BR
	SRK05-08	6903063	592690	0.5	2.1	7.6	2005	Overburden
	SRK05-09	6902986	593058	0.94	0.5	3.5	2005	Overburden

x

Table 3.2-26. Groundwater Quality Summary of Grum Rock Dump Area

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Grum Area																			
Moderately Impacted	N	17	17	2	16	17	18	18	18	18	18	18	18	18	18	18	18	18	18
	Mean	463	2149	1645	7.23	995	0.00006	0.0656	0.0032	288.17	0.00033	0.00258	0.002	0.003	0.172	0.199	0.0213	0.0016	0.029
	Median	469	2040	1645	7.2	916	0.00005	0.0125	0.00125	287.5	0.000288	0.00075	0.0025	0.0025	0.015	0.03	0.00375	0.00125	0.0221
	Minimum	223	957	1480	6.5	376	< 0.00004	< 0.01	< 0.001	138	< 0.000085	< 0.0006	< 0.002	0.0029	< 0.03	0.00063	< 0.002	< 0.001	< 0.005
	Maximum	765	3270	1810	8.15	1760	< 0.00025	0.848	0.0266	408	0.00101	0.0146	< 0.01	< 0.01	1.82	1.15	0.147	< 0.005	0.091
Slightly Impacted	N	8	8	2	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Mean	149	480	172	7.95	113	0.00002	0.0084	0.0171	51.80	0.00002	0.00028	0.001	0.001	0.740	0.079	0.0012	0.0027	0.062
	Median	151	448	172	8.0	96	0.00001	0.00605	0.0137	51.0	0.000023	0.00025	0.0005	0.0005	0.647	0.08	0.001	0.00057	0.0069
	Minimum	140	430	172	7.75	85	< 0.00002	< 0.005	0.00593	46.4	< 0.000017	< 0.0003	< 0.0005	< 0.001	0.205	0.0487	< 0.001	< 0.0005	< 0.005
	Maximum	159	602	172	8.13	179	< 0.00005	0.023	0.0471	58.6	< 0.00005	0.00067	< 0.002	< 0.002	1.42	0.104	< 0.005	0.0146	0.402
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)					**-**	**1000**	**0.015** [A1]		**0.050**	**-**	**0.0006** [A2]	**0.009**	**0.01** [B1]**-0.09** [B2]	**0.07-0.09** [A3]	**-**	**-**	**1.1-1.5** [a4]	**0.06-0.16** [A5]	**0.9-2.4** [A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

Table 3.2-27. Monitoring Wells Downgradient of Vangorda Rock Dump

Groundwater Impact Level	Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Vangorda WRD Area								
Moderately Impacted	V35	6902371	593293	0.44	-	-	1994	Alluvium
Slightly Impacted	V34	6902295	593553	0.55	-	-	1994	BR
Slightly Impacted	V36	6902733	593243	0.5	-	-	1994	Alluvium
	V37	6902913	593420	0.47	-	-	1994	Alluvium
	P2001-02A	6902677	593252	0.34	25.8	27.3	2001	Till
	P2001-02B	6902677	593252	0.34	12.3	13.9	2001	Clay and Gravel
	P2001-03	6902700	593214	0.68	58.5	61.6	2001	Till / BR

Table 3.2-28. Groundwater Quality Summary of Vangorda Rock Dump Area

Parameter		Physical Parameters					Dissolved Metals												
		ALK-T mg/L	COND µS/cm	HARD mg/L	pH pH unit	SO4 mg/L	Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Vangorda Area																			
Moderately Impacted	N	6	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Mean	543	2295	1003	6.99	1083	0.00006	0.0558	0.0014	356.50	0.00015	0.00075	0.002	0.002	0.031	0.199	0.0082	0.0017	0.033
	Median	585	2430	1003	7.1	1175	0.00005	0.0125	0.00125	353	0.0001475	0.00075	0.0025	0.0025	0.015	0.09	0.00705	0.00125	0.02155
	Minimum	377	1410	966	6.47	495	< 0.0001	< 0.01	0.0011	214	< 0.0001	< 0.001	0.0014	0.0012	< 0.03	< 0.01	0.0059	0.0006	< 0.005
	Maximum	677	3050	1040	7.48	1680	< 0.00025	0.27	< 0.005	521	< 0.00025	< 0.0025	< 0.005	< 0.005	0.08	0.815	< 0.025	< 0.005	0.113
Slightly Impacted	N	32	32	9	31	32	32	32	32	32	32	32	32	32	32	32	32	32	32
	Mean	433	1143	692	7.38	265	0.00003	0.0449	0.0140	135.23	0.00009	0.00052	0.001	0.001	0.824	0.136	0.0030	0.0009	0.015
	Median	440	1155	675	7.4	292	0.00002	0.0064	0.00785	154.5	0.000025	0.0003	0.00075	0.001	0.837	0.11	0.001	0.0005	0.0088
	Minimum	305	769	389	6.28	42	< 0.00002	< 0.002	< 0.001	49.6	< 0.000017	< 0.0002	< 0.0005	< 0.0002	< 0.03	0.00679	< 0.001	< 0.0001	0.004
	Maximum	506	1760	1140	8.06	693	< 0.00025	0.682	0.0818	251	0.000888	< 0.0025	< 0.005	0.0069	1.95	0.593	< 0.025	0.0081	0.047
Yukon Government Contaminated Sites Regulations (CSR) for Aquatic Life (Yukon Environment, 2002)					**-**	**1000**	**0.015**[A1]	**-**	**0.050**	**-**	**0.0006**[A2]	**0.009**	**0.01**[B1]**-0.09**[B2]	**0.09**[A3]	**-**	**-**	**1.5**[A4]	**0.16**[A5]	**2.4**[A6]

N: number of samples used for calculations.

A: Criteria are in accordance with minimum hardness values.
A1: 0.0005 @ H≤100 mg/L; 0.015 @ H>100 mg/L.
A2: 0.0001 @ H<30 mg/L; 0.0003 @ H = 30<90 mg/L; 0.0005 @ H = 90<150 mg/L; 0.0006 @ H = 150<210 mg/L.
A3: 0.02 @ H<50 mg/L; 0.03 @ H = 50<75 mg/L; 0.04 @ H = 75<100 mg/L; 0.05 @ H = 100<125 mg/L; 0.06 @ H = 125<150 mg/L; 0.07 @ H = 150<175 mg/L; 0.08 @ H = 175<200 mg/L; 0.09 @ H≥200 mg/L.
A4: 0.25 @ H<60 mg/L; 0.65 @ H = 60<120 mg/L; 1.1 @ H = 120<180 mg/L; 1.5 @ H≥180 mg/L.
A5: 0.04 @ H<50 mg/L; 0.05 @ H = 50<100 mg/L; 0.06 @ H = 100<200 mg/L; 0.11 @ H = 200<300 mg/L; 0.16 @ H≥300 mg/L.
A6: 0.075 @ H<90 mg/L; 0.15 @ H = 90<100 mg/L; 0.90 @ H<200 mg/L; 1.65 @ H<300 mg/L; 2.4 @ H = 300<400 mg/L.

B1: Standard is specific to chromium (+6).
B2: Standard is specific to chromium (+3).
Exceeds CSR.

3.3 Surface Water Quality

3.3.1 Introduction

Surface water quality has been extensively monitored at the Faro Mine Complex for regulatory compliance, environmental monitoring, and closure planning purposes since cessation of mining activities in 1998. Selected water quality data collected though these programs have been used to characterize existing surface water quality conditions at the Faro Mine Complex within the Rose Creek and Vangorda Creek drainages, as well as a portion of the Anvil Creek drainage, to which Rose Creek drains, and a portion of the Pelly River to which these tributaries (Anvil Creek and Vangorda Creek) drain.

Surface water quality has historically been monitored at several different locations. Some of these stations have been selected for characterisation to support the objectives of the environmental and socio-economic assessment of the closure plan. Water quality sites upstream and downstream of former mine activities and of proposed closure activities have been included, in addition to mine impacted locations, and locations where closure activities are expected to have an impact.

Water quality prior to the establishment of a mine at this site is unavailable. Therefore, existing water conditions, rather than historical pre-mining or operational water quality characteristics, will be used to assess potential effects associated with implementation of the Faro Mine Closure Plan. Some historical trends are discussed for the period from 1998 to 2005, where there is sufficient data of sufficient quality for assessment, and where the data is relevant. In addition, for all water quality monitoring stations selected for characterisation for Environmental and Socio-Economic Assessment, existing conditions are documented for the period from 2005-2007, a period for which water quality testing had sufficiently low method detection limits that metals concentrations could be characterised, and for which there are sufficient sampling events to characterise the pre-closure conditions.

3.3.1.1 Regional Setting

The Faro Mine Complex footprint is located within two watersheds: the Rose Creek watershed (includes Faro Creek drainage) and the Vangorda Creek watershed. The Rose Creek watershed forms a part of the larger Anvil Creek watershed, as Rose Creek is a tributary of Anvil Creek. Anvil Creek and Vangorda Creek are tributaries of the Pelly River (Figure 3.3-1). The two watersheds (Rose Creek and Vangorda Creek) receive drainage from the mine sites by means of surface run-off, treated effluent discharge, natural and diverted surface water inflows and groundwater/surface water interactions. The confluence of Rose Creek and Anvil Creek is located approximately 24 km (linear distance) downstream of the nearest site of mine activities (foot of tailings ponds).

The larger Anvil Creek watershed and the Vangorda Creek watershed are contained within the larger watershed of the Pelly River, which, in turn, drains to the Yukon River. The confluence of Anvil Creek and the Pelly River is approximately 40 km from the Rose Creek/Anvil Creek confluence, and is therefore approximately 64 km from the nearest site of mine activities. The confluence of Vangorda Creek and the Pelly River is approximately 17 km from the nearest former mine and proposed closure activities along

Vangorda Creek. Along the Pelly River, it is approximately 64 km from the Vangorda Creek confluence to the Anvil Creek confluence.

3.3.2 Study Areas

3.3.2.1 Regional Study Area

The surface water quality regional study area (RSA) encompasses the areas outside of the project footprint that are characterised to determine direct effects on surface water quality downstream of the study area and which allow for the determination of cumulative impacts where project effects extend beyond the study area boundary. The boundary of the surface water quality RSAs are typically based on watershed boundaries as well as the zone of influence of the mine on downstream receiving environments. The RSA encompasses a portion of the Pelly River watershed that is just upstream and downstream of its confluence with Vangorda Creek and upstream and downstream of its confluence with Anvil Creek. It includes portions of Faro, Rose, Anvil, and Vangorda Creeks watersheds, along with some tributaries to these creeks, all of which drain to the Pelly River. The surface water RSA is illustrated in Figure 3.3-1.

Water quality within the RSA is monitored at many locations as part of several monitoring programs. The water quality monitoring stations selected for characterisation of the RSA, as well as for two local study areas (LSAs) identified within the RSA, are described later in this section and are shown in Figures 3.3-1 to 3.3-3. The monitoring programs through which source data was collected are also described later in the surface water quality section of this study.

3.3.2.2 Local Study Areas

There are two local study areas (LSAs) for surface water quality: Faro Creek and Vangorda LSAs. The two LSAs are based on the physical and hydrological footprint of the Faro and Vangorda/Grum mine sites and include drainages that are directly influenced by site infrastructure associated with closure activities including the haul roads, waste rock piles, pits and discharges of treated water. The LSA extends from reference stations, which are located upstream from the Faro and Vangorda/Grum mine sites, to the first monitoring point downstream of treated effluent discharge points and site influenced drainage inflows. The water quality LSAs for the environmental assessment of the Closure and Remediation Plan of the Faro Mine Complex are illustrated in Figures 3.3-1 to 3.3-3, along with the LSA boundararies.

Rose LSA – General Description

The Rose LSA encompasses a section of the Rose Creek watershed, with boundaries just upstream of former mine and proposed closure activities, to a point downstream of the former mining activities and proposed closure activities. The Rose LSA includes sections of the watersheds of several tributaries that flow into Rose Creek.

Faro Creek, has been diverted north of the Faro Pit, and flows into the North Fork of Rose Creek, at a location northeast of the Faro Pit. The North Fork of Rose Creek flows past the eastern edge of the Faro Waste Rock Piles and is joined by the South Fork of Rose Creek, in the area southeast of the Faro Rock

Dumps and of the Tailings Ponds. Rose Creek then flows westward, via the Rose Creek diversion constructed south of the Tailings Ponds, and on to Anvil Creek.

The Rose LSA includes reaches of Faro Creek and of the Faro Valley West Interceptor, upstream of mining and closure impacted areas, and continues past the confluence with the North Fork of Rose Creek, and with the South Fork of Rose Creek, downstream of the Tailings Ponds.

The Rose LSA also includes the North Wall Interceptor that flows into Rose Creek from the north. The upstream sections of the North Wall Interceptor were originally the upper reaches of Guardhouse Creek, prior to the construction of the North Wall Interceptor Ditch. Flows circumvent the Faro Pit and the associated Waste Rock piles to the west, except for a reach where the flows pass through a northwest section of the Faro Waste Rock, in its upper reaches. The flows are then diverted north of the Tailings Ponds and discharge to Rose Creek east of the Tailings Ponds. This tributary is internal to the LSA.

The Rose LSA also includes Guardhouse Creek, which is internal to the LSA, and carries flows from just north of the Guardhouse to the Intermediate Pond.

Water Monitoring Stations To Characterise Rose LSA

The water quality monitoring stations selected to characterise the water quality of the Faro LSA are shown in Figures 3.3-1 and 3.3-2, which also show watershed boundaries, the LSA boundaries, and creeks. These stations are listed in Table 3.3-1 and described below.

The up-gradient boundary of the Rose LSA extends upstream of mining and proposed closure activities. The boundary is characterised by reference monitoring stations situated upstream of mining and closure activity impacts on Rose Creek and on tributaries of Rose Creek. Faro Creek upstream of the Faro Pit is characterised at station FDU. This monitoring station is downstream of the confluence of the Faro Valley Interceptor and Faro Creek. The North Fork of Rose Creek upstream of mine and proposed closure activities is characterised upstream of the Faro Creek confluence at monitoring station R7. LSA reference stations for the South Fork of Rose Creek and from a larger tributary to the South Fork of Rose Creek referred to as "1st Tributary" are not characterised, because there is insufficient data upstream of former mine activity areas to adequately characterise the creeks. In the North Wall Interceptor, reference water quality is characterised at water quality monitoring station W10, upstream of the Faro Waste Rock Dump.

Several monitoring stations internal to the LSA are characterised for purposes of monitoring changes along reaches of Rose Creek, where closure activities are proposed and where tributary flows contribute significantly to Rose Creek flows.

This includes monitoring station **X2**, downstream of the confluence of Faro Creek and the North Fork of Rose Creek, and also downstream of the reach of the North Fork of Rose Creek that flows to the east of the Faro Rock Dumps.

This also includes monitoring station **R1**, which characterises flows to Rose Creek from the South Fork of Rose Creek, upstream from the South Fork and North Fork confluence. Flows upstream of

R1 flow through the former freshwater reservoir, through former sedimentation ponds and past the pumphouse reservoir. The South Fork of Rose Creek is a possible receiving environment for groundwater flows from the Faro Waste Rock Dumps that escape capture zones of pump and treat systems, from Haul Road activities and from activities in areas upgradient of the Tailings Ponds in the Rose Creek Valley. Station R1 is also a benthic monitoring station.

Water quality will also be characterised at monitoring station **X3**, which is located at the outflow of the pumphouse pond. Monitoring this water includes evaluating all flow from the South Fork of Rose Creek and a majority of the flow from the North Fork of Rose Creek that flows through location X2. A small portion of the flow from the North Fork of Rose Creek bypasses the pumphouse pond during high flow events via a secondary diversion channel. This "bypass" flow enters the Rose Creek diversion immediately downstream of the pumphouse pond.

Water quality will also be characterised at monitoring station **X10**, which is located downstream of the Tailings Ponds, in the Rose Creek Diversion, but upstream of the confluence of the North Wall Interceptor.

Water quality at monitoring station **X5** is also characterised, to provide existing conditions water quality from the Cross Valley Pond. Flows from the Cross Valley Pond flow to the North Wall Interceptor.

Water quality is also characterised at **X13** to represent combined seepage flows from the toe of the Cross Valley Dam, and this flow also is directed to the North Wall Interceptor.

The downstream boundary of the Rose LSA is downstream of the Tailings Ponds and of the mixing zone after the confluence of the North Wall Interceptor and Rose Creek. Water quality is characterised in Rose Creek at water quality monitoring station **X14**. It is anticipated that changes observed at this site will monitor for effects of proposed changes to the cross valley dam area. Therefore, while this site forms the downstream boundary of the Rose LSA, it is still considered a mine impacted site, rather than a receiving water site.

Vangorda Creek LSA – General Description

The Vangorda LSA encompasses a section of the Vangorda Creek watershed, with boundaries just upstream of former mine and proposed closure activities, to a point downstream of the former mining activities and proposed closure activities. Sections of the watersheds of several tributaries that flow into Vangorda Creek are included.

Vangorda Creek flows southward from areas north of the Vangorda Pit. The creek flows around the western side of the Vangorda Pit via the Vangorda Diversion Flume through to the Plunge Pool. At the Plunge Pool, the flows are merged with those from the Sheep Pad Sediment Ponds and from the Vangorda Pit Northwest Interceptor, which flows approximately parallel with and east of the Vangorda Diversion Flume. Sheep Pad Sediments Ponds receive flows from the Grum Interceptor Ditch, which flows in an east direction, and is located north of the Grum Pit; and from the Clarification Pond, which receives discharge from the Vangorda

Wastewater Treatment Plant. After the Plunge Pool, Vangorda Creek flows past the eastern side of the Little Creek Dam area, to the west of the Grum Waste Rock Dumps, and to the east side of the Vangorda Waste Rock Dump, to its confluence with the Pelly River, just downstream of the Town of Faro. Both Shrimp Creek and the West Fork of Vangorda flow into Vangorda Creek downstream of the Plunge Pool. Shrimp Creek receives flows from the Northwest Vangorda Pit Interceptor, and from Dixon Creek prior to discharging to Vangorda Creek. Dixon Creek/Shrimp Creek is potentially the receiving water for deep groundwater flows from the Vangorda Waste Rock Dumps. The West Fork of Vangorda Creek flows in a generally southern direction to the west of the Grum Waste Rock Dumps. It has its confluence with the main stem of Vangorda Creek southeast of the Vangorda and Grum former mining areas, and may receive groundwater discharged to the west from the Grum Waste Rock area.

The Vangorda Treatment Plant is not operated every year, and water quality downstream of the Treatment Plant discharge varies depending on whether or not there was discharge from the treatment plant. During the period from 2005 to 2007, the Water Treatment Plant was operated during the open water season of 2005 only.

Water Monitoring Stations To Characterise Vangorda LSA

The water quality monitoring stations selected to characterise the water quality of the Vangorda LSA are shown in Figures 6.3-1 and 6.3-3, which also show water shed boundaries, the LSA boundaries, and creeks. These stations are listed in Table 3.3-1 and described below.

The up-gradient boundary of the Vangorda LSA extends upstream of mining and proposed closure activities. The boundary is characterised by reference monitoring stations situated upstream of mining and closure activity impacts on Vangorda Creek and on tributaries of Vangorda Creek. Vangorda Creek upstream of the Vangorda Pit is characterised at station **V1**. In the West Fork of Vangorda Creek, reference water quality is characterised upstream of the Haul Road at water quality station **VR**.

Several monitoring stations internal to the LSA are characterised for purposes of monitoring changes along reaches of Vangorda Creek, where closure activities are proposed and where tributary flows contribute significantly to Vangorda Creek flows.

This includes monitoring station **V25BSP** which characterised water quality discharged from Sheep Pad Pond to Vangorda Creek. As shown in Figure 3.3-3, water from the Vangorda Water Treatment Plant Clarification Pond and from the Grum Interceptor, flow to Sheep Pad Pond. The water quality at monitoring station V25BSP, therefore, has varying water quality, depending on whether or not the Vangorda Water Treatment Plant is in operation.

Water quality is also characterised internally in Grum Creek at monitoring station **V2**, upstream of its confluence with Vangorda Creek. Grum Creek is a receiving water for seepage from the east side of the Grum Waste Rock Dump. A portion of the flows upstream of V2 have been diverted to Moose Pond. From Moose Pond, the water infiltrates and provides recharge to Vangorda Creek through seepage upstream of the Grum Creek/Vangorda Creek confluence.

Water quality is also characterised internally to the LSA at monitoring station **V27**. This station is downstream of the Grum Creek confluence, but upstream of the confluence with Shrimp Creek. As previously noted, Shrimp Creek includes flows from Dixon Creek and North East Vangorda Pit Interceptor, as well as possibly deep groundwater flows from the Vangorda Dump.

Water quality in Shrimp Creek, upstream of Vangorda Creek, is, therefore, also characterised as a mine impacted LSA site, at monitoring station **V4**.

Receiving water within the Vanogorda LSA is characterised at three sites in Vangorda Creek: at monitoring stations **VGMAIN**, downstream of the Shrimp Creek/Vangorda Creek confluence and upstream of the confluence with the West Fork of Vangorda Creek; **V5**, at the mouth of the West Fork of Vangorda Creek; and just upstream of the mouth of Vangorda Creek at monitoring station **V8**, before the creek drains to the Pelly River. This represents the downstream boundary of the Vangorda LSA.

Water Monitoring Stations To Characterise Pelly RSA

Water quality upstream of former mine and proposed closure activities is characterised at all the LSA reference stations (i.e., at **FC, FDU, W10, R7, V1, and VR**) and at two additional sites: **P1**, located in the Pelly River upstream of its confluence with Vangorda Creek, and at **R6**, in Anvil Creek, upstream of its confluence with Rose Creek.

Water quality is also characterised in the RSA in Rose Creek, Anvil Creek and the Pelly River, which are downstream of mine impact waters. Specifically, RSA water quality is characterised at monitoring station **R4**, which is located in Rose Creek, just upstream of its confluence with Anvil Creek. In Anvil Creek, water quality is characterised at **R6**, just downstream of the Rose Creek/ Anvil Creek confluence, and at monitoring station **R11** (has also been referred to as “Anvil Creek” and as “A1”). In the Pelly River, water quality is characterised at monitoring station **P2**, which is located just downstream of the Vangorda Creek/Pelly River confluence; at **P3**, which is located just upstream of the Anvil Creek/Pelly River confluence; and at **P4**, which is located just downstream of the Anvil Creek/Pelly River confluence.

Water quality in the Pelly River is characterised based on only four samples collected in late 2007, due to the limited availability of the data from this location in the 2005 to 2007 period, and therefore represents only a preliminary characterisation. It is expected that the permitting process for the closure plan will extend at least until after the end of the 2009, after which it is recommended that site characterisation, especially for these locations, be updated. We note that the characterisation process can also continue until such time as any closure activities take place upstream of any monitoring site.

General Observations with Respect to Rose and Vangorda LSAs

The Anvil Range Mine produced lead and zinc concentrates from 1969 to 1998, when it closed permanently. Initial activity at the complex was in the area of the Faro Mine. The impact of activities at the Faro Mine area, has therefore occurred over a longer period than at the Vangorda and Grum areas of the site. Ore was trucked from the Grum/Vangorda site to be processed at the Faro site. The Tailings Ponds are therefore included within the Rose LSA. There are no tailings ponds in the Vangorda/Grum area.

3.3.3 Temporal Scope of Baseline Compilation

For the purposes of the assessment of the closure plan, a temporal range spanning from 2005 to 2007 (inclusive) was selected for characterization of *existing* baseline water quality conditions ('existing conditions') in background, mine impacted and receiving waters draining from the Faro Mine site. This three year temporal range allows for characterization of seasonal trends and represents a time frame of consistent sampling and laboratory analysis techniques and detection limits. For stations and parameters that demonstrate long-term historical changes, water quality over a larger temporal range (1998-2007) is discussed for the purposes of historical trend analysis, but does not form part of the record for the baseline. Data collected prior to 1998 will not be included in the historical trend analysis due to inconsistent laboratory methodology, including variable detection limits.

Although data from 2008 was also available at the time this existing conditions document was finalised, 2008 data was not included to keep reference periods for all disciplines as consistent as possible, and for co-ordination with other aspects of closure planning. As a result, these are as few as four samples collected within a span of four months in the latter part of 2007 that are available to characterise some sites. Since permitting procedures for the closure plan will likely extend beyond 2009, there is an opportunity to compile and assess water quality from a longer time period after 2009 for closure planning purposes.

3.3.4 Data Sources

Water quality sampling and analysis has taken place at Anvil Range Complex to fulfill several different objectives, including monitoring required by the Water Licence, monitoring required through the Adaptive Management Plan, response to Adaptive Management Plan trigger activation, optimization of care and maintenance activities, and closure planning. The following lists and describes the programs through which surface water quality was monitored and/or assessed for the period from 2005 to 2007, and that provided source water quality data used in the characterisation of water quality:

The large majority of source data included in the characterisation of the regional and local study areas was monitored as part of former water licence requirements.

3.3.4.1 Seeps Monitoring

Seeps monitoring at several locations was included as part of the water licence requirements. Seep quality was additionally surveyed yearly, when seeps were found. Assessment of seeps quality has been undertaken in connection with AMP event triggers responses, and with closure planning. Seep monitoring complements the groundwater program in providing an indication of the potential loading to creeks. Existing conditions seeps have not been characterised, since it is expected that the effect of loading to creeks from the seeps will be monitored through the water quality in the creeks. Existing seep quality was, however, used to evaluate for contaminants of potential concern.

3.3.5 Contaminants of Potential Concern

The parameters used to characterise water quality are those that were identified as contaminants of potential concern and those that provide additional information which contribute to an understanding of the chemical interactions at the site.

Metals contaminants of potential concern were identified through a risk assessment screening process that was based on existing water quality by SENES (SENES 2009). Sediment, surface water and seep quality (seep quality was diluted by a factor of 0.01) was compared with CCME Guidelines, with existing toxicity data, and with up-gradient reference data to identify the metals contaminants of concern. 20 metals (total metals) were identified for the Faro site, and three less for the Vangorda site.

All metals data, including dissolved and total metals, is presented in Appendix B2, over two time ranges: from 1998 to 2007 and from 2005 to 2007. The total metals which were identified as contaminants of concern are noted as such in the data tables included in the appendices. Of these parameters, where there was sufficient data with sufficiently low detection limits to characterise a site, the parameter has been included as part of a summary table to characterise a selected location. Metals concentrations for metals that were not identified as contaminants of concern are included in Appendix B2, but have not been summarised in the body of this report.

The parameters screened through the risk assessment process include all the major parameters that would in theory be mobilized under acidic conditions and would be considered toxic to aquatic life. While fewer parameters are identified on the Vangorda side than on the Faro side, the Faro side has been in operation for longer than the Vangorda side, and there is stronger likelihood that waste rock dumps on the Faro side are fully wetted, and may be further along with oxidation and travel of potential contaminants from oxidation sites to surface water receivers. That being said, more parameters of concern were identified through surface water comparisons with standards, toxicity considerations and comparison with reference sites on the Faro side than on the Vangorda side.

Total metals, rather than dissolved metals, were selected to characterise exiting conditions based on the following rationale:

- guidelines (and therefore selected benchmarks) for the protection of aquatic life are predominately based on total metals;
- significant correlation between dissolved and total metals species have been demonstrated through previous investigations (Minnow 2007); and
- filtering was delayed for some historic sampling sites until samples were received by the laboratory.

Dissolved metal concentrations for sampling sites within the LSA and RSA have been evaluated for existing conditions characterization in the context of determining the dominant source of analysed concentrations (i.e., dissolved versus solid phase).

Non-metals parameters were not included in the screening.

Other parameters used to characterise sites include pH, hardness, calcium, ammonia, TSS, conductivity and sulphate. The following table describes the rationale for inclusion of these parameters in site characterisation.

3.3.6 Existing Conditions Description

As previously noted, existing surface water quality is discussed separately for portions of two watersheds occurring within the mine footprint: the Rose Creek drainage and the Vangorda Creek drainage. Surface water quality within the ultimate downstream receiving environment, the Pelly River, is discussed for the portion of the river that captures inflows potentially influenced by the mine site within the regional study area.

Surface water quality data is presented in Appendix B2. Statistical analysis was performed on water quality data for the existing conditions temporal range of 2005-2007. A larger temporal range (1998-2007) was evaluated to enable historical trend analysis. Method detection limits (MDLs) were set to one-half the method detection limit for statistical calculations.

To facilitate the interpretation of current influence of the mine site on surface water quality, existing water quality was evaluated through:

- comparison of water quality to reference stations;
- comparison of water quality between sites; and
- comparison of water quality to selected water quality guidelines (described below).

In addition, reference stations are compared with background benchmarks, also described below.

Water quality guidelines have been derived from the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME 1999), or where no CCME guideline exists, the most conservative provincial water quality criterion from the British Columbia, Saskatchewan, or Ontario, or the Canadian Drinking Water Quality Guidelines was selected. For parameters for which no water quality guideline exists, alternative criteria were identified that represent a low- or no- observed effect concentration reported in the scientific literature for a sensitive aquatic species. A total hardness of 100 mg/L was used for those metals where the CCME guidelines are hardness dependent. Selected guidelines values for the identified contaminants of concern, as well as the additional parameters included for site characterisation, are shown at the top of the summary tables included in this section. Selected guideline values were developed and methodology described by Minnow Environmental (December 2008), to further the development of site specific water quality objectives.

Concurrent to the identification of water quality guidelines, background water quality benchmarks were developed for the Faro Mine Complex on behalf of the Faro Project Management Team, also as part of the development of site specific water quality objectives (Minnow 2008[1]). These benchmarks characterize reference (background) water quality in the Rose Creek and Vangorda Creek watersheds and will facilitate application of a standardized approach for comparing mine exposed stations to natural reference conditions.

[1] *Minnow Environmental Inc. Faro Background Data Evaluation. Report Prepared for Assessment and Abandoned Mines, Yukon Government, Whitehorse. December 2008.*

Water quality from nine locations upstream of mine impacted sites, seven in the Rose Creek/Anvil Creek watersheds and two in the Vangorda watershed, were combined into one dataset to evaluate for background benchmark values. Over one third of the benchmark data was from station R7, in the North Fork of Rose Creek, and this is relevant in the characterisation of this station. Parameters evaluated as part of the development of the selected water quality criteria and the background benchmark analysis included both total metals and non-metals parameters. The upstream locations selected for the development of background benchmarks include the reference stations characterised for existing conditions in this report, in addition to water quality from two stations that were sampled one or two times between 2005 and 2007, and therefore had insufficient data to characterise.

Background benchmarks were developed from this pooled dataset generally using the upper 95% value (for most parameters) for water quality data from the period of 2005 to 2007 as the benchmark value. For three parameters (cadmium, silver and zirconium), where the datasets from 2005 to 2007 were insufficient to determine background benchmarks, additional data from 2008 was used to identify benchmarks. Since, in general, the 95 percentile was used, it would be expected that median and 75% values, which have been used to characterise existing conditions at one reference station, would have parameter concentrations below the benchmark value.

Statistical analysis of the reference dataset used to develop the background benchmarks was undertaken (Minnow, 2008) and outlier values were removed from the dataset, based on data that varied by greater than three standard deviations from the dataset. Outliers were not identified, nor were they removed from the data used to characterise existing conditions.

For copper, the background benchmark and the water quality guideline value identified from the CCME Aquatic Life Guidelines are the same number (0.002 mg/L), indicating that copper concentrations upstream of former mine activities and of proposed closure activities at the site, approximate the CCME Aquatic Life Guidelines.

For two parameters, aluminum and cadmium, background benchmark values, 0.156 mg/L and 0.00004 mg/L, respectively, exceeded water quality guideline values, which for these parameters were also based on CCME Aquatic Life Guidelines. This indicates that any aluminum and cadmium concentrations which exceed guideline values downstream of former mine/ closure plan activities can not be attributed to mine former mine/ closure plan activities alone, and that for these parameters especially, comparison with reference concentrations is needed to evaluate impact of the activities.

Direct comparison of reference waters to the background benchmarks is made as part of the characterisation of upstream sites. Existing water quality is also compared with guideline values, as identified in the Minnow, (2008), report, which are largely based on CCME Aquatic Life Guidelines. Analytical method detection limits used during routine sampling from 2005 to 2007 precluded the comparison of silver and cadmium to CCME derived guideline values, since the method detection limits were higher than the guideline values.

3.3.7 Rose Creek Watershed Surface Water Quality\

3.3.7.1 Reference Water Quality

Reference or background water quality in the Rose Creek watershed was regularly monitored at stations FDU, R7, and W10 (Figure 3.3-1). These sites receive surface runoff that have no direct contact with mining activities or site infrastructure. Reference water quality in the Rose Creek drainage collected through routine monitoring programs is compiled in Appendix B2. A summary of reference water quality for selected parameters monitored under this program is provided in Table 3.3-4 and Table 3.3-5.

In addition, water quality monitoring was undertaken as part of the Interim Aquatic Ecosytem Monitoring Plan, establishing monitoring station FC, located upstream of the proposed shift upgradient for the Faro Valley West Diversion. Monitoring station FC is included as an RSA reference water quality monitoring station, rather than the Rose LSA, to group this site with a larger set of data, since only a preliminary characterisation could be provided, based on the limited 2005 to 2007 data available from this site (four samples in late 2007).

Water quality monitoring station FDU is located in Faro Creek immediately upstream of the Faro Creek diversion interception point. It is expected that the proposed closure plan changes to the diversion will place this station downstream of the diversion interception point. Water quality observed between 2005 and 2007 at location FDU is neutral to slightly alkaline, with low hardness (7 mg/L to 21.1 mg/L) and low alkalinity. Low total zinc and sulphate concentrations were observed over the study period, with median concentrations of 0.0025 and 1.76 mg/L, respectively. No historical temporal trends for the above noted parameters are apparent at this location. Total copper at location FDU exceeded the background benchmark and water quality guideline value (CCME) for one sampling event in October 2007. Total aluminum at location FDU exceeded the background benchmark (CCME) for one sampling event in October 2007Total zinc concentrations did not exceed the selected benchmark between 2005 and 2007.

Reference water quality in North Fork Rose Creek is measured at location R7. The pH at this location ranged from 7.5 to 8.3 and hardness ranged from 28 mg/L $CaCO_3$ to 147 mg/L $CaCO_3$. Total zinc concentrations range from below MDL (<0.001 or <0.005 mg/L to 0.035 mg/L). Total zinc concentrations exceeded the selected benchmark of 0.0164 mg/L three times, and the water quality guideline of 0.03 mg/L once, between 2005 and 2007. At R7 background benchmark was also exceeded for aluminum, arsenic, chromium, copper, iron, manganese, selenium and strontium. Dissolved zinc concentrations at W10 ranged from below MDL (<0.005 mg/L) to 0.0025 mg/L over the study period.

Water quality at station W10 represents reference water quality in Upper Guardhouse Creek, upstream of the northwest rock dump. Field pH ranged from 7.2 to 7.9 and sulphate concentrations were low, with a median concentration of 3.59 mg/L. Total zinc concentrations ranged from 0.0017 to 0.023 mg/L. Total zinc concentrations exceeded the background benchmark of 0.0164 mg/L once between 2005 and 2007. Dissolved zinc concentrations at W10 ranged from below MDL (<0.005 mg/L) to 0.006 mg/L over the study period. Total copper concentrations at location W10 met or exceeded the background benchmark and water quality guideline value (CCME) of 0.002 mg/L, on one sampling events.

Between 2005 and 2007, water quality at routinely monitored reference stations (FDU, R7, and W10) were typically below selected benchmarks. As previously noted, this would be expected since the benchmark concentrations were generally set at the upper 95% of the observed concentrations and since these stations were included in the development of the background benchmark values. Concentrations above the background benchmark were infrequently observed from 2005 to 2007 with the majority of concentrations elevated above the benchmark observed at location R7. Excluding silver and cadmium, where the summary statistics reflect method detection limits, maximum total metals concentrations observed at R7 exceeded water quality guidelines for aluminum, chromium, copper, iron, selenium and zinc.

Total aluminum, chromium, copper, and iron concentrations recorded above the guideline values at location R7 were generally associated with spring (mid-May) sampling events. Elevated suspended solids and significantly higher total iron and aluminum concentrations compared to dissolved concentrations were observed during these sampling events, suggesting that all elevated concentrations of these parameters are attributed to suspended solids. Total chromium, copper and selenium concentrations were only slightly elevated above the guidelines on these occasions. Total zinc exceeded the selected benchmark at location R7 during the January 2005 sampling event.

In summary, trace metal concentrations upstream of former mine/proposed closure activities in the North Fork of Rose Creek and in Faro Creek exceeded the background benchmarks infrequently for aluminum and copper and in Upper Guardhouse Creek infrequently for copper. In addition, total metals concentrations observed at R7 exceeded water quality guidelines for aluminum, chromium, copper, iron, selenium and zinc during a limited number of sampling events (less than 20% of the total sampling events for each parameter), and for aluminum, chromium, copper and iron, the observed concentrations are likely associated with elevated suspended solids during the spring freshet. Based on the background benchmark for cadmium, which included 2008 data and was higher than the water quality guideline, it is possible that cadmium concentrations also exceeded the water quality guidelines during 2005 to 2007, but this could not be evaluated since the MDL over this period for this parameter was higher than the guideline value.

3.3.7.2 Mine Runoff, Effluent and Internal Receiving Water Bodies

Previous studies have noted that sulphate and zinc concentrations undergo a general increase along the North Fork of Rose Creek from upstream reference station R7 to station X2, located at the crossing of the mine access road downstream of the rock drain and rock dumps (GLL 2008). This trend is typically observed during winter months, during low flow conditions. It is suggested that during winter baseflow conditions, groundwater entering the creek is influencing surface water quality; however, in summer months the signature of groundwater contributions are masked by dilution due to higher flow volumes.

Water chemistry at location X2 is circum neutral, with hardness concentrations ranging from 33 to 187 mg/L $CaCO_3$, depending on the season and the relative proportion of base flow and runoff. Zinc concentrations are typically an order of magnitude higher at this location in comparison to upstream reference station R7. Comparison of zinc concentrations over a larger temporal range (1998 to 2007) indicates an increasing trend over the last several years at location X2 (Figure 3.3-5). Sulphate concentrations are approximately two to three times higher at X2 compared to R7. Median and maximum copper concentrations at X2, however, are the same as at R7.

Recent investigations suggest that groundwater impacted by seepage from the adjacent waste rock piles is entering the channel via groundwater inflows between locations R7 and X2. Reviews of groundwater quality, seepage quality, surface water quality and flows in and along reaches of the North Fork of Rose Creek downstream of the Haul Road, (the area is commonly referred to as the "S-wells area") concluded that zinc loading to the creek was occurring along this section, and that the primary source of the zinc loading via the S-Wells area was from the Main East and Intermediate Waste Rock Dumps. The impact of the loading was most evident in winter, when the creek flows are dominated by groundwater base flows. The increasing trend along the studied section of the North Fork of Rose Creek is not apparent for other trace metals. While a rapid increase in sulphate was observed over time in groundwater, a rapid increase in sulphate loading was not observed in the North Fork of Rose Creek.

Aluminum, copper and iron concentrations were in the same range as those observed at R7, and as at R7, FDU and W10, maximum concentrations were observed to exceed water quality guidelines infrequently (<20% of samples). These higher values were observed during spring sampling each year, when total suspended solids were also elevated. Unlike at R7, lead concentrations were infrequently observed at or higher than the water quality guideline (7 of 32 samples). Lead maxima were observed generally during spring sampling.

Water quality in the South Fork of Rose Creek is monitored at R1. The headwaters of the South Fork of Rose Creek are upstream of the Haul Road and just to the west of the divide between the catchment for the West Fork of Vangorda Creek and the Rose Creek watershed. Location R1 is downstream of the Haul Road, downstream of the previous freshwater reservoir area and upstream of the pumphouse pond.

pH at R1 was neutral to slightly alkaline, ranging from 7 to 8, approximating the pH of reference sites. Hardness approximated the range observed in the reference site of the North Fork of Rose Creek (R7), with a median of 116 mg/L $CaCO_3$.

At R1, many total metals concentrations are lower than background benchmark concentrations. Iron, manganese, nickel and strontium concentrations are the exceptions to this. Iron median concentrations at R1 exceed the CCME water quality guideline of 0.3 mg/L and a maximum of 0.405 mg/L was observed between 2005 and 2007. Maximum copper concentrations meet the CCME based water quality guideline of 0.002 mg/L. Total zinc concentrations ranged from 0.0007 to 0.013 mg/L and sulphate ranged from 13.4 to 29.6 mg/L.

Station X3 is located at the outflow of the pumphouse pond, which is downstream of the confluence of the North and South Forks of Rose Creek. A small portion of the flow from the North Fork of Rose Creek bypasses the pumphouse pond during high flow events via a secondary diversion channel that was constructed in previous years. This "bypass" flow enters the Rose Creek diversion channel immediately downstream of the pumphouse pond, and therefore downstream of X3.

Sulphate concentrations at location X3 ranged from 5.9 to 45.9 mg/L, with a median concentration of 21.9 mg/L. Zinc concentrations at this site followed previously established trends, with maximum concentrations observed during the spring, followed by a decrease to lower concentrations by the next

sampling event. From 2005 to 2007, the total zinc concentrations at location X3 ranged from 0.006 and 0.14 mg/L, and the 75-percentile concentration was higher than the water quality guideline.

As with R7 and X2, aluminum, copper and iron at X3 were observed to exceed the water quality guideline from 2005 to 2007, and concentrations at X3 were roughly in the same range as at R7 and X2. These higher concentrations were generally observed during spring sampling, and at times when total suspended solids were relatively high. During one spring sampling event, chromium was observed at a level higher than the detection limit, and therefore higher than the water quality guideline at X3.

Station X3 represents the upstream extent of the constructed diversion channel that passes Rose Creek around the tailings facility. The downstream extent of the diversion is represented at station X10, which is just upstream of the confluence with the discharges at X13 and X5.

Locations X2, X3, and X10 generally follow the same trends in zinc and sulphate concentrations, with seasonal fluctuations of both zinc and sulphate and higher concentrations typically observed during winter months (Figure 3.3-6 and Figure 3.3-7).

Between 2005 and 2007, total zinc concentrations at X10 ranged from 0.011 mg/L to 0.10 mg/L, comparable to water quality observed at this location since the cessation of mining activities in 1998. Total zinc concentrations at location X10 exceeded the water quality guideline of 0.03 mg/L for half of the sampling events conducted between 2005 and 2007. Minimum total zinc concentrations at this location are comparable to reference water quality, while the upper concentration range of 0.1 mg/L is approximately one order of magnitude higher than reference station concentrations.

The median sulphate concentrations from 2005 to 2007 at X10 was 25.4 mg/L, and was generally in the same range as at X2. At location X10, no apparent historical trends were observed. Trace metal concentrations at this location have remained low since 1998. Aluminum, copper and iron concentrations infrequently exceeded water quality guidelines in less than 15% of the total sampling events, as they did at R7, X2, and X3. These exceedances generally occurred in the spring, and in conjunction with relatively high suspended solids concentrations. Lead concentrations at X10 met or slightly exceeded the water quality guideline of 0.002 mg/L during five sampling events, also generally in the spring. This is also consistent with lead concentrations observed at X2, and X3.

Water that has had contact with mining activities is treated and discharged from the site, via outflow from the Cross Valley Pond (Station X5). Combined seepage flows from the Cross Valley Dam are monitored at station X13. These two water streams mix with water from the Rose Creek Diversion Channel (which contains diverted clean water and water that may have interacted with mine infrastructure/components).

The discharge of water from the Faro site occurs as seasonal discharge over the Cross Valley Dam (Site X5) The discharge consists of treated Faro Pit and Intermediate Pond water and overland runoff from the mine site, and in 2005 and 2006, water treated in the Down Valley Treatment System. In 2007, water collected from site runoff, including the Emergency Tailings Area (ETA), was collected and discharged in the Intermediate Pond. Water from the Intermediate Pond was then pumped for treatment in the Mill Water Treatment System, with treated effluent discharged into the Cross Valley Pond prior to release via X5.

Water quality at X5 and X13 was sampled on a regular basis starting in 1986. Prior to 1992, water quality in the Cross Valley Pond was controlled primarily by the characteristics of the settled tailings supernatant from upstream deposition of mill tailings. Zinc and sulphate concentrations averaged 0.24 and 436 mg/L, respectively, and pH ranged from 6.7 to 9.6. Seepage from the pond had lower pH levels (6.1 – 7.8), and zinc concentrations ranged from 0.01 to 0.167 mg/L. Iron levels in the seepage (X13) averaged 2.0 mg/L.

Discharge water quality conditions from 1998 to 2007 at X5 showed moderate to high levels of calcium (12.8 mg/L to 361 mg/L) as a result of lime treatment upstream. This was also evident at X13 seepage water. Sulphate concentrations generally remained stable from 1998 to 2002; however, a slight increasing trend was apparent between 2002 and 2007 (Figure 3.3-8). Sulphate concentrations in effluent discharged from the Cross Valley pond between 2005 and 2007 ranged from 74.2 mg/L to 1,180 mg/L and pH ranged from neutral to alkaline (7.1 to 8.8). The pond is effective in settling solids, as total suspended solids ranged from <1 to 5 mg/L (2005 to 2007), below the guideline value of 8 mg/L, which is based on the CCME guideline of not more than 5 mg/L above background.

Zinc concentrations increased to an average of 0.334 mg/L in the dam discharge from 1998 to 2002, compared to 0.24 mg/L during operations. This was likely related to the periodic introduction of a relatively large volume of water pumped from the Faro Main pit beginning in 1998, which was ultimately released to Rose Creek as treated and compliant effluent via location X5.

The implementation of the Mill Treatment system in 2001 resulted in lower zinc concentrations in effluent discharged via X5 than those observed in previous years (Figure 3.3-9). Total zinc concentrations in effluent discharged from 2005 to 2007 via location X5 ranged from 0.018 mg/L to 0.47 mg/L (2005 to 2007), with a median concentration of 0.15 mg/L. Approximately 98% of zinc concentrations at X5 exceeded the CCME Guideline for the Protection of Aquatic Life of 0.03 mg/L. Total zinc concentrations at X5 were approximately one order of magnitude higher in comparison to those of reference (background) stations.

In addition to moderate to high calcium levels, other parameters that were observed to be elevated at X5 compared to the Rose Creek Diversion included cobalt, manganese, and selenium. Median values exceeded the water quality guidelines at X5 from 2005 to 2007 for cobalt and manganese. Cobalt concentrations were slightly higher than atreference sites and X10, and sites upstream of X10. Manganese concentrations at X5 ranged from 0.86 mg/L to 26.5 mg/L, approximately two to four orders of magnitude higher than concentrations (0.001 to 0.15 mg/L) observed at reference stations FDU, R7 and W10. The 75th percentile value met the water quality guidelines at X5 from 2005 to 2007 for selenium. While this was in the range of concentrations observed at R7, selenium was below detection limits at X10 and all stations upstream of X10, except R7.

Other trace metal concentrations at location X5 remained low throughout the study period (2005 to 2007). Strontium concentrations were slightly higher at X5 than at stations upstream of the tailings impoundment and X10, but did not exceed the water quality guideline. While the copper maximum at X5 exceeded the water quality guideline, similar to the reference stations, the aluminum maximum at X5, did not. Aluminum concentrations were therefore higher at reference locations than at X5.

Cyanide at X5 exceeded the CCME water quality guideline in 45% of sampling events from 2005 and 2007, while ammonia (NH_3-N) exceeded the water quality guideline of 0.24 mg/L in all but one of the 67 sampling events, for the same period.

Zinc concentrations in the Cross Valley Pond seepage (location X13) were reduced during the care and maintenance phase following mine closure. They averaged 0.039 mg/L between 1998 and 2002, approximately 15% of the concentrations recorded during mine operations. Zinc concentrations increased (average of 0.334 mg/L) in the dam discharge during the care and maintenance phase, compared to 0.24 mg/L during operations, likely related to the periodic introduction of a relatively large volume of water pumped from the Faro Main pit beginning in 1998, which was ultimately released to Rose Creek as treated and compliant effluent via location X5. Zinc concentrations in the seepage at X13 were generally less than those observed at X5 and were comparable to reference water quality, ranging from below MDL (<0.005 mg/L) to 0.015 mg/L between 2005 and 2007 (Figure 3.3-10). The median sulphate and pH values were 756 mg/L and 7.2, respectively, for the same time period.

At location X13, manganese and iron concentrations had median values of 10.4 and 2.05 mg/L, respectively, with concentrations exceeding the water quality guidelines for all sampling events recorded between 2005 and 2007. Manganese and iron concentrations at X13 were typically one to three orders of magnitude greater than concentrations observed at reference stations.

The median cobalt value at X13 from 2005 to 2007 exceeded water quality guidelines. Cyanide water quality guidelines were exceeded once at X13 between 2005 and 2007.

As at X5, other trace metal concentrations at location X13 remained low throughout the study period (2005 to 2007). Strontium concentrations were slightly higher at X13 than at stations upstream of the tailings impoundment and X10, but did not exceed the water quality guideline. While the copper maximum at X13 exceeded the water quality guideline, similar to the reference stations, the aluminum maximum at X13, did not. Aluminum concentrations were therefore higher at reference locations than at X13.

Water quality downstream of the mine site is influenced by the discharge of compliant effluent from the Cross Valley Pond, seepage from the dam, groundwater inflows from the Rose Creek Aquifer and inflows from in the Rose Creek Diversion Channel, which contain source loadings from surface runoff and groundwater inputs from mine areas and waste rock dumps via the North Fork of Rose Creek. Water quality within the local study area and downstream of the mine site is regularly monitored at location X14.

Sampling station X14 is located downstream of the confluence of effluent discharges (locations X5 and X13) and Rose Creek. It is located downstream of the mixing zone of flows that pass by stations X5, X13, and X10. Water quality observed at location X14 is significantly influenced during periods of active discharge of treated effluent from the Cross Valley Pond. Sulphate and zinc concentrations typically increase during periods of active discharge (summer months), with peak annual concentrations observed in concert with initiation of active discharge in the spring (Figure 3.3-11: concentrations ~100 m downstream of X14 at station R2 are also shown in this figure).

Total zinc concentrations had a median value of 0.033 mg/L between 2005 and 2007, slightly elevated in comparison to reference stations, but in a similar range to medians observed at X2, X3 and X10. Total zinc exceeded the selected benchmark during 55% of the sampling events. Sulphate concentrations at this location were approximately 5 to 10 times higher than reference concentrations, ranging from 16.8 to 704 mg/L (Table 3.3-6). (Figure 3.3-12, along with R2 sulphate).

The water at X14 was neutral to slightly alkaline, with hardness concentrations ranging from 54 to 812 mg/L $CaCO_3$ (Table 3.3-6). Aluminum, copper, and lead exceeded the water quality guidelines during 12 to 13% of all sampling events between 2005 and 2007, and concentrations were slightly higher than those observed at X2, X3 and X10. Median manganese concentrations exceeded the water quality guideline of 1.0 mg/L on several occasions (33%), as was seen at X5 and X13. Cobalt concentrations were also higher than at X10 and stations upstream of X10, although concentrations higher than the water quality guideline were observed infrequently (less than 20% of samples). Total iron concentrations exceeded the selected benchmark of 0.3 mg/L for during half of the sampling events between 2005 and 2007. This may have been due to high iron observed from X13 seepage, since the relatively higher concentrations observed at R1, were not observed between X3 and X10. The ammonia maximum at X14 was higher than the water quality guideline.

3.3.7.3 Rose Creek Watershed Surface Water Quality Summary

In summary, baseline water quality conditions in the Rose Creek Watershed are characterized by:

- circumneutral to alkaline conditions, low total suspended solids, low sulphate concentrations with trace metals of aluminum, cadmium, chromium, copper, iron, selenium and zinc exceeding the CCME guideline for the protection of aquatic life in reference waters;
- elevated iron observed in the South Fork of Rose Creek, upstream of its confluence with the North Fork;
- concentrations of calcium, cobalt, manganese, and sulphate in effluent released from the Cross Valley Pond that were several orders of magnitude above reference water quality, and elevated concentrations of ammonia, iron, lead, selenium, and zinc above reference and X10 and upstream concentrations;
- concentrations of calcium, cobalt, iron, manganese, and sulphate seepage from the Cross Valley Pond that were several orders of magnitude above reference water quality, and elevated concentrations of ammonia, above reference and X10 and upstream concentrations, with the exception of at R1;
- water quality immediately downstream of the mine site reflects the signature of mine discharge, with elevated concentrations of trace metals above water quality guidelines including calcium, cobalt, copper, iron, manganese, selenium and zinc; and
- water quality immediately downstream of the mine site also reflects elevated aluminum that is not seen from the Cross Valley Pond discharge or seepage.

3.3.8 Vangorda Watershed Surface Water Quality

3.3.8.1 Reference Water Quality

Location V1 is in the Main Fork of Vangorda Creek, immediately upstream of mine activities. This location provides background reference stream water quality for Vangorda Creek upstream of the mine site. Location V1 was sampled seventeen times between 2005 and 2007. An additional reference station, site VR, was monitored five times as part of the Pelly River Aquatics Effects Assessment in 2007. Site VR is located in the

west fork of Vangorda Creek, upstream of the haul road (Figure 3.3-3). Reference site water quality data are provided in Table 3.3-8. Water quality data from monitoring programs other than routine monitoring for water licence compliance purposes are provided in Appendix B2.

Other water quality stations, including V4 and V20 were used to characterize reference water quality during the 2003 environmental assessment for care and maintenance activities (GLL 2003a). Although these locations do not directly receive mine discharge inflows, these location are not physically located upstream of mine infrastructure including waste rock piles, and therefore have not been included in the characterization of reference water quality. Station V4 has been characterized later in this document.

Between 2005 and 2007, sulphate concentrations ranged from 3.62 to 12.4 mg/L, and pH was neutral to slightly alkaline ranging from 6.37 to 8.3 for station V1. The stream waters were clear, with total suspended solids levels of less than 1 to 3 mg/L. Ammonia concentrations were less than detection limit (0.01mg/L) for all sampling events between 2005 and 2007 with the exception of the June 2005 sampling event (0.03 mg/L). Sulphate concentrations during this period were also similar to historical concentrations, including a seasonal sulphate trend, with slightly higher concentrations observed during winter months (Figure 3.3-13). Reference stream water quality for 2005 to 2007 had low to moderate hardness ranging from 13 to 59 mg/L $CaCO_3$.

Trace metal concentrations in reference waters indicate mineralized geology, with detectable concentrations of most trace metals (Table 3.3-9). Aluminum, arsenic, chromium, copper, iron, manganese, nickel, lead, strontium and zinc in Upper Vangorda Creek generally did not exceed the selected benchmarks between 2005 and 2007, while total metal concentrations for silver, arsenic, boron, cadmium, cobalt, chromium, copper, nickel, lead, selenium, antimony, thallium, tin and vanadium were generally less than the detection limit.

Total zinc concentrations ranged from 0.0006 mg/L to 0.038 mg/L. Zinc concentrations in 2007 were similar to those previously recorded between 1998 and 2007 at this site (Figure 3.3-14). Total iron concentrations ranged from 0.005 to 0.14 mg/L and were below the guideline benchmark of 0.246 mg/L for all sampling events between 2005 and 2007. Lower detection limits used for samples collected at V1 through additional monitoring programs indicate that cadmium concentrations did not exceeded the background benchmark concentration of 0.00004 mg/L (Appendix C3). Silver concentrations remained below the detection limit during this monitoring program. Higher detection limits reported during routine monitoring programs prevent the comparison of cadmium and silver concentrations to background benchmarks for this dataset.

Water quality at station VR during 2007 was comparable to V1, with neutral pH, low hardness, alkalinity, and sulphate concentrations. Total zinc concentrations ranged from 0.009 to 0.0049 mg/L, with all recorded concentrations below the benchmark value of 0.0164 mg/L. Low detection limits employed during analyses of samples collected from this location facilitate comparison of cadmium and silver to background benchmark concentrations, as detection limits were below benchmarks for these analyses. One recorded cadmium concentration (0.000036 mg/L) was slightly below the CCME derived benchmark of 0.00004 mg/L in October 2007, whereas silver concentrations remained below the detection limit for all five samples collected. Other parameters were generally below benchmark concentrations. Limited data prevents the analyses of seasonal trends at this site.

3.3.8.2 Mine Runoff and Effluent

Mine runoff water and effluent from the Vangorda Plateau enter the receiving water, Vangorda Creek, at five locations as follows.

1. Location V25BSP is the outlet of the Sheep Pad Pond, which includes periodic or seasonal release of effluent from the Grum/Vangorda water treatment plant. There is typically no flow at this location in the winter season.
2. Location V2 is the outlet of Grum Creek that includes runoff from the Grum rock dump.
3. Location V6A is the outlet of AEX Creek that includes runoff from the ore transfer pad.
4. Location V4 is at Shrimp Creek upstream of the confluence with the Main Fork of Vangorda Creek.
5. Location V27 is in the Main Stem of Vangorda Creek, immediately below the mine site and upstream of the confluence with Shrimp Creek.

Water quality at V25BSP, V2, and V6A were sampled on a regular basis starting in 1996, 1988 and 1989, respectively. Data for the five sites above for the 2005 to 2007 timeframe is summarized in Table 3.3.-10 and Table 3.3.-11.

Sheep Pad Pond

Location V25BSP was created in 1995 as part of the sediment mitigation activities that rerouted the Grum Interceptor Ditch into the Sheep Pad Pond. Location V25BSP consists of all water that enters Vangorda Creek via the Sheep Pad Pond, including water discharged from the water treatment plant/clarification pond and natural runoff. Location V25BSP is a licence discharge location and is a point of compliance for water entering Vangorda Creek from the Sheep Pad Pond. Sampling is undertaken weekly during periods of discharge from the water treatment plant and monthly at other times.

The concentrations of total suspended solids at location V25BSP were below the maximum allowable discharge limit of 15 mg/L, with the exception of the May 2005 sample (34 mg/L). Hardness was elevated between 2005 and 2007 in comparison to reference stations V1 and VR, ranging from 63 to 1,300 mg/L $CaCO_3$.

The concentrations of sulphate ranged from 27.8 to 1340 mg/L with peak concentration occurring during August 2005. The peak concentration observed in August 2005 is well above the maximum concentration seen in 2006 and 2007 (Figure 3.3-15). The pH ranged from 7.0 to 8.3, neutral to slightly alkaline. Ammonia levels were elevated (0.12-0.46 mg/L) during the summer of 2005 to levels consistently above the Vangorda reference stations maximum of 0.030 mg/L. In 2006 and 2007 ammonia concentrations were detectable, but low (<0.01 to 0.04 mg/L) and within Vangorda reference stations concentrations.

The concentrations of total and dissolved zinc ranged from 0.026 mg/L to 0.26 mg/L and from <0.005 to 0.27 mg/L, respectively, between 2005 and 2007. The median concentration of total zinc was moderately elevated at 0.0755 mg/L in comparison to the median of reference location V1 (0.0025 mg/L). All total zinc concentrations were greater than the median of reference location V1 (0.0025 mg/L). The highest zinc concentration (0.26 mg/L) occurred in April 2005.

The total cadmium, copper, iron, and lead concentrations ranged from 0.0002 mg/L to 0.0048 mg/L, <0.001 mg/L to 0.018 mg/L, <0.05 mg/L to 2.12 mg/L and <0.001 mg/L to 0.008 mg/L, respectively. Maximum iron and lead concentrations correspond with maximum total suspended solid concentrations observed during spring sampling events.

The signature of treated effluent is apparent in existing water quality at V25BSP, particularly throughout 2005, through comparison to water quality at the reference location (V1). The concentration of calcium and hardness is higher during periods of lime treated effluent discharge. Figure 3.3-16 illustrates the elevated calcium signature at V25BSP during active treatment prior to 2006. No treatment was required in 2006 and 2007 due to substantial drawdown and treatment of pit water in 2005. Ammonia is slightly elevated above reference water quality and sulphate is elevated by one order of magnitude. Concentrations of cadmium, manganese and zinc were elevated by an order of magnitude over concentrations in the reference stream. Concentrations of silver, arsenic and iron were below concentrations observed at the reference locations. Concentrations of copper and lead are similar to reference locations.

Existing water quality conditions at location V25BSP reflect a source of ongoing metals loadings to the receiving environment. Of most concern is zinc because of a combination of elevated loadings and relatively high toxicity. Relatively high concentrations of sulphate are also discharged. Sulphate concentrations serve as a good indicator of mine influence on receiving waters, but are relatively non-toxic to aquatic life in comparison to other contaminants of concern. Elevated concentrations of manganese are also discharged in comparison to reference water quality.

Grum Creek

Location V2 is in Grum Creek upstream of entry its into Vangorda Creek. The changes to the water management system implemented during 1995 and 1996 diverted a large portion of the Grum Creek catchment area into the Sheep Pad Pond and this, in combination with the interception of shallow ground water by the Grum open pit, reduced the flow in Grum Creek substantially from its original (i.e., pre-mine) levels.

Location V2 was sampled monthly or bimonthly for the period of 2005 to 2007. The concentration of total suspended solids at location V2 continued to be greatly improved over previous years prior to about 1996. The concentrations of total suspended solids ranged from less than 1 mg/L to 18 mg/L between 2005 and 2007 and were below the maximum allowable discharge limit of 15 mg/L with the exception of the January 2005 sampling event (18 mg/L). The pH, being neutral to slightly alkaline, ranged from 7.5 to 8.3.

The concentrations of sulphate at location V2 between 2005 and 2007 ranged from 554 mg/L to 1,160 mg/L (Figure 3.3-17). An increasing trend in the concentration of sulphate at V2 is evident from 1989 (beginning of sample record) through 2005, with a sharp increase observed between 2000 and 2005. Sulphate concentrations appear to have stabilized over the last two years. There has not been a corresponding increase in the concentrations of total or dissolved zinc. This trend in sulphate is consistent with upstream location V15. The sulphate concentrations are higher at location V15, which is reasonable given that it is a smaller flow closer to the suspected source, the Grum rock dump.

The hardness at V2 was elevated between 2005 and 2007 in comparison to reference concentrations, 13 to 59 mg/L, between 2005 and 2007.

The concentrations of total and dissolved zinc at location V2 between 2005 and 2007 ranged from less than 0.005 mg/L to 0.074 mg/L and from <0.001 mg/L to 0.11 mg/L, respectively (Figure 3.3-18). Total copper and iron concentrations ranged from 0.01 mg/L to 0.02 mg/L and <0.01 mg/L to 0.63 mg/L, respectively. Total lead concentrations were 76% less than detection limit for samples between 2005 and 2007 with a median of 0.0005 mg/L, which is the same as the median concentration for reference station V1. The median concentration of total zinc was slightly elevated above reference water quality at 0.018 mg/L.

The signature of runoff and seepage from the Grum Rock Dump was apparent in existing water quality at location V2 as compared to water quality at the reference locations. The concentrations of calcium and hardness were elevated by one order of magnitude. Ammonia was slightly elevated above reference concentrations and sulphate concentrations were higher than reference by one order of magnitude. Concentrations of arsenic, copper, iron, manganese, nickel, lead and zinc were elevated from the reference location V1. Total aluminum concentrations were within ranges typically observed within reference water quality.

AEX Creek

Location V6A is in AEX Creek immediately upstream of its entry into the West Fork of Vangorda Creek. AEX Creek at this location includes the tributary sampled at upstream location V17A which receives runoff from the slopes north of Grum Pit and the Ore Transfer Pad. Location V6A was sampled fourteen times between 2005 and 2007. The concentrations of total zinc ranged from 0.013 to 0.031 mg/L and dissolved zinc concentrations were 0.011 to 0.029 mg/L. The total zinc concentrations for V6A were greater than the reference station V1. Total lead concentrations ranged from less than 0.00036 to 0.0020 mg/L. Total iron and copper concentrations ranged from 0.076 to 0.61 mg/L and 0.00038 to 0.0030 mg/L, respectively.

The concentrations of sulphate between 2005 and 2007 ranged from 13.6 to 53.5 mg/L. These concentrations are consistent with those observed since mine shut down in 1998. The pH between 2005 and 2007 was neutral to slightly alkaline ranging from 7.4 to 8.3. Ammonia levels were detectable, but low, with the exception of the September 2007 sampling event (0.32 mg/L).

Hardness was slightly elevated above reference concentrations and median sulphate concentrations were three times higher than at reference station V1. Concentrations of aluminum, calcium, copper, iron, magnesium manganese, nickel, lead, strontium and zinc were elevated from the reference location V1.

Water quality at location V6A in AEX Creek was only slightly degraded compared to that at the reference locations. This indicates that runoff from the ore transfer pad and haul road (in the AEX Creek drainage area) was not having a significant effect in AEX Creek and was therefore indicative of minimal mine-related metals loadings to the receiving environment.

Shrimp Creek

Location V4 is on Shrimp Creek upstream of the confluence with the Main Fork of Vangorda Creek. This location provides reference information regarding water quality in the Shrimp Creek area being impacted by the Vangorda plateau and includes inflows from the upstream tributary sampled at location V20.

Location V4 was sampled twelve times between 2005 and 2007. Total and dissolved zinc concentrations ranged from 0.0013 to 0.0090 mg/L and 0.0013 to 0.0080 mg/L, respectively. Sulphate concentrations ranged from 22.5 mg/L to 63.7mg/L. Station V4 had slightly alkaline pH ranging from 7.92 to 8.30.

Conductivity, hardness and sulphate were slightly elevated above their values at reference stations. Concentrations of arsenic, calcium, copper, iron, magnesium manganese, nickel, and strontium were elevated from the reference location V1. Concentrations of aluminum, lead and zinc concentrations were within the ranges seen at reference station V1.

Vangorda Creek Main Stem

Location V27 is in the Main Stem of Vangorda Creek, immediately below the mine site and upstream of the confluence with Shrimp Creek. All surface water from the Grum rock dump, the Grum Interceptor Ditch/Sheep Pad Pond, and the Vangorda Northeast Interceptor Ditch reports to location V27 via Grum Creek or the Vangorda Creek plunge pool. This location is internal to the local study area, but is influenced by the discharge of treated and compliant effluent and other runoff waters and by mixing with water from the Vangorda Creek Diversion Flume.

Between 2005 and 2007, sulphate ranged from 8.46 to 106 mg/L, pH from 7.5 to 8.3 and total zinc from 0.016 to 0.0318 mg/L. Historical trends of zinc indicated a peak in concentration in 2003 to 0.175 mg/L, followed by a decline and subsequent stabilization to concentrations observed during recent years (2005 to 2002), averaging 0.0246 mg/L. Zinc concentrations were elevated at location V27 in comparison to reference water quality. The total iron concentrations between 2005 and 2007 were comparable to reference stations, with the exception of the June 2007 sampling event. The June 2007 sampling had the maximum observed total suspended solids concentrations between 2005 and 2007. Total copper and lead concentrations were low, but detectable ranging from less than 0.001 to 0.002 mg/L. Analytical detection limits for cadmium used during the routine monitoring program were too high to compare to the reference locations with the exception of three samples taken during the fall of 2007. Lower detection limits employed during the IAEAMP indicate that cadmium concentrations were elevated above the reference location by one order of magnitude.

The waters at location V27 continued to show elevated levels of some metals as compared to the reference locations throughout the baseline study period. However, elevated concentrations of aluminum, cadmium, calcium, copper, iron, manganese, nickel, lead, strontium and zinc suggest impairment from mining related drainage. Concentrations of arsenic, cobalt and silver were the same as, or less than, concentrations at the reference water quality sites at locations V27.

In summary, receiving water quality in the main stem of Vangorda Creek contained elevated concentrations of aluminum, iron, copper, manganese, nickel, zinc and sulphate when compared to reference water quality.

Most metals concentrations that exceeded those at the reference water quality stations occurred during discharge periods (2005) and were therefore short-term events.

3.3.8.3 Receiving Water Quality

Vangorda Main Stem

Location VGMAIN is at the extent of the local study area on the Main Stem of Vangorda Creek immediately upstream of the confluence with the West Fork. VGMAIN includes water from the Main Stem via location V27, plus water from Shrimp Creek via reference location V4, plus natural runoff into the creek below Shrimp Creek. Routine sampling was introduced here in 1997. Historic seasonal trends for sulphate continued throughout the baseline study period, with higher sulphate concentrations typically observed during the winter season. Waters at this location were neutral to alkaline, with low to moderate alkalinity. Total zinc ranged from 0.010 to 0.086 mg/L (averaging 0.0208 mg/L), with concentrations elevated in comparison to reference locations. Total cadmium and lead were generally less than the detection limits of 0.0002 mg/L and 0.001 mg/L, respectively, for routine monitoring. Total iron concentrations at VGMAIN ranged from <0.05 to 0.95 mg/L. The May 2005 sampling event had the maximum observed total suspended solids concentrations (23 mg/L) between 2005 and 2007. The median total copper concentration between 2005 and 2007 was 0.0005 mg/L and was the same as the median for reference station V1.

The receiving waters at location VGMAIN (Table 3.3-12 and Table 3.3-13) continued to show elevated levels of some metals compared to the reference locations between 2005 and 2007. Comparison of water quality in Vangorda Creek with that in the mine runoff water showed substantial dilution and assimilation of mine water in the receiving environment. Spatial comparison of water quality at location VGMAIN shows that most metals were reduced in concentration along the length of the main stem of Vangorda Creek. Elevated concentrations of iron, manganese, nickel, strontium and zinc, however, suggest impairment to receiving water quality from mining related drainage. Concentrations of aluminum, arsenic, cadmium, copper, cobalt, lead and silver were the same as, or less than, concentrations at the reference water quality sites at the receiving water location VGMAIN.

In summary, receiving water quality in the main stem of Vangorda Creek contained elevated concentrations of aluminum, iron, copper, manganese, nickel, zinc and sulphate when compared to reference water quality. Most metals that exceeded the reference water quality stations occurred during discharge periods (2005) and were therefore short-term events.

Vangorda Creek West Fork

Location V5 is at the downstream boundary of the local study area in the West Fork of Vangorda Creek, immediately upstream of the confluence with the Main Stem. V5 includes runoff water from AEX Creek, plus a portion of the Grum Rock Dump (excluding the sulphide cell), plus natural runoff into the creek below the mine access road. Routine sampling was introduced here in 1991. From 2005 to 2007, water quality at this site was slightly alkaline, circum neutral (pH 7.4 to 8.4), with sulphate concentrations (28 to 174 mg/L) typically above reference sites. Total zinc concentrations ranged from 0.0039 to 0.046 mg/L, comparable to reference water quality. Sulphate and hardness concentrations typically followed pre-established seasonal

trends, with higher concentrations associated with winter conditions, when surface runoff was minimal (GLL 2008). On occasion sediment loading was also very high at location V5 (range from 2 to 249 mg/L total suspended solids), which was attributed primarily to sediment flushed into the creek during freshet originating from “non-mine” areas such as the landslide area and the old ski hill area.

During 2005 to 2007, the receiving waters at location V5 (Table 3.3-12 and Table 3.3-13) continued to show elevated levels of some metals compared to the reference locations. Receiving water quality was impaired when compared with the selected benchmarks for sulphate, aluminum, chromium, copper, and iron. Concentrations of silver, cadmium and were similar, or less than concentrations at the reference water quality site (V1). Concentrations of aluminum, arsenic, copper, iron, manganese, nickel, lead and zinc were slightly greater than at the reference sites.

In summary, during the baseline study period (2005 to 2007), receiving water quality in the West Fork of Vangorda Creek contained elevated concentrations of aluminum, copper, iron, zinc, sulphate and total suspended solids when compared to reference water quality and selected benchmarks.

Vangorda Creek Downstream of Confluence of Main Stem and West Fork of Vangorda Creek

The area downstream of the immediate receiving waters for the Vangorda Plateau site is described by water quality at location V8, immediately upstream of its discharge to the Pelly River. This includes flow from the Main Stem via location VGMAIN, plus flow from the West Fork via location V5, plus natural runoff into the creek below the confluence of the Main Stem and West Fork along the north perimeter of the Town of Faro. The Town of Faro water supply is taken from groundwater wells located at the entry of Vangorda Creek into the Pelly River.

From 2005 to 2007, water quality at this site was variable with sulphate ranging from 33.3 to 312 mg/L, pH from 7.3 to 8.5 and zinc from 0.007 to 0.064 mg/L (averaging 0.019 mg/L). Seasonal trends in sulphate mirrored those observed upstream, with elevated concentration typically observed during winter months. On occasion sediment loading was also high at location V8 (ranging from less than 1 to 67 mg/L total suspended solids), which is attributed primarily to natural sources and which was also seen at station V5, upstream.

From 2005 to 2007, the receiving waters at location V8 (Table 3.3-12 and Table 3.3-13) continued to show elevated levels of some metals as compared to the reference locations. Aluminum, copper, iron, manganese strontium and zinc are elevated compared to reference location V1. Concentrations of arsenic, chromium, cobalt and lead were the same as, or less than, concentrations at the reference water quality site. Concentrations of cobalt, manganese, nickel, and zinc were slightly greater than the reference sites. Sediment loading continued to be elevated during freshet at location V8 (range up to 67 mg/L total suspended solids), which is attributed primarily to the influence of natural debris.

In summary, receiving water quality contained elevated concentrations of aluminum, copper, iron, manganese, nickel, strontium, sulphate and total suspended solids when compared to reference water quality.

3.3.8.4 Vangorda Watershed Surface Water Quality Summary

The existing water quality for the Vangorda Plateau Mine Site is described by the following:

- Alkaline conditions, low solids and concentrations of some metals which exceeded background benchmarks in reference waters isolated from mine influence;
- Entry into Vangorda Creek of mine runoff and effluent waters from the Sheep Pad Pond and Grum Creek, which contained calcium, hardness, cadmium, zinc, sulphate and manganese at concentrations that were an order of magnitude above reference levels, and other trace metals that exceeded reference levels by a factor of two;
- Water quality in the main stem of Vangorda Creek downstream of the mine facilities, which reflected the influence of the mine facilities as elevated levels of aluminum, copper, manganese, nickel, iron, zinc and sulphate;
- Water quality in the West Fork of Vangorda Creek downstream of the mine facilities, which reflected the influence of the mine facilities as elevated levels of aluminum, copper, iron, manganese, nickel, lead and zinc; total suspended solids was also elevated between 2005-2007 and this was attributed to a natural debris flow; and
- Water quality in the main stem of Vangorda Creek upstream from the confluence of the Pelly River has elevated concentrations of aluminum, copper, iron, manganese, nickel strontium, zinc and sulphate in comparison to the reference locations.

3.3.9 Regional Study Area Water Quality, Rose/ Anvil/ Pelly River

The Pelly River flows through Selkirk First Nation traditional territory, downstream of the Faro Mine Complex. Vangorda Creek drains into the Pelly River, as does Anvil Creek. Rose Creek drains into Anvil Creek. Water quality sampling sites used to characterize regional water quality within Rose Creek, Anvil Creek and the Pelly River are listed in Table 3.3-14, and are shown in Figure 3.3-1. Water quality data is compiled in Appendix B2.

The IAEMP was implemented in 2007 to delineate water quality for assessment purposes and development of site-specific water quality objectives using improved detection limits. It should be noted that although there is duplication in station names between the Pelly River Aquatic Effects Assessment (PRAEA) program and the IAEMP, sample locations are not consistent. Analytical detection limits used for the IAEMP were improved over previous programs, allowing comparison to low level water quality benchmarks, including those for cadmium and silver. The samples provide only a preliminary characterisation of these sites, since they were sampled only four times at the end of 2007.

The reference sites noted above supplement the reference stations characterised as part of the Rose LSA and the Vangorda LSA. They add data for significant flows not included within the area of the RSA, but that contribute to the Pelly River downstream of the possible mine influence. Monitoring station FC is also added and the rationale for adding FC is explained below. Water quality for all RSA reference stations is summarised in Table 3.3-15 and Table 3.3-16.

In Faro Creek, a monitoring station was established in 2007 upstream of existing station FDU as part of the Interim Aquatic Ecosystem Program. It is expected that Rose LSA reference station FDU will be downstream of the Faro Valley West Interceptor when it is moved as part of the closure plan. As previously noted, the characterisation of this site is considered preliminary.

Water chemistry at this location is slightly acidic to slightly alkaline, with low alkalinity and low hardness suggesting sensitivity to acidic inputs. Sulphate and total zinc concentrations are low, ranging from 1.2 mg/L to 2.9 mg/L, and 0.0015 mg/L to 0.0061 mg/L, respectively. These concentrations are comparable to those at the downstream monitoring location FDU. Lower analytical detection limits employed for these analyses allowed comparison of cadmium and silver to selected benchmark values. Neither cadmium nor silver concentrations exceeded the selected benchmarks during these sampling events (Appendix B2); however, further monitoring with ultra-low detection limits will be required to evaluate seasonal variability as these samples represent low flow conditions only. No background benchmarks were exceeded during this sampling program at location FC with the exception of chromium, where one sample had the same concentration (0.001 mg/L) as the benchmark value. Aluminum was lower than the water quality guidelines (as previously noted, the background benchmark concentrations of aluminum and cadmium were higher than the water quality guideline). Water quality at location FDU was also monitored under this sampling program in March 2007. Water quality was comparable to routine sampling events, with low metal and sulphate concentrations and circum neutral pH.

Station R6, located on Anvil Creek just upstream of the confluence with Rose Creek, was sampled biannually. Water quality at this site was monitored as part of Water Licence requirements, as part of the PRAEA and as part of the IAEMP. Waters at this station can be characterized as neutral to alkaline, with pH concentrations ranging from 7.4 to 8.4. Waters in Anvil Creek appear to have higher hardness and alkalinity in comparison to other reference stations, ranging from 7 to 14 mg/L $CaCO_3$ and 122 to 135 mg/L $CaCO_3$, respectively. Higher calcium, magnesium, sulphate and hardness observed at this location in comparison to other reference stations suggests different geochemistry in the upper Anvil Creek watershed than in watersheds upstream of the other reference stations (Minnow 2007). Total zinc concentrations average 0.0047 mg/L, ranging from less than MDL (<0.005 mg/L) to 0.011 mg/L. Silver, calcium, chromium, copper, nickel, selenium, and strontium had maximums higher than the background benchmark concentrations. Median calcium concentrations at R6 were also higher than the background benchmark concentrations. The sulphate maximum at R6 was higher than both the background benchmark value and the water quality guideline. Silver, aluminum, chromium and copper had maximums higher than water quality guidelines. (Appendix B2).

Water quality upstream of the confluence of all mine drainages was monitored at location P1 in the fall of 2007 (four sampling events), through the IAEMP to serve as a preliminary characterisation. Station P1 is located within the main stem of the Pelly River immediately upstream of the confluence with Vangorda Creek. Water quality at PB, one of fifteen water quality monitoring stations that were established along the Pelly River and its tributaries as part of the PRAEMP is also discussed to supplement the discussion of the Pelly River quality.

Water quality at P1 was circumneutral with hardness ranging from 154 to 216 mg/L. The majority of trace metals were detectable, with total zinc concentrations ranging from 0.0142 to 0.0234 mg/L (Appendix B2).

Sulphate concentrations remained low, ranging from 56 to 69 mg/L, although they exceeded the water quality guideline value of 50 mg/L, based on British Columbia's Freshwater Aquatic Life Guidelines. Calcium, cadmium, chromium, iron, nickel, selenium, strontium and zinc had maximums higher than the background benchmark concentrations. Median calcium concentrations at R6 were also higher than the background benchmark concentrations. Cadmium concentrations exceeded the CCME guideline of 0.00003 mg/L during all sampling events. The sulphate median at P1 was higher than both the background benchmark value and the water quality guideline. Aluminum, cadmium and chromium had maximums higher than water quality guidelines.

3.3.9.1 Regional Receiving Water Quality

Location R4 is located within Rose Creek, upstream of the confluence with Anvil Creek. Water chemistry at R4 was characterized by neutral to alkaline conditions with hardness ranging from 160 mg/L $CaCO_3$ to 619 mg/L $CaCO_3$. Zinc concentrations at R4 were comparable to reference water quality concentrations. Sulphate, calcium, and manganese also remained elevated above reference concentrations within this reach of Rose Creek; however, the low toxicity of these parameters suggests minimal impact to aquatic life. One cadmium concentration in exceedence of the water quality guideline was observed at this site, however this was in the same order of magnitude as the maximum observed at X14 upstream of R4 and at R7, the upstream reference station in the North Fork of Rose Creek. One silver concentration at R4 was observed to exceed the water quality guideline, and this was one order of magnitude higher than the other concentrations observed at this site. The selenium maximum was higher than the water quality guideline, but the same as observed at reference station R7.

Further downstream, below the confluence of Anvil and Rose Creek, water quality at station R5 was comparable to reference water quality, with the exception of calcium and magnesium concentrations, which were slightly elevated over reference sites. One silver concentration at R5 was observed to exceed the water quality guideline, and this was at least one order of magnitude higher than the other concentrations observed at this site. Since this silver concentration was observed on the same day as the elevated silver at R4, it will be important to assess this data point with respect to a larger dataset.

Site R11, called A1 in the IAEMP, represents the most downstream water quality monitoring station within Anvil Creek, immediately upstream of the confluence with the Pelly River. Water quality at this location was comparable to reference water quality conditions. Total zinc concentrations at this location ranged from below MDL (<0.005 mg/L) to 0.008 mg/L, comparable to reference locations. Sulphate, calcium and conductivity were elevated in comparison to reference stations. One silver concentration at R11 was observed to exceed the water quality guideline, and this was at least one order of magnitude higher than the other concentrations observed at this site. Since this silver concentration was observed on the same day as the elevated silver at R4 and R5, it will be important to assess this data point with respect to a larger dataset. Aluminum, iron, copper, chromium, nickel lead and zinc concentrations at R11 were within ranges typically observed at reference stations. Inadequate detection limits in the analyses of silver and cadmium preclude comparison to benchmark concentrations. The selenium maximum was higher than the water quality guideline, but the same as observed at reference station R7.

Comparison of spatial water quality trends from R4 to R11 suggests that dilution of mine site related discharge is the dominant influence on water quality along the length of these tributaries. Typically, median metal concentrations decreased as distance from the mine site increases from R4 to R5, and concentrations between R5 and R11 were generally within the same order of magnitude for metals and general parameters (Table 3.3-17 and Table 3.3-18).

Water quality immediately downstream Vangorda Creek was monitored through the Interim Aquatic Ecosystem Monitoring Program (IEAMP) at location P2 during the fall of 2007. Characterisation of this site is considered preliminary. Total aluminum, copper, lead and zinc concentrations at P2 were comparable to upstream (P1) values. Cadmium exceeded the CCME derived benchmark of 0.00003 mg/L during the four consecutive months of samples, as did cadmium concentrations at P1. The aluminum and selenium maximums were higher than the respective water quality guidelines, but were comparable with reference concentrations. Sulphate concentrations between P1 and P2 were comparable. Metal concentrations were typically higher during the September sampling event in comparison to subsequent months.

Comparison of water chemistry between stations P2 and P3 suggests that slight dilution of iron, nickel, lead, strontium and zinc may have occurred along the length of this portion of the Pelly River. Concentrations of other trace metals at site P3, however, were comparable or slightly elevated (copper and cadmium, for example) in comparison to P2, suggesting that natural metal loading and/ or dilution from inflowing tributaries was the dominant influence on trace metal concentrations. Annual or seasonal temporal trends cannot be determined for this program due to limited data. Cadmium concentrations exceeded the CCME derived water quality guideline of 0.00003 mg/L for the four fall samples.

Location P4 is located immediately downstream of Anvil Creek. Water at this station represents mixing of drainage from the Anvil Creek and the Pelly River, and therefore is potentially influenced by mine related discharges from the Faro Mine site. Total metals concentrations were generally comparable between P3 and P4. Cadmium concentrations exceeded the CCME derived water quality guideline of 0.00003 mg/L for the four fall samples, ranging from 0.000099 and 0.000177 mg/L.

3.3.9.2 Pelly River Aquatic Effects Assessment (PEAEA)

Since the IAEMP sampling program had a limited water quality sampling base in 2007, some results of the 2004 to 2006 Pelly River Aquatic Effects Assessment program are discussed to supplement the understanding of water quality in the Pelly River. The Pelly River Aquatic Effects Assessment locations sampled are illustrated in Figure 3.3-17. Note that although some stations names are similar to the IAEMP names, the Pelly River stations are not the same in the two different programs.

Water quality of the Pelly River upstream of inflowing tributaries draining the Faro and Vangorda mine sites was monitored at location PB which is immediately upstream of Blind Creek. Water quality at this site was similar to that observed at upstream locations under the IAEMP, with detectable trace metal concentrations, neutral to alkaline pH, and low sulphate. This station reported total and dissolved zinc concentrations of 0.005 mg/L and 0.035 mg/L, and 0.003 mg/L and 0.012 mg/L for the July 2004 and August 2005 sampling events, respectively (Access *et al.*, 2005, 2006), indicating that the majority of the total zinc is associated with the solid phase (particulate matter). Total cadmium and iron concentrations upstream of mine drainage

exceeded the selected water quality benchmarks during both sampling events. Zinc, aluminum and selenium were slightly elevated above benchmark concentrations during two separate sampling events. Total suspended solids range from 292 to 400 mg/L, well above the background benchmark of 8 mg/L and above that of other reference stations.

During the program, water quality was monitored in the Pelly River approximately mid-point between Vangorda Creek and Anvil Creek, at location P1 (PREAE, upstream of IAEMP station P3). Water quality was also measured downstream of the confluence of Anvil Creek, at station P1A (which corresponds with IAEMP station P5, not discussed in this report, and located downstream of IAEMP station P4). During the 2004 program, Access Consulting Group noted that total zinc concentrations within the Pelly River slightly increased along the length of the river between stations PB, P1 and P1A with concentrations of 0.005 mg/L, 0.007 mg/L and 0.01 mg/L (Access *et al.* 2005). An opposite trend was noted in 2005, with decreasing concentrations observed between PB and P1A, suggesting natural zinc loading, presumably from inflowing tributaries, was occurring within this portion of the study area in 2005. No data is available for station PB in 2006; therefore, a similar comparison cannot be made for this sampling year. It should be noted that total zinc was below the CCME guideline of 0.03 mg/L throughout the sampling program, except at station PB in 2005. Cadmium concentrations exceeded the water quality guideline of 0.00003 mg/L at stations P1 and P1A from 2004 to 2006. Total aluminum and selenium concentrations exceeded the CCME derived benchmarks during 75% and 50% of the sampling events, respectively.

Of interest is the lack of discernable trend in sulphate concentrations between the upstream reference station, PB, and station P1A, the station located downstream of the Pelly River and Anvil Creek confluence. Although sulphate does not pose the same toxicology risk as other contaminants of concern, it does serve as an indicator of mining related activities on the receiving environment.

3.3.9.3 Anvil Creek and Pelly River Water Quality Summary

Evaluation of water quality data collected from Anvil Creek and the Pelly River monitoring programs indicates that although waters draining from the Faro and Vangorda mine sites may influence water chemistry within Anvil Creek and the Pelly River, the signature of drainage is not readily apparent or consistent between sampling dates and programs. Although some spatial trends in total zinc, copper, and lead concentrations were occasionally evident, natural contributions to the watershed combined with significant dilution (and limited data) suggest that the mine-related influences on Anvil Creek and the Pelly were not readily detectable.

Monitoring locations upstream of all mine-related drainages indicate concentrations of total cadmium, aluminum and selenium above water quality guidelines (CCME), and total suspended solids were also slightly elevated above guideline concentrations. Calcium and sulphate were elevated at the mouth of Rose Creek, but not significantly in comparison with the Anvil Creek and Pelly River reference sites.

Water quality at the downstream boundary of the Pelly River RSA is characterized by neutral to slightly alkaline pH and low sulphate concentrations. Cadmium concentrations were consistently above the CCME guideline of 0.00003 mg/L.

P4
R11
P3
R5
R6
R4
P2
P1
VR
V6A
V25BSP
V1
V2
V4
V27
V5
V8
VGMAIN
FC
FDU
W10
X14
X10
X13
X5
X2
X3
R1
R7
Mill Site
Faro Pit
Tailings Impoundment
Grum Culvert
Grum Pit
Vangorda Pit
Faro Townsite
Airfield
MT. Aho
MT. Mye
Rose Mountain
Sheep Mountain
Anvil Range
Anvil Creek
Pelly River
Glenlyon Lake
Glenlyon River
Rose Creek
Tintina Trench
Dixon River
Dixon Lake
Haul Road
North Fork Road Creek
North Fork Rose Creek
Vangorda Creek
Vangorda Ck West Fork
Shrimp Lake
Johnson Lake
Blind Creek
Robert Campbell Highway

Legend

- Reference Site
- Receiving Site
- Mine Run-off Effluent and Internal Site
- Existing Surface Drainage
- Roads
- Regional Study Area
- Rose Creek Local Study Area
- Vangorda Local Study Area
- Rose Creek Watershed
- Vangorda Watershed
- Surface Water
- Buildings

Basemapping from Yukon Territory Government

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Kilometers
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UTM Zone 8N, NAD 83

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Map Sub-Title

Surface Water Quality Study Areas

March 2009
Project 107403 - 80649

AECOM

Figure 3.3-1

Map Document: (.\GIS_Utilities\ArcGIS_MapTemplates\11x17-Landscape_AECOM.mxd)
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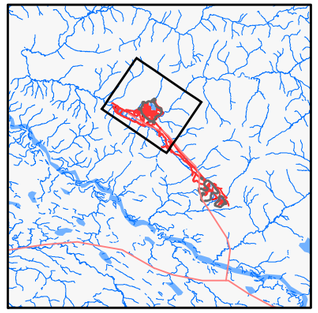
FC
FDU
R7
W10
X2
R1
X5
X13
X10
X14
Faro Creek Diversion
North East Rock Dump
North West Rock Dumps
Water Treatment Pipeline
Pumping Well
Zone II Pit (Backfilled)
Main Rock Dump
Intermediate Rock Dump
North Fork Rose Creek
Haul Road
Emergency Tailings Area
North Wall Interceptor Ditch
Guardhouse Creek
Next Creek
Cross Valley Dam
Intermediate Dam
Original Tailings Impoundment
Second Impoundment
Intermediate Impoundment
Pumphouse Pond
South Fork Rose Creek
Rose Creek
Rose Creek Diversion

Legend

- Reference Site
- Mine Run-off Effluent and Internal Site
- Receiving Site
- Existing Surface Drainage
- Pre-Mine Drainage
- Effluent Pipeline
- Water Treatment Pipeline
- Pipeline
- Roads
- Buildings
- Rock Dump



Basemapping from Yukon Territory Government

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Map Sub-Title

Faro Mine Site Surface Water Quality Sampling Locaitons

April 2009
Project 107403 - 80649

AECOM

Figure 3.3-2

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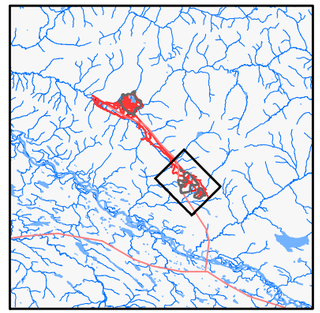
Magazine Area
Water Treatment Plant
Clarification Pont
Ditch
Fresh Water Supply Pond
Grum Interceptor Ditch
Sub-Station
Overland Water Treatment Pipeline
Ore Transfer Pad
Grum Pit (Not Current)
VR
V1
Blind Creek Road
Vangorda Creek
Vangorda NW Interceptor
Vangorda Creek Diversion Flume
Vangorda NE Interceptor Ditch
Vangorda North East Interceptor
Vangorda Haul Road
Former Ore Haul Shop
V6A
Aex Creek
Waste Rock Piles
Sheep Pad Sediment Ponds
V25BSP
Plunge Pool
Till Stockpile
Former Shop U/G Portal
Former Lube Station
Fuel Tanks
Former Core Shacks
Former Maintenance Storage Area
Shop
Office
Fuel Tank
Little Creek Dam
Emergency Spillway
Moose Pond
Vangorda Rock Dump
Grum Creek
Grum Rock Dump (Not Current)
Sulphide Cell (Design)
V2
Seepage Collection Ditch
West Fork of Vangorda Creek
Dixon Creek
Shrimp Creek
Vangorda Creek
V27
V4

Legend

- Reference Site
- Mine Run-off Effluent and Internal Site
- Receiving Site
- Pipelines
- Water Treatment Pipelines
- Roads
- Existing Surface Drainage
- Surface Drainage



Basemapping from Yukon Territory Government

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Map Sub-Title

Vangorda Plateau Mine Site Surface Water Quality Sampling Locations

March 2009
Project 107403 - 80649

AECOM

Figure 3.3-3

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Figure 3.3-4. Sulphate at X2

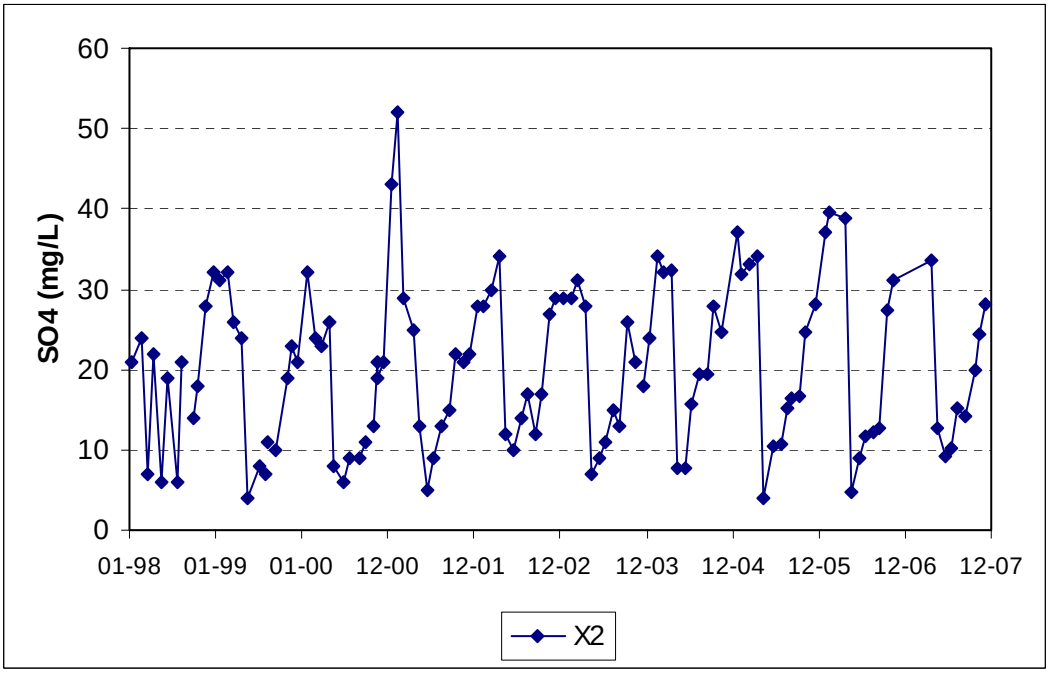


Figure 3.3-5. Total Zinc at X2

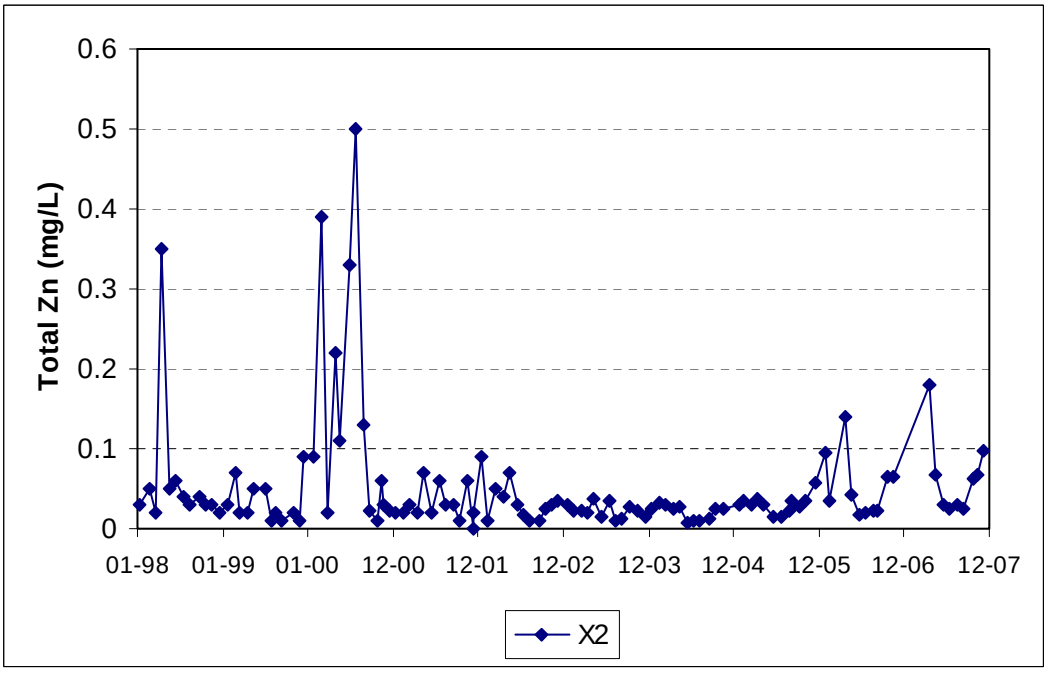


Figure 3.3-6. Sulphate at X2, X3 and X10

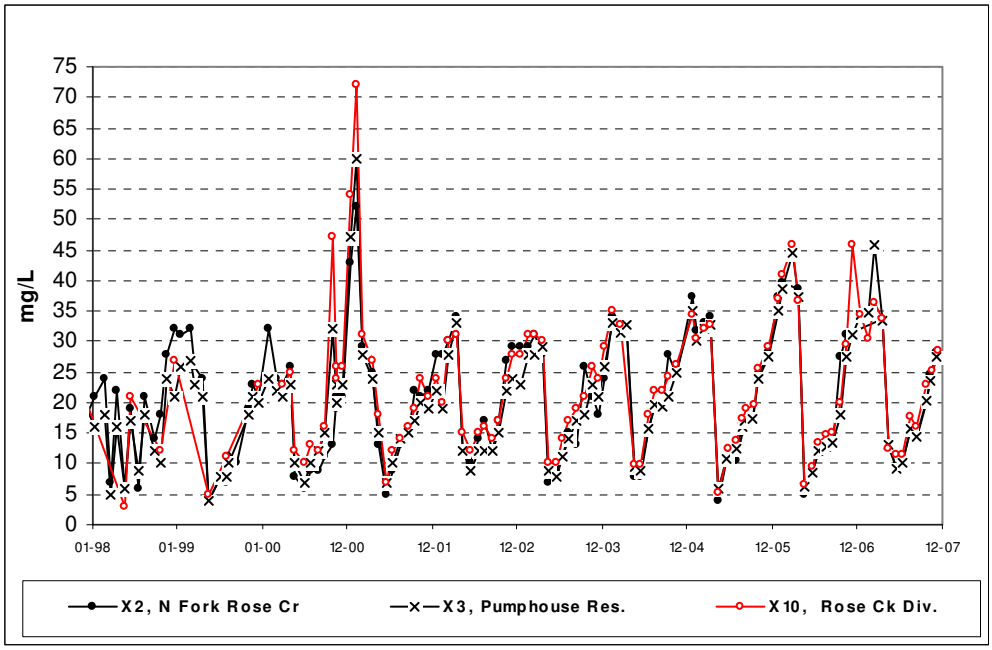


Figure 3.3-7. Total Zinc at X2, X3 and X10

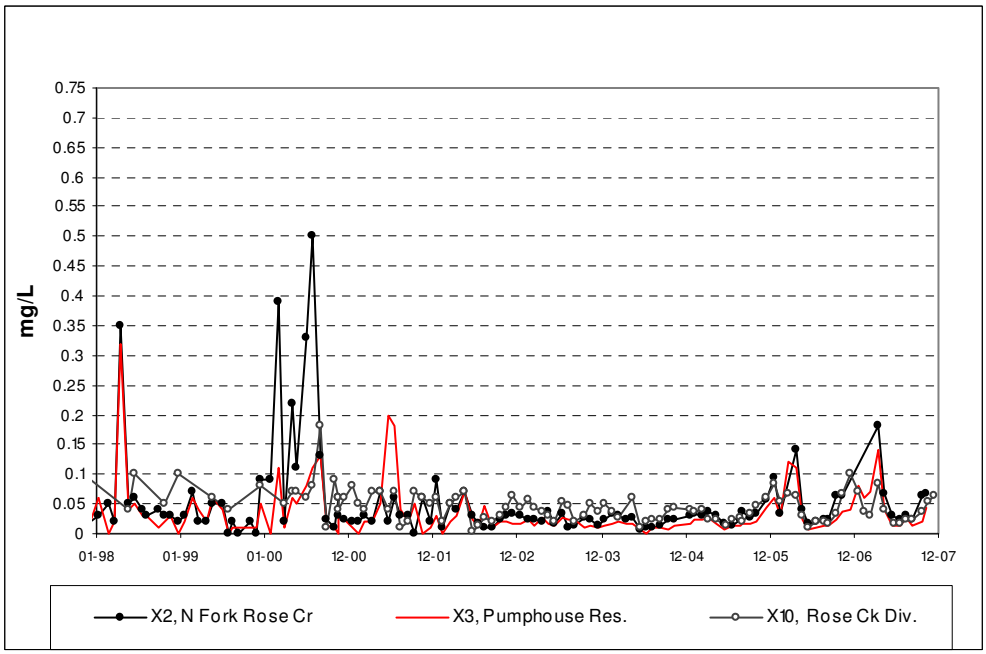


Figure 3.3-8. Sulphate at X5

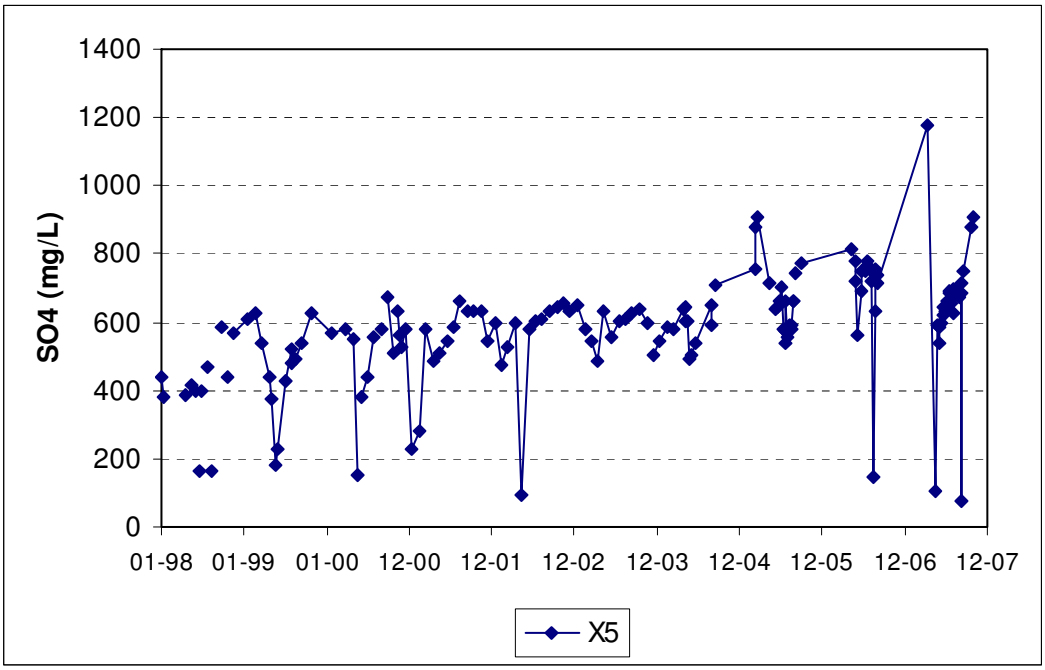


Figure 3.3-9. Total Zinc at X5

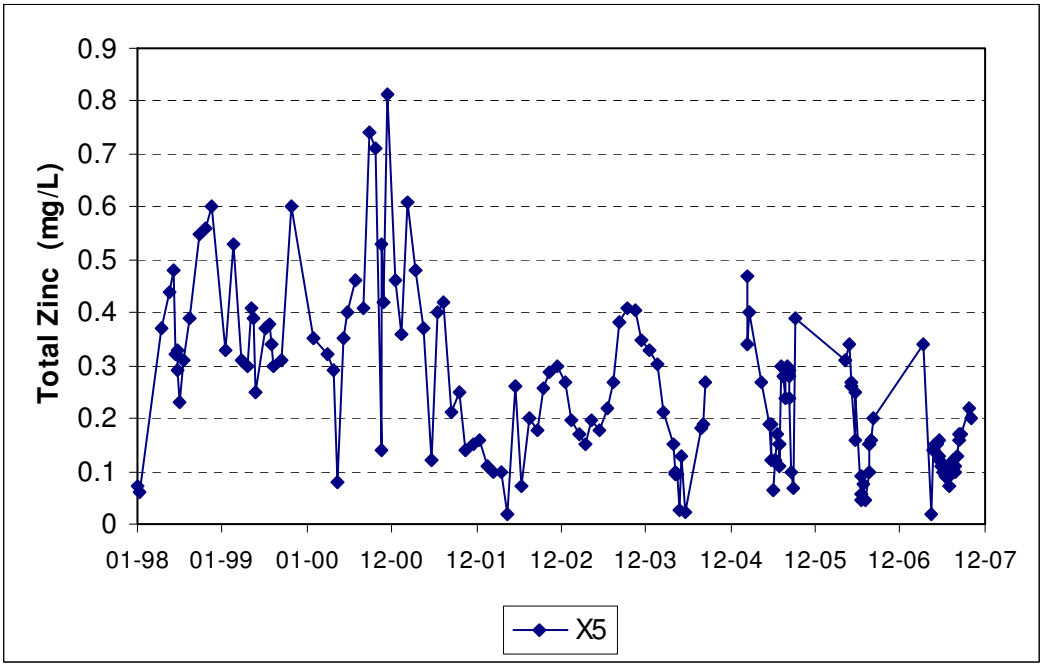


Figure 3.3-10. Total Zinc at X13

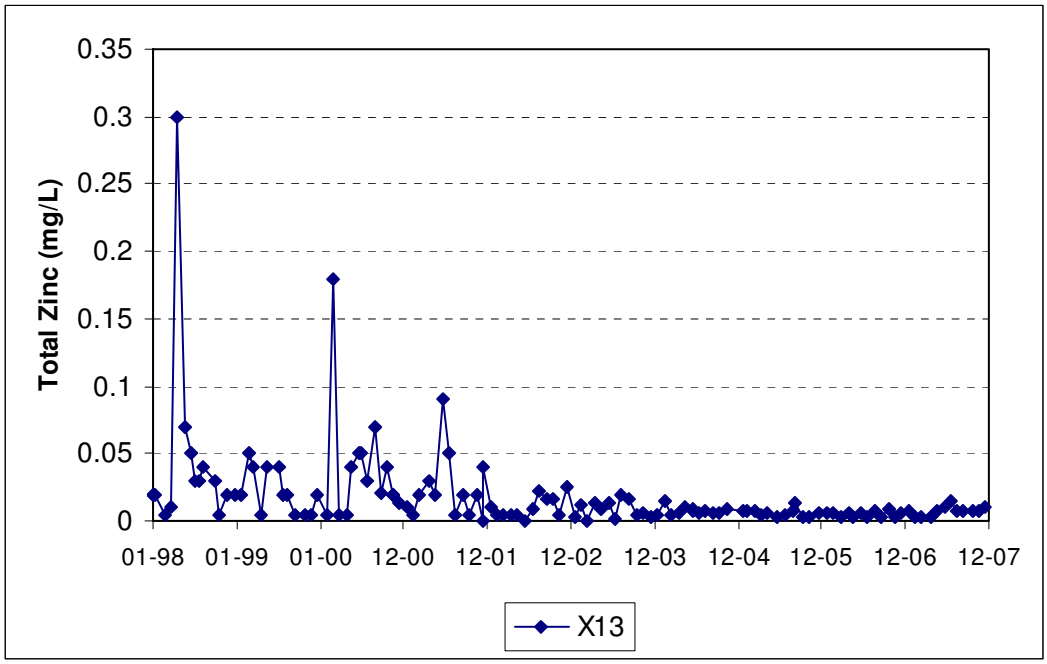


Figure 3.3-11. Total Zinc Concentrations at X14 and R2

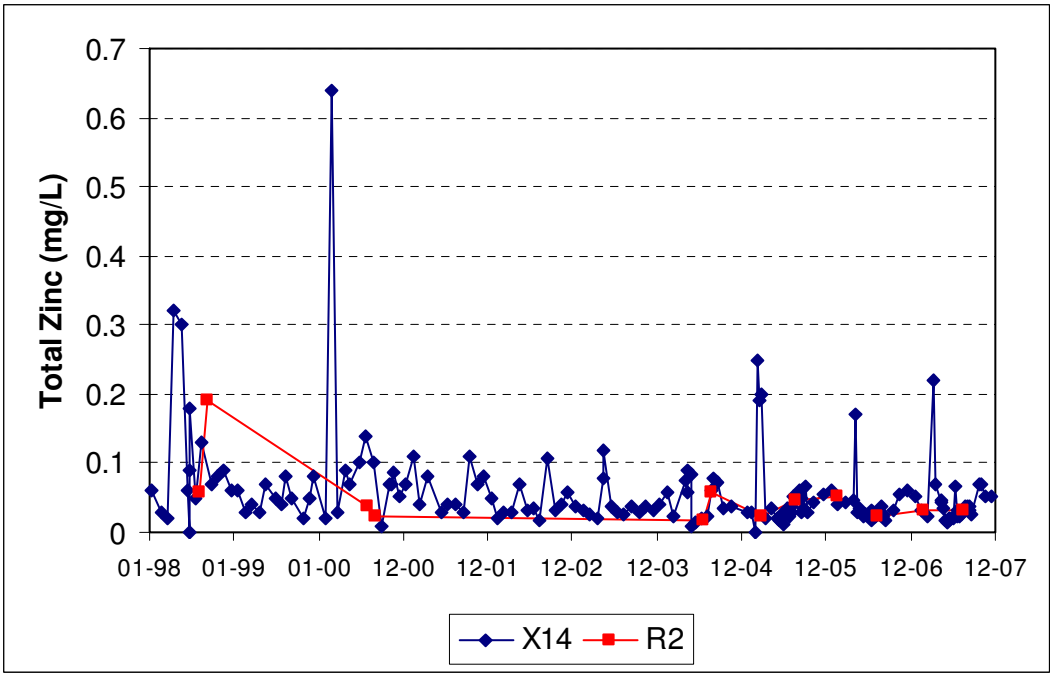


Figure 3.3-12. Sulphate Concentrations at X14 and R2

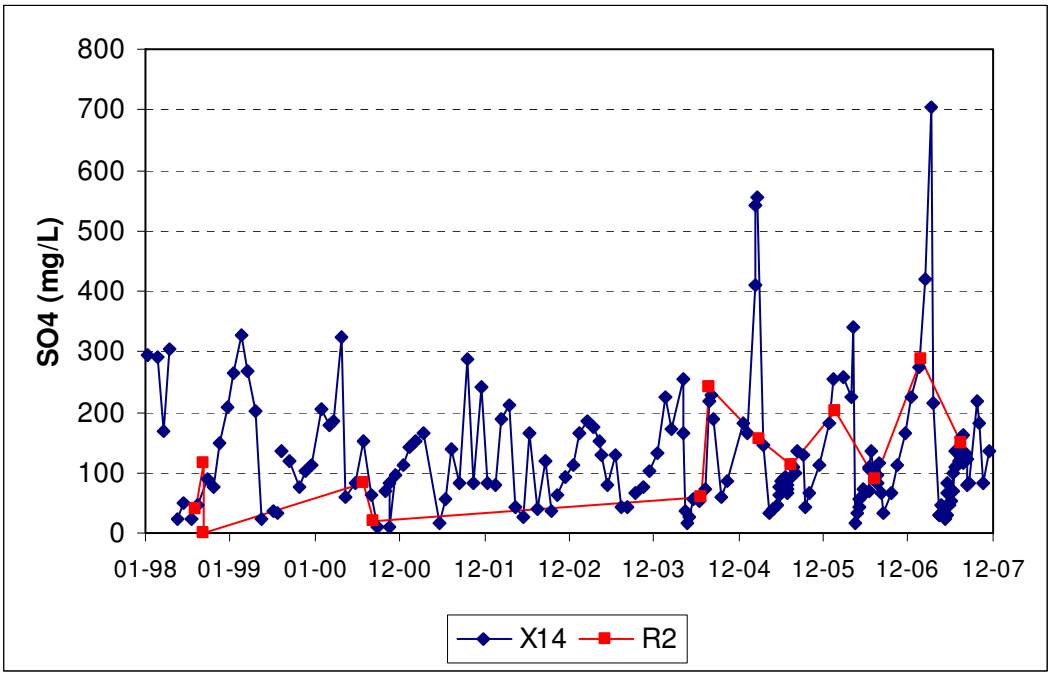


Figure 3.3-13. Sulphate Concentrations at V1

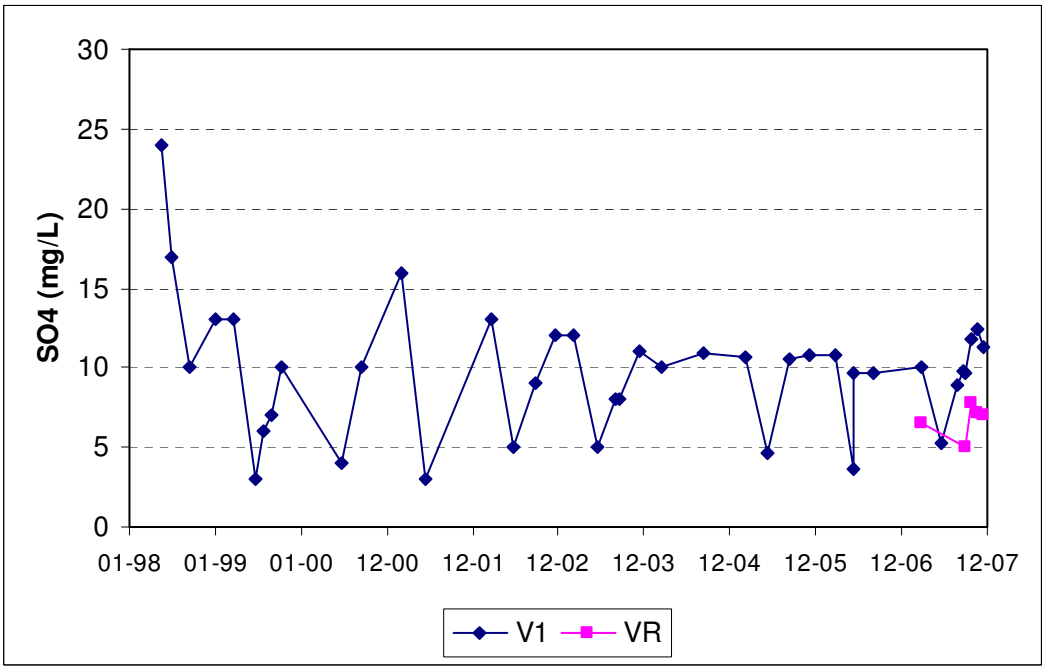


Figure 3.3-14. Zinc Concentrations at V1

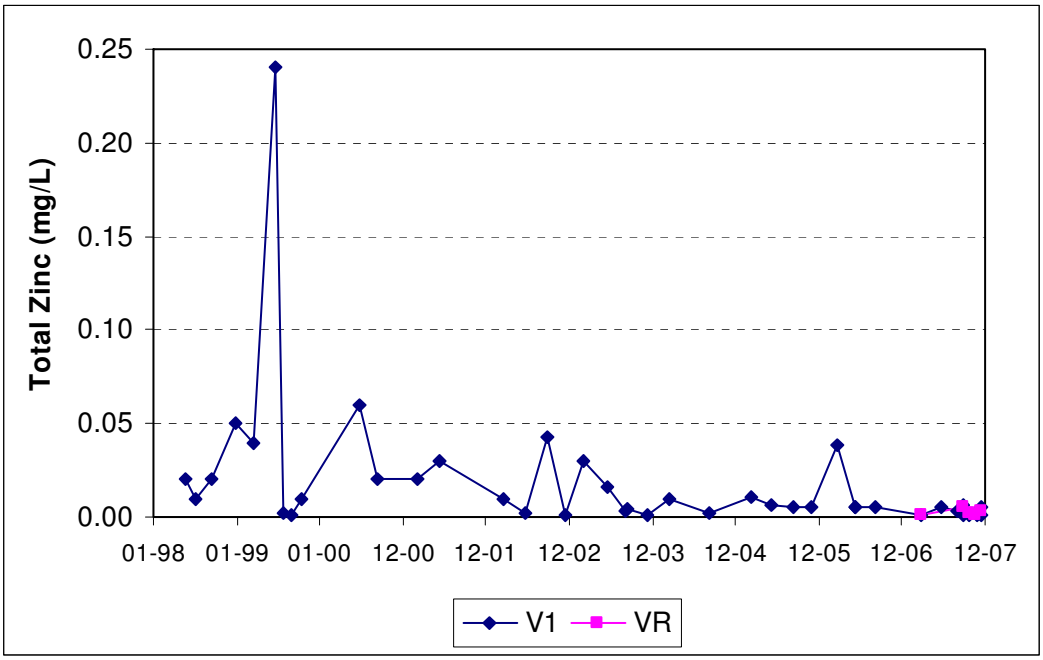


Figure 3.3-15. Sulphate at V25BSP

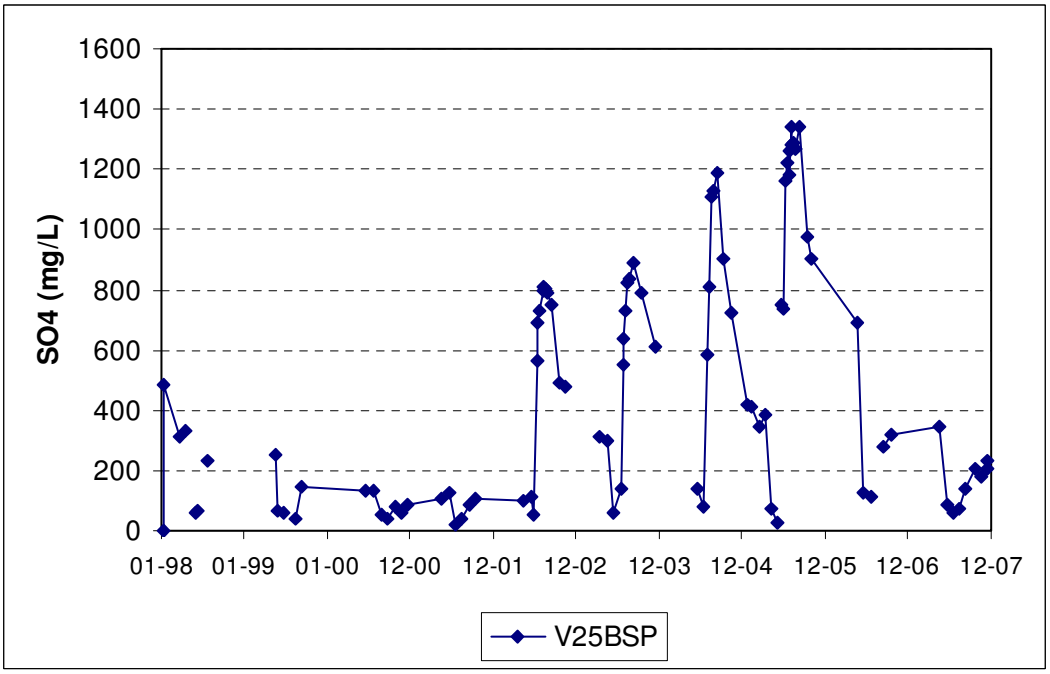


Figure 3.3-16. Calcium at V25BSP

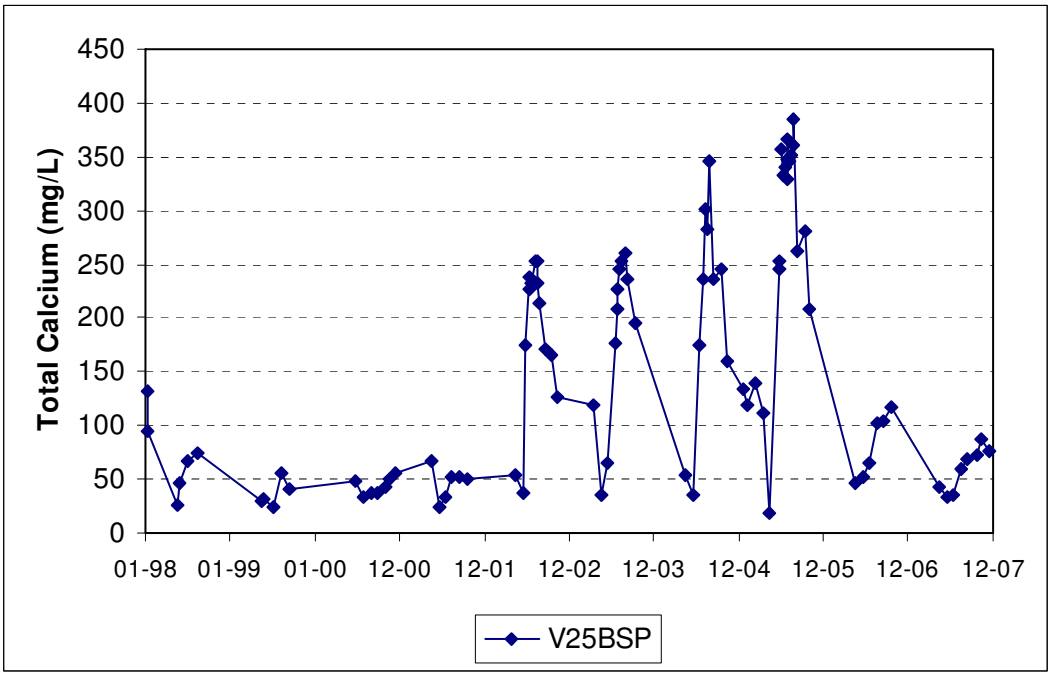


Figure 3.3-17. Sulphate at V2

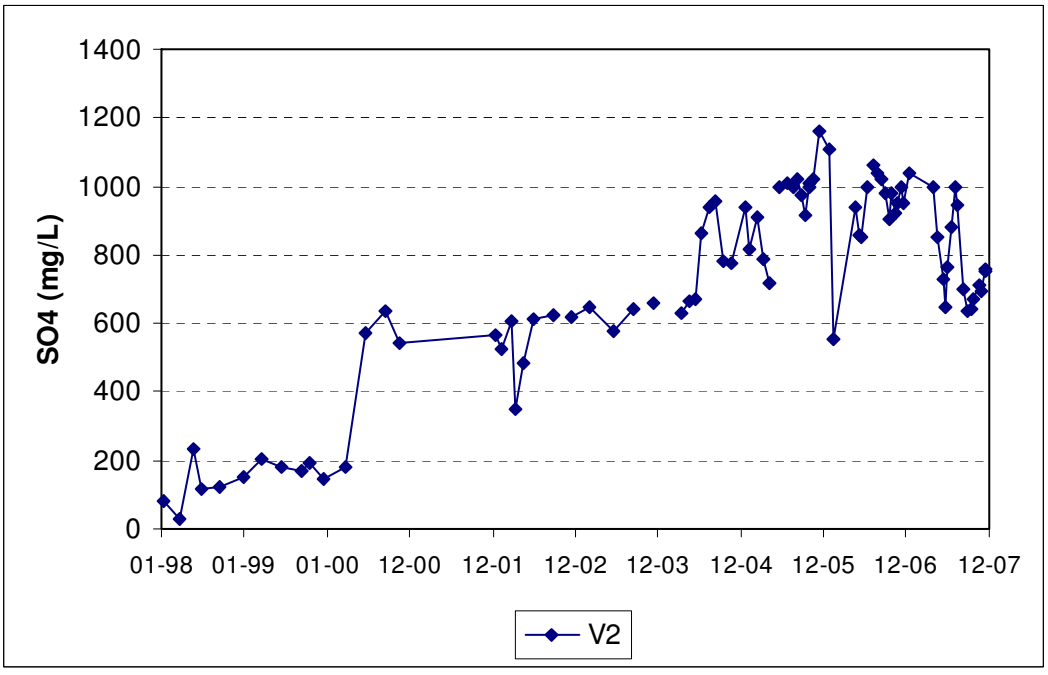
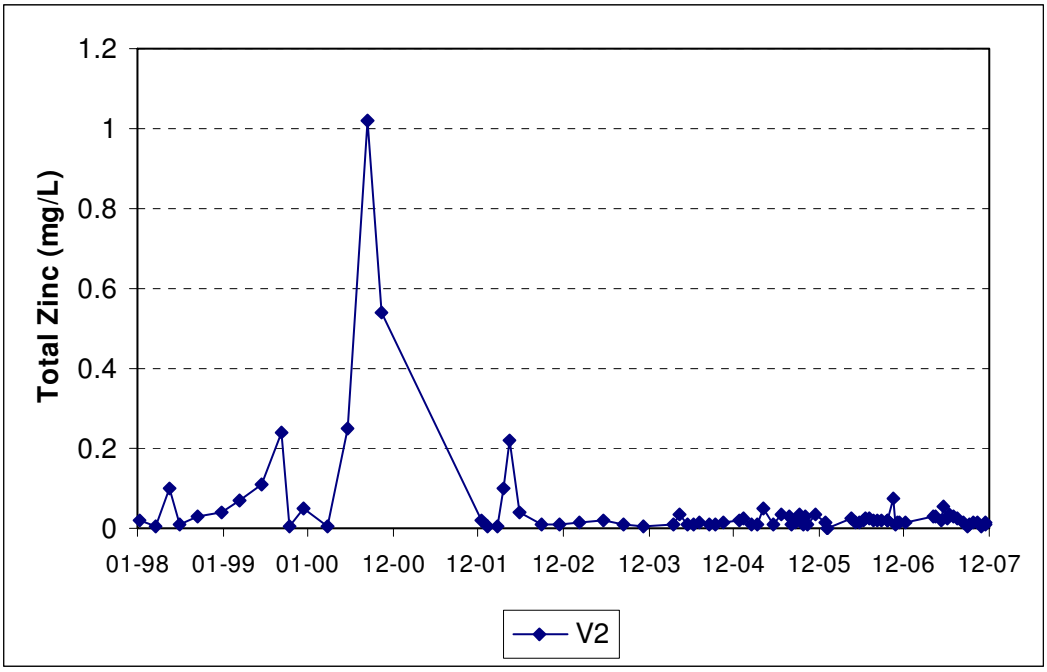
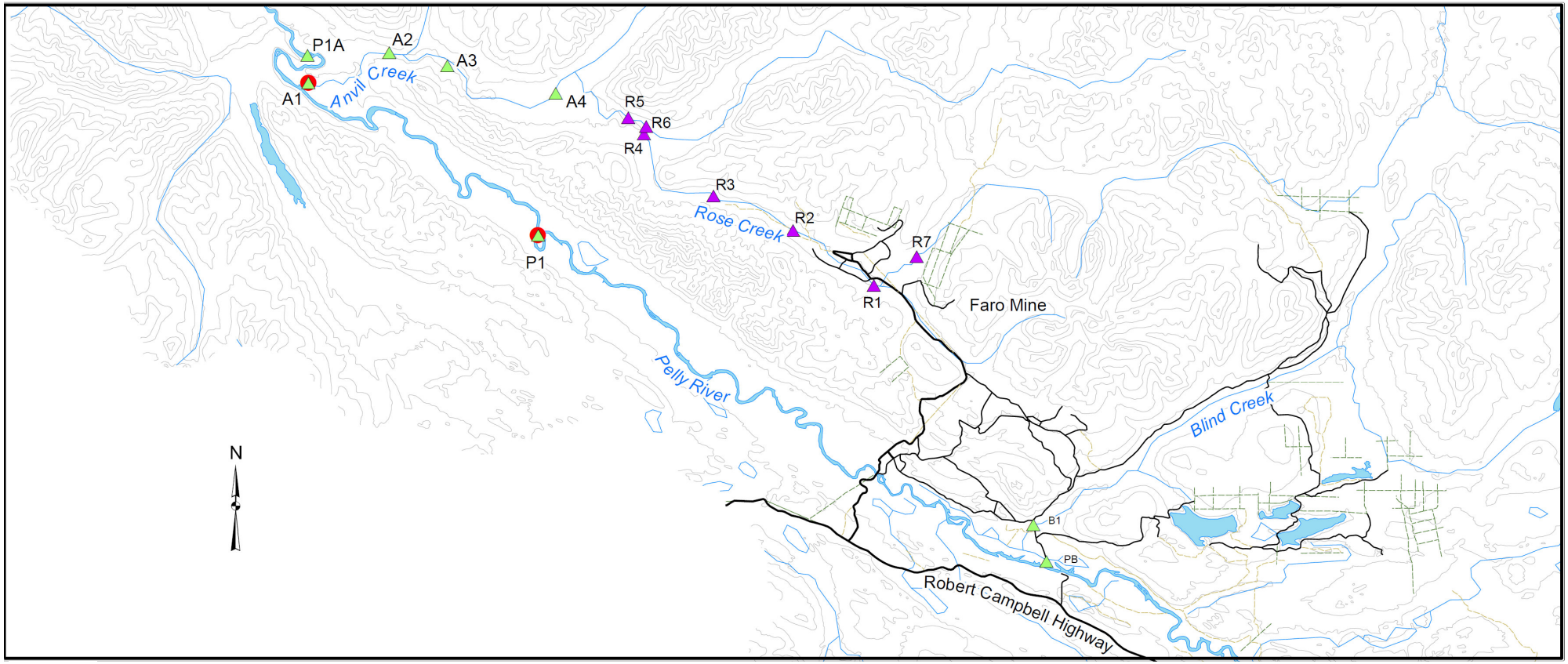


Figure 3.3-18. Total Zinc at V2





Legend

- Selkirk First Nation Monitoring Station
- Aquatic Effects Monitoring Station
- Faro Mine Licence Monitoring Station
- 100ft Topographical Contour
- Watercourses
- Cut line
- Limited-used road
- Road
- Trail
- Waterbodies

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0 2.5 5 10 15 20 km

Source:
Access Consulting Group, 2005. Pelly River Aquatic Assessment – 2004, prepared for Selkirk First Nation, Whitehorse, December 2005.

AECOM

Faro Mine Closure
Fermeture de la mine Faro

Job No: 107403 (80642-1)

File: 107403_80649_WQ Monitoring Locations.ppt

Faro Mine Complex
Closure and Reclamation

Faro Mine Complex

Anvil Creek and Rose Creek Monitoring Station Locations

Date: March 2009

Approved: FKP

Figure: 3.3-19

Table 3.3-1. Water Quality Station Descriptions

Station Function	Station ID	Station Description
Rose LSA – Faro/Rose Watershed (portion of)		
Reference – LSA and RSA	FDU	Faro Creek, downstream of Faro Valley West Interceptor
	R7	North Fork Rose Creek – upstream of Mine
	W10	Upper Guardhouse Creek
Mine Runoff, Effluent and Internal Receiving Water Body	X5	Cross Valley Pond Outflow
	X13	Cross Valley Dam Seepage
	X2	North Fork Rose Creek, 100 m upstream of rock drain
	R1	South Fork Rose Creek,
	X3	Pumphouse Pond, after confluence of North and South Forks of Rose Creek (except at high flows, when secondary diversion is used and this portion bypasses X3)
	X10	Rose Creek Diversion Channel upstream of X13
	X14	Rose Creek, downstream of diversion channel
Vangorda LSA – Vangorda Watershed		
Reference – LSA and RSA	V1	Vangorda Creek above mine
	VR	West Fork Vangorda Creek, above haul road
Mine Runoff, Effluent and Internal Receiving Water Body - LSA	V6A	AEX Creek
	V25BSP	Vangorda Creek, below Sheep Pad Pond
	V2	Grum Creek
	V4	Shrimp Creek, upstream of Vangorda Creek
	V27	Vangorda Creek, Main Stem, downstream of mine flow
Receiver - LSA	VGMAIN	Vangorda Creek, above confluence with West Stem
	V5	West Stem Vangorda Creek
	V8	Vangorda Creek, upstream of the confluence with the Pelly River.
Pelly RSA - Anvil/Pelly River Watersheds (portion of)		
Reference – RSA	FC[b]	Faro Creek, upstream of diversion
	R6	Anvil Creek – upstream of confluence with Rose Creek
	P1[b]	Pelly River, Upstream of Vangorda Creek
Receiver – RSA	R4	Rose Creek at Anvil Creek
	R5	Anvil Creek, downstream of confluence with Rose Creek
	R11(A1)	Anvil Creek, upstream of confluence with Pelly River
	P2 [b]	Pelly River, downstream of Vangorda Creek
	P3 [b]	Pelly River, Upstream of Anvil Creek
	P4 [b]	Pelly River, downstream of Anvil Creek

[A] *Sampled under the Pelly River Aquatic Effects Assessment Program.*

[b] *Sampled under the Interim Aquatic Ecosystem Monitoring Program.*

Table 3.3-2. Sources of Water Quality Data

Monitoring Program	Program Description
Water Licence QZ03-059 – Monitoring Program	The Water Licence, in Schedule A of the licence, identified, stations and monitoring frequency for the majority of the monitoring stations included in this characterisation of existing conditions. A total of 64 water quality monitoring stations are identified in the Water Licence, for the Faro area, and an additional 32 for the Vangorda area. This includes some wells and seeps locations, in addition to surface water sites. The frequency of water sampling varied at different locations, with some sites sampled twice per year (spring and fall), and some sites sampled as frequently as monthly. Results of water quality monitoring were reported to the Water Board on a monthly basis and compiled in Annual Reports to the Water Board. Surface water samples were collected by site staff (i.e., the Interim Receiver).
Adaptive Management Plan (AMP) (Gartner Lee Ltd, (now AECOM) 2004)	This plan was completed in 2004, as a requirement of the Water Licence. Monitoring and assessment of data at several sites for comparison with trigger activation criteria associated with eight events identified as possible future conditions that would require a management response, occurred on a monthly basis, and was reported to the Yukon Water Board. The frequency of monitoring at some sites already included through the water licence monitoring program was increased to allow for assessment using the adaptive management process. Some triggers were activated through the AMP process and additional monitoring sites were added and assessed in response to trigger activation for some of the events.
Anvil Range Mine Complex 2002 Baseline Environmental Information Report (Gartner Lee Ltd, (now AECOM) 2002)	These environmental assessment documents were used to establish and confirm long-term historical trends observed in surface water quality at the Faro and Vangorda sites. Information from this report was used to establish monitoring programs.
2004 to 2008 Water Licence Renewal of Environmental Assessment Report, Volume II of III, Existing Environment (Gartner Lee Ltd, (now AECOM) 2003a)	Water quality data was compiled and assessed for the purposed of renewing the water licence for the Anvil Range site. The information contained in this report was used to develop the water licence monitoring program through which most of the data used in this existing conditions characterisation was used.
Pelly River Aquatics Effects Assessment (PRAEA) – 2004 to 2006 (Access et al. 2004, 2005, 2006 (Draft only))	Water quality within the Pelly River was monitored through the Pelly River Aquatics Effects Assessment (PEAEA) from 2004 to 2006 (Access *et al.*, 2005, 2006, 2007) and through the Interim Aquatic Ecosystem Monitoring Program (IAEMP) in 2007. The Pelly River Aquatics Effects Assessment program was conducted in conjunction with Selkirk First Nation (SFN). The program was enhanced in 2007 to facilitate water quality analyses with method detection limits below water quality current guideline concentrations (CCME 1999), and incorporated into the Interim Aquatic Ecosystem Monitoring Program (IAEMP). The results were also used in this report to characterize water quality within the RSA receiving environment.
Interim Aquatic Ecosystem Monitoring Program (IAEMP) – 2007 to 2008 (Selkirk First Nation, Ross River Dena Council and Access Consulting Group)	The objective of this monitoring program is to collect additional monitoring data/information for use in the development of a long-term monitoring program that would replace the expired Water Licence monitoring requirements. In 2007, the *Pelly River Aquatics Effects Assessment* was expanded for this program to include additional sites upstream and downstream of the mine site, including environmental monitoring at 19 sites on Rose Creek, Anvil Creek, Vangorda Creek and the Pelly River. Four monthly sampling events in late 2007, sampled under the IAEMP program, were included in this characterisation of existing conditions. Both FC and VR were sampled under a non-routine monitoring program, the Interim Aquatic Ecosystem Monitoring Program (IAEMP). Station FC is a historic sampling station that after a period of inactivity was sampled in 2007. Station VR is a station that has been recently established for the purpose of characterizing reference water quality.
Faro Background Data Evaluation (Minnow 2009)	This assessment included statistical analysis of existing surface water quality data at reference stations upstream of the mine impacted environment and further development of background water quality benchmarks from work previously undertaken by Gartner Lee Ltd. (now AECOM). 2005 to 2007 water quality from upstream reference locations, including some of those used in this existing conditions characterisation, were compiled into one data pool, to provide background benchmarks, with the objective of using these to derive site specific water quality

Monitoring Program	Program Description
	objectives. All of the sites used as reference sites for the LSAs and/or the RSA are also reference locations for the background benchmark evaluation. Some additional water quality data collected for the development of the background benchmarks was used in this existing conditions characterisation.
Ecological Impact Assessment (Minnow 2007)	An ecological impact assessment included a review of water and sediment quality data, benthic invertebrate communities, fish communities, and fish tissue residues and was conducted to compile, assess, and integrate the results of the various aquatic receiving environment monitoring activities at the Anvil Range Complex for the period from 1975 to 2006. The Interim Aquatic Monitoring Program built upon this Impact Assessment to develop the monitoring program.

Table 3.3-3. Non-Metals Parameters for Characterisation of Existing Conditions

Parameter	Rationale
pH	Important for understanding chemical interactions, especially for pH dependent reactions
hardness	Important for understanding chemical interactions, especially for pH dependent reactions
calcium	Important for aquatic life
conductivity	Important for understanding chemical interactions, provides indication of dissolved ions content, including hardness and sulphate
ammonia	Indicative of explosives, landfill and septic impact on waters; pH and temperature dependent toxicity to aquatic life
TSS	Indicatives of physical site disturbances to waters; can have negative impact on aquatic life
sulphate	Indicator of acid mine drainage;

Table 3.3-4. Water Quality at Rose Creek Reference Sites (2005-2007)

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
Background Benchmark		**303**	**158**	**0.03**	**6.58-8.16**	**20.3**	**3**
Water Quality Guidelines		**-**	**-**	**0.24**	**6.5 - 9.0**	**50**	**8**
FDU	n	7	6	6	6	7	7
	Median	33	11.5	0.0075	7.45	1.76	1
	Mean	32.1	12.7	0.0092	7.5	1.66	0.79
	Minimum	19	7	< 0.01	7.1	1.04	< 1
	Maximum	56	21.1	0.02	7.9	2.1	< 1
	25th Percentile	24	11	0.005	7.25	1.36	0.5
	75th Percentile	34.5	13.5	0.01	7.8	1.98	1
R7	n	36	36	34	35	35	36
	Median	203	107	0.0075	7.8	8.85	0.50
	Mean	194	100	0.0134	7.78	8.48	2.31
	Minimum	53	28	< 0.01	7.3	1.7	< 1
	Maximum	294	147	0.07	8.2	16.9	**21**
	25th Percentile	143	73.5	0.005	7.70	7.08	0.5
	75th Percentile	260	132	0.02	7.90	9.93	2
10	n	8	7	8	8	8	8
	Median	104	50.4	0.005	7.6	3.59	0.5
	Mean	95.8	48.7	0.0088	7.60	3.59	0.94
	Minimum	55	27	< 0.005	7.2	2.5	< 1
	Maximum	123	60	0.04	7.9	4.3	3
	25th Percentile	89	47	0.0044	7.40	3.30	0.5
	75th Percentile	109	54.6	0.005	7.83	4.13	1

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

Bold *Maximum Meets or Exceeds Guideline*

Bold, italics *75% and/ or Median Meets or Exceeds Guideline*

underlined *>50% of samples < Method Detection Limit (MDL);*

\- *100% of samples <MDL*

Table 3.3-5. Trace Metals (Total) Concentrations at Rose Creek Reference Sites (2005– 2007)

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Sr	Zn
		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	mg/L
Background Benchmark		**<0.00005**	**0.156**	**<0.001**	**44.9**	**0.00004**	**<0.001**	**<0.001**	**0.002**	**0.246**	**0.0264**	**<0.001**	**<0.001**	**<0.001**	**0.18**	**0.0164**
Water Quality Guidelines		**0.0001**	**0.1**	**0.005**	**116[a]**	**0.00003**	**0.004**	**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.001**	**9.3[b]**	**0.03**
FDU	n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	Median	-	0.074	-	3.37	0.0001	-	-	0.0005	0.07	0.002	0.0005	0.0005	-	0.02	0.0025
	Mean	-	0.0863	-	3.54	8.71E-05	-	-	0.000986	0.0671	0.00207	0.000486	0.000514	-	0.0206	0.00443
	Minimum	< 0.00005	0.047	< 0.0002	2.07	0.00001	< 0.0002	< 0.0002	0.0004	< 0.05	0.001	0.0004	0.0006	< 0.0002	0.013	0.003
	Maximum	< 0.00025	**0.18**	< 0.001	6.15	< 0.0002	< 0.001	< 0.001	**0.003**	0.14	0.004	< 0.001	< 0.001	< 0.001	0.033	0.011
	25th Percentile	-	0.0625	-	2.71	1E-04	-	-	0.0005	0.0375	0.00175	0.0005	0.0005	-	0.017	0.0025
	75th Percentile	-	0.0890	-	4	1E-04	-	-	0.001	0.0800	0.002	0.0005	0.0005	-	0.022	0.005
R7	n	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	Median	0.000125	0.018	0.0005	31.9	0.0001	-	0.0005	0.0005	0.115	0.014	0.0005	-	0.0005	0.12	0.0025
	Mean	0.000130	0.0515	0.00058	29.9	0.00011	-	0.000531	0.00074	0.200	0.0248	0.00057	-	0.000597	0.119	0.006
	Minimum	< 0.00005	< 0.005	0.0004	8.41	0.00001	< 0.0002	< 0.0002	0.0003	< 0.05	0.005	0.0004	< 0.0002	0.0005	0.035	< 0.001
	Maximum	**0.0004**	**0.35**	0.002	43.9	**0.0004**	< 0.001	**0.002**	**0.003**	**1.41**	0.15	< 0.001	< 0.001	**0.002**	0.19	**0.035**
	25th Percentile	0.000125	0.00875	0.0005	22	0.000100	-	0.0005	0.0005	0.0900	0.0115	0.0005	-	0.0005	0.0812	0.0025
	75th Percentile	0.000125	0.0540	0.0005	39.4	0.000100	-	0.0005	0.0005	0.192	0.0192	0.0005	-	0.0005	0.160	0.00625
W10	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Median	-	0.0315	0.0005	16.4	0.0001	0.0005	-	0.001	0.025	0.0005	0.0005	0.0005	0.0005	0.0536	0.00375
	Mean	-	0.0403	0.00040	15.1	0.000081	0.000382	-	0.00124	0.0418	0.00177	0.00041	0.00043	0.000384	0.0494	0.00643
	Minimum	< 0.000005	0.011	0.0001	7.67	0.000018	0.000014	< 0.0001	0.00085	0.015	0.00045	< 0.00002	0.000134	< 0.00004	0.027	0.0017
	Maximum	< 0.00025	**0.13**	< 0.001	20.0	< 0.0002	< 0.001	< 0.001	**0.003**	0.14	0.007	< 0.001	< 0.001	< 0.001	0.063	0.023
	25th Percentile	-	0.0124	0.000405	13.6	8.25E-05	0.000385	-	0.00076	0.025	0.0005	0.00045	0.00045	0.000387	0.0438	0.0025
	75th Percentile	-	0.0450	0.0005	17.7	0.000100	0.0005	-	0.00132	0.0323	0.00205	0.0005	0.0005	0.0005	0.0597	0.00665

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

A — *Calcium Guideline is based on effects on zooplankton, as developed in Background Benchmark Report (Minnow 2008)*

B — *Strontium Guideline is based on effects on fish, as developed in Background Benchmark Report (Minnow 2008)*

Bold — *Maximum Exceeds Guideline*

Bold, italics — *75% and/ or Median Exceeds Guideline*

underlined — *>50% of samples < Method Detection Limit (MDL);*

- — *100% of samples <MDL*

Table 3.3-6. Water Quality at Rose Creek, Mine Effluent/Runoff Sites (2005-2007)

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
Water Quality Guidelines		**-**	**-**	**0.24**	**6.5 - 9.0**	**50**	**8**
R1	n	9	9	9	9	9	9
	Median	223	116	0.05	7.61	21.9	1
	Mean	240	112	0.032	7.70	24	1
	Minimum	158	75.8	< 0.005	7.00	13.4	< 1
	Maximum	285	203	0.1	8.00	29.6	2
	25th Percentile	173	85	0.010	7.42	16.7	0.5
	75th Percentile	270	138	0.080	7.86	26.8	1
X2	n	32	32	32	31	32	32
	Median	188	102	0.005	7.50	16.5	0.5
	Mean	209	109	0.0134	7.54	20.7	1.97
	Minimum	61	33	< 0.01	7.10	4	< 1
	Maximum	344	187	0.06	8.00	39.7	**9**
	25th Percentile	148	73	0.005	7.40	11.4	0.5
	75th Percentile	285	149	0.02	7.70	31.3	2
X3	n	36	36	36	36	36	36
	Median	220	122	0.01	7.65	21.9	0.05
	Mean	227	118	0.022	7.63	23.0	1.31
	Minimum	82	40	< 0.01	7.10	5.9	< 1
	Maximum	368	181	0.18	8.10	45.9	**13**
	25th Percentile	160	85	0.005	7.50	13.03	0.05
	75th Percentile	300	164	0.03	7.80	32.98	1.25
X5	n	67	67	67	63	63	67
	Median	1300	692	***0.89***	7.80	***683***	0.5
	Mean	1338	715	0.826	7.89	669	0.918
	Minimum	297	266	0.08	7.10	74.2	< 1
	Maximum	2260	1230	**1.67**	8.80	**1180**	5
	25th Percentile	1185	660	0.640	7.60	624	0.5
	75th Percentile	1470	742	***0.970***	8.20	***747***	1
X10	n	40	40	40	40	40	40
	Median	245	127	0.005	7.80	25.4	0.5
	Mean	240	127	0.013	7.73	24.2	1.38
	Minimum	79	40	< 0.005	**5.00**	5.4	< 1
	Maximum	421	212	0.03	8.50	45.8	**14**
	25th Percentile	174	91.6	0.005	7.58	15.0	0.5
	75th Percentile	297	168	0.02	8.10	32.3	0.5
X13	n	36	36	36	52	36	36
	Median	1645	831	***0.62***	7.20	***756***	4
	Mean	1638	841	0.61	7.22	730	4.1
	Minimum	852	578	0.35	7.00	422	1.0
	Maximum	2700	1120	**0.77**	7.70	**939**	6.0
	25th Percentile	1505	760	0.580	7.10	679	3.0
	75th Percentile	1785	900	***0.65***	7.30	***801***	5.0

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
X14	n	93	93	93	88	89	93
	Median	340	175	0.09	7.8	***99.3***	1
	Mean	427	216	0.106	7.82	131	3.67
	Minimum	112	54	< 0.005	7.2	16.8	< 1
	Maximum	1630	812	**0.56**	8.4	**704**	**46**
	25th Percentile	279	135	0.0500	7.70	65.4	0.5
	75th Percentile	502	235	0.130	8	***137***	3

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

Bold *Maximum Meets or Exceeds Guideline*

Bold, italics *75% and/ or Median Meets or Exceeds Guideline*

underlined *>50% of samples < Method Detection Limit (MDL);*

- *100% of samples <MDL*

Table 3.3-7. Trace Metals (Total) Concentrations at Rose Creek, Mine Effluent/Runoff Sites (2005– 2007)

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Sr	Zn
		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	mg/L
Water Quality Guidelines		**0.0001**	**0.1**	**0.005**	**116[a]**	**0.00003**	**0.004**	**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.001**	**9.3[b]**	**0.03**
R1	n	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	Median	0.00015	0.0156	0.00045	36.5	0.000227	0.00032	0.00036	0.00067	***0.394***	0.125	0.00382	0.00041	0.00044	0.185	0.00359
	Mean	0.000125	0.014	0.0005	34.8	0.0001	0.0005	0.0005	0.0005	0.280	0.0892	0.0005	0.0005	0.0005	0.181	0.0025
	Minimum	< 0.000005	0.0061	0.00033	23.4	0.000007	0.00008	< 0.0001	0.00037	0.246	0.047	< 0.00002	0.00009	< 0.00004	0.118	0.0007
	Maximum	0.0008	0.0358	< 0.001	64.1	< 0.003	< 0.001	< 0.001	**0.002**	**0.990**	0.38	0.031	< 0.001	< 0.001	0.32	0.013
	25th Percentile	2.50E-06	0.0103	0.00040	26.2	2.40E-05	0.00009	0.00010	0.00040	0.250	0.0520	0.00044	0.00010	0.00015	0.130	0.00250
	75th Percentile	0.00013	0.0204	0.00050	44	0.00010	0.00050	0.00050	0.00050	***0.405***	0.122	0.00050	0.00050	0.00050	0.217	0.00380
X2	n	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
	Median	-	0.0215	0.0005	29.5	0.0001	-	0.0005	0.0005	0.19	0.0635	0.00075	0.0005	-	0.12	***0.033***
	Mean	-	0.0470	0.00053	31.3	0.00010	-	0.00053	0.00095	0.226	0.074	0.00091	0.00122	-	0.128	0.0470
	Minimum	< 0.00025	< 0.005	< 0.001	9.71	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.019	< 0.001	< 0.001	< 0.001	0.042	0.015
	Maximum	< 0.00025	**0.27**	< 0.001	53.4	< 0.0002	< 0.001	< 0.001	**0.003**	**0.66**	0.21	0.002	**0.007**	< 0.001	0.23	**0.18**
	25th Percentile	-	0.015	0.0005	21.2	0.00010	-	0.0005	0.0005	0.158	0.0337	0.0005	0.0005	-	0.0822	0.0245
	75th Percentile	-	0.0625	0.0005	42.8	0.00010	-	0.0005	0.001	0.258	0.0985	0.001	0.001	-	0.175	***0.0633***
X3	n	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	Median	-	0.021	0.0005	35.85	-	-	0.0005	0.0005	0.205	0.0825	0.0005	0.0005	0.0005	0.148	0.0235
	Mean	-	0.0414	0.0005	34.5361	-	-	0.0005	0.0008	0.2350	0.0774	0.0008	0.0008	0.0005	0.15	0.0364
	Minimum	<0.00025	0.0025	0.0005	12.1	<0.0002	<0.001	0.0005	0.0005	0.06	0.022	0.0005	0.0005	< 0.001	0.053	0.006
	Maximum	<0.00025	**0.35**	0.001	51.7	<0.0002	<0.001	**0.002**	**0.003**	**1.02**	0.15	0.002	**0.004**	< 0.001	0.23	**0.14**
	25th Percentile	-	0.0125	0.0005	24.9	-	-	0.0005	0.0005	0.1375	0.044	0.0005	0.0005	0.0005	0.107	0.015
	75th Percentile	-	0.046	0.0005	46.65	-	-	0.0005	0.001	0.2425	0.101	0.001	0.0005	0.0005	0.200	***0.04325***
X5	n	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
	Median	0.000125	0.008	0.0005	214	0.0001	***0.006***	-	0.001	0.19	4.82	0.012	0.0005	0.0005	0.68	***0.15***
	Mean	0.000160	0.00970	0.000530	***216***	0.00012	0.0072	-	0.00102	0.236	***6.09***	0.0144	0.00122	0.000716	0.686	0.178
	Minimum	< 0.00025	< 0.005	< 0.001	90.6	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.86	0.002	< 0.001	< 0.001	0.27	0.018
	Maximum	0.001	0.039	< 0.001	**361**	0.0005	**0.026**	< 0.001	0.005	1.02	**26.5**	0.051	**0.005**	**0.003**	1.03	**0.47**
	25th Percentile	0.000125	0.0025	0.0005	195	1.0E-04	0.0045	-	0.0005	0.130	3.49	0.009	0.0005	0.0005	0.63	0.1
	75th Percentile	0.000125	0.0135	0.0005	***226***	1.0E-04	***0.008***	-	0.001	0.270	***6.35***	0.0155	***0.002***	***0.001***	0.725	***0.255***
X10	n	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
	Median	0.000125	0.011	0.0005	36.5	0.0001	0.0005	-	0.0005	0.221	0.045	0.0005	0.0005	0.0005	0.155	***0.036***
	Mean	0.000167	0.0290	0.000493	36.5	0.00009	0.00046	-	0.000727	0.241	0.047	0.00075	0.00082835	0.000486	0.152	0.0410
	Minimum	< 0.000005	0.0045	0.00022	11.7	0.00001	0.000079	< 0.0001	0.00043	< 0.05	0.009	< 0.00002	0.000145	< 0.00004	0.05	0.011
	Maximum	0.0023	**0.25**	< 0.001	62.6	< 0.0002	< 0.001	< 0.001	**0.003**	**0.81**	0.089	0.003	**0.005**	< 0.001	0.26	**0.1**
	25th Percentile	0.000125	0.006	0.0005	26.3	0.0001	0.0005	-	0.0005	0.164	0.0297	0.0005	0.0005	0.0005	0.108	0.0227
	75th Percentile	0.000125	0.0239	0.0005	47.3	0.0001	0.0005	-	0.0007	0.280	0.0610	0.001	0.0005	0.0005	0.192	***0.0571***
X13	n	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
	Median	-	0.005	0.002	***246***	0.0001	0.006	-	0.00075	2.02	10.4	0.0145	-	0.0005	0.66	0.006
	Mean	-	0.0077	0.0019	251	0.00013	***0.0063***	-	0.00078	***2.05***	***10.4***	0.0147	-	0.000694	0.67	0.0060
	Minimum	< 0.00025	< 0.005	< 0.001	173	< 0.0002	0.002	< 0.001	< 0.001	0.55	6.01	0.011	< 0.001	< 0.001	0.44	< 0.005
	Maximum	< 0.00025	0.031	0.003	**328**	0.0006	**0.012**	< 0.001	**0.002**	**3.26**	**14.5**	0.019	< 0.001	**0.002**	0.87	0.015
	25th Percentile	-	0.0025	0.002	229	1.0E-04	0.005	-	0.0005	1.76	9.12	0.013	-	0.0005	0.600	0.0025

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Sr	Zn
		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	mg/L
	75th Percentile	-	0.0092	0.002	***271***	1.0E-04	***0.0073***	-	0.001	***2.23***	***11.4***	0.0160	-	0.0005	0.730	0.0073
X14	n	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93
	Median	0.000125	0.024	0.0005	52.0	0.0001	0.0005	0.0005	0.001	0.3	0.78	0.002	0.0005	0.0005	0.19	***0.033***
	Mean	0.000163	0.0658	0.000521	63.5	0.000103	0.00130	0.00049	0.00120	***0.378***	***1.44***	0.0035	0.00114	0.00055	0.214	0.0449
	Minimum	< 0.000005	0.0025	0.00029	16.1	0.00002	0.00023	< 0.0001	0.00042	0.12	0.19	0.0009	0.00021	< 0.00004	0.055	0.011
	Maximum	0.0023	**0.58**	0.002	**243**	0.0003	**0.015**	< 0.001	**0.012**	**1.59**	**16.0**	0.03	**0.008**	**0.002**	0.63	**0.25**
	25th Percentile	0.000125	0.015	0.0005	40.1	1.0E-04	0.0005	0.0005	0.0005	0.260	0.450	0.002	0.0005	0.0005	0.14	0.025
	75th Percentile	0.000125	0.0560	0.0005	69.3	1.0E-04	0.0010	0.0005	0.0010	***0.410***	***1.23***	0.003	0.001	0.0005	0.25	***0.051***

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

a *Calcium Guideline is based on effects on zooplankton, as developed in Background Benchmark Report (Minnow 2008)*

b *Strontium Guideline is based on effects on fish, as developed in Background Benchmark Report (Minnow 2008)*

Bold *Maximum Exceeds Guideline*

Bold, italics *75% and/ or Median Exceeds Guideline*

underlined *>50% of samples < Method Detection Limit (MDL);*

- *100% of samples <MDL*

Table 3.3-8. Reference Water Quality, Local Study Area, Vangorda Creek Drainage (2005 - 2007)

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
Background Benchmark		**303**	**158**	**0.03**	**6.58-8.16**	**20.3**	**3**
Water Quality Guidelines		**-**	**-**	**0.24**	**6.5 - 9.0**	**50**	**8**
VR	n	5	5	4	3	5	5
	Median	79.0	35.0	0.0058	7.3	7	0.5
	Mean	81.0	35.8	0.0105	7.54	6.69	1.1
	Minimum	62.0	28.9	< 0.005	6.87	5.0	< 1
	Maximum	103	44.2	0.028	8.44	7.8	3.0
	25th Percentile	76.0	31.8	0.0025	7.08	6.54	0.5
	75th Percentile	85.0	39.3	0.0137	7.87	7.10	1.0
V1	n	17	16	16	19	17	17
	Median	73.0	32.7	0.0050	7.58	10	0.5
	Mean	82.2	36.6	0.0058	7.46	9.51	0.68
	Minimum	35.0	13.0	< 0.005	6.37	3.62	< 1
	Maximum	125	59.0	0.030	8.3	12.4	3.0
	25th Percentile	67	28.0	0.0025	6.95	9.70	0.50
	75th Percentile	104	48.5	0.005	8.06	10.8	0.50

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)
BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

Bold *Maximum Meets or Exceeds Guideline*
Bold, italics *75% and/ or Median Meets or Exceeds Guideline*
underlined *>50% of samples < Method Detection Limit (MDL);*
- *100% of samples <MDL*

Table 3.3-9. Trace Metals (Total) Concentrations in Vangorda Creek Local Study Area Reference Waters (2005-2007)

Parameter		AG-T mg/L	AL-T mg/L	AS-T mg/L	CA-T mg/L	CD-T mg/L	CO-T mg/L	CR-T mg/L	CU-T mg/L	FE-T mg/L	MN-T mg/L	NI-T mg/L	PB-T mg/L	SE-T mg/L	SR-T mg/L	ZN-T mg/L
Background Benchmark		**<0.00005**	**0.156**	**<0.001**	**44.9**	**0.00004**	**<0.001**	**<0.001**	**0.002**	**0.246**	**0.0264**	**<0.001**	**<0.001**	**<0.001**	**0.18**	**0.0164**
Water Quality Guidelines		**0.0001**	**0.1**	**0.005**	**116[a]**	**0.00003**	**0.004**	**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.001**	**9.3[b]**	**0.03**
VR	n	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Median	-	0.0245	0.00018	11.0	0.00002	0.000028	0.0001	0.0008	0.029	0.00176	0.00025	0.0002	0.00006	0.0566	0.0024
	Mean	-	0.0321	0.000162	11.1	0.0000208	0.000045	0.00039	0.000734	0.0304	0.0017	0.000262	0.000235	0.00009	0.0551	0.00246
	Minimum	<0.000005	0.0205	<0.0001	8.85	0.00001	0.000017	< 0.0002	0.00045	0.024	0.00107	0.00017	0.000149	0.00006	0.042	0.0009
	Maximum	<0.00001	0.0627	0.0002	13.4	**0.000036**	< 0.0002	**0.0015**	0.0010	0.042	0.00267	<0.0005	0.000347	<0.0005	0.064	0.0049
	25th Percentile	-	0.024	0.00017	9.89	0.000012	0.00002	0.0001	0.0005	0.027	0.0012	0.00021	0.00016	0.00002	0.0529	0.0010
	75th Percentile	-	0.0286	0.0002	12.3	0.000026	0.00006	0.0002	0.00088	0.03	0.0018	0.0003	0.00032	0.0001	0.0601	0.0031
V1	n	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Median	-	0.012	0.0005	10.6	0.0001	0.0005	0.0005	0.0005	0.025	0.00072	0.0005	0.0005	0.0005	0.0539	0.0025
	Mean	-	0.0773	0.000516	11.6	6.96E-05	0.000333	0.000379	0.000533	0.0376	0.00190	0.000404	0.000353	0.00099	0.0582	0.00504
	Minimum	< 0.000005	0.0051	< 0.00002	4.31	< 0.000005	< 0.000005	< 0.0001	0.00029	0.005	0.0004	< 0.00002	0.000008	< 0.00004	0.022	0.0006
	Maximum	< 0.00025	0.99	0.002	18.7	< 0.0002	< 0.001	< 0.001	0.0020	0.14	0.014	< 0.001	< 0.001	0.011	0.11	0.038
	25th Percentile	-	0.007	0.00029	9.38	2.3E-05	2.3E-05	1E-04	0.0004	0.019	0.0005	0.00025	0.0002	0.00015	0.044	0.0013
	75th Percentile	-	0.024	0.0005	15.4	0.00010	0.0005	0.0005	0.0005	0.027	0.002	0.0005	0.0005	0.0005	0.0724	0.0027

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

a Calcium Guideline is based on effects on zooplankton, as developed in Background Benchmark Report (Minnow 2008)

b Strontium Guideline is based on effects on fish, as developed in Background Benchmark Report (Minnow 2008)

Bold *Maximum Exceeds Guideline*

italics Maximum exceeds background benchmark

Bold, italics *75% and/ or Median Exceeds Guideline*

underlined >50% of samples < Method Detection Limit (MDL);

- 100% of samples <MDL

Table 3.3-10. Water Quality at Vangorda Creek Mine Site Runoff and Effluent Site (2005 – 2007)

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
Water Quality Guidelines		-	-	**0.24**	**6.5 - 9.0**	**50**	**8**
V25BSP	n	34	34	34	35	33	34
	Median	735	420	0.020	7.9	***387***	0.50
	Mean	1002	629	0.132	7.77	614	1.90
	Minimum	119	63	< 0.01	7.0	27.8	< 1
	Maximum	2190	1300	**0.46**	8.3	**1340**	**34**
	25th Percentile	493	236	0.005	7.55	177	0.5
	75th Percentile	1685	1130	***0.288***	8	***1180***	0.5
V2	n	49	49	31	50	48	49
	Median	1900	1210	0.005	8.0	***940***	0.5
	Mean	1889	1138	0.0127	8.01	892	1.67
	Minimum	1270	719	< 0.01	7.5	554	< 1
	Maximum	2410	1460	0.04	8.3	**1160**	**18**
	25th Percentile	1720	1010	0.005	7.90	765	0.5
	75th Percentile	2120	1250	0.02	8.10	***1000***	2
V4	n	12	12	12	10	12	12
	Median	522	294	0.010	8.20	49.1	2.00
	Mean	497	291	0.012	8.16	47.0	4.96
	Minimum	281	154	< 0.005	7.92	22.5	< 1
	Maximum	670	411	0.040	8.30	**63.7**	**13.0**
	25th Percentile	414	279	0.0050	8.06	42.7	0.88
	75th Percentile	593	304	0.015	8.25	***51.8***	***10.5***
V6A	n	14	14	14	12	14	14
	Median	182	91.5	0.0075	7.95	28.2	1.0
	Mean	203	104	0.0345	7.90	32.5	2.21
	Minimum	99	47	< 0.005	7.4	13.6	< 1
	Maximum	315	182	**0.32**	8.3	**53.5**	**11.0**
	25th Percentile	165	75.5	0.005	7.69	20.4	0.5
	75th Percentile	261	133	0.0175	8.10	45.9	1.75
V27	n	13	12	13	10	13	13
	Median	210	97	0.005	7.88	***50.2***	0.50
	Mean	227	106	0.0071	7.90	55.4	1.46
	Minimum	47	17	< 0.005	7.50	8.46	< 1
	Maximum	420	209	0.03	8.30	**106**	6
	25th Percentile	185	77.3	0.0025	7.72	47.5	0.5
	75th Percentile	239	120	0.005	8.11	***64.1***	2

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)
BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

Bold *Maximum Meets or Exceeds Guideline*

Bold, italics *75% and/ or Median Meets or Exceeds Guideline*

underlined *>50% of samples < Method Detection Limit (MDL);*

- *100% of samples <MDL*

Table 3.3-11. Trace Metals (Total) Concentrations at Vangorda Creek Mine Site Runoff and Effluent Sites (2005 – 2007)

Parameter		Ag-T mg/L	Al-T mg/L	As-T mg/L	Ca-T mg/L	Cd-T mg/L	Co-T mg/L	Cr-T mg/L	Cu-T mg/L	Fe-T mg/L	Mn-T mg/L	Ni-T mg/L	Pb-T mg/L	Se-T mg/L	Sr-T mg/L	Zn-T mg/L
Water Quality Guidelines		**0.0001**	**0.1**	**0.005**	**116[a]**	**0.00003**	**0.004**	**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.001**	**9.3[b]**	**0.03**
V25BSP	n	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
	Median	0.000125	0.0265	0.0005	***126***	***0.00055***	***0.004***	0.0005	***0.004***	0.08	0.102	0.002	0.0005	0.0005	0.45	***0.0755***
	Mean	0.000136	0.0932	0.00056	184	0.0012	0.00534	0.000574	0.0046	0.177	3.19	0.0025	0.00112	0.00076	0.715	0.0994
	Min	< 0.00025	< 0.005	< 0.001	18.6	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	< 0.001	< 0.001	< 0.001	0.074	0.026
	Max	**0.0005**	**1.55**	0.002	**384**	**0.0048**	**0.035**	**0.002**	**0.018**	**2.12**	**13.1**	0.006	**0.008**	**0.003**	1.71	**0.26**
	25th Percentile	0.000125	0.0155	0.0005	70.1	0.0002	0.00125	0.0005	***0.002***	0.025	0.0268	0.002	0.0005	0.0005	0.26	0.049
	75th Percentile	0.000125	0.0605	0.0005	***331***	***0.00167***	***0.00575***	0.0005	***0.006***	0.148	***7.86***	0.003	0.001	0.0005	1.3	***0.14***
V2	n	49	49	49	49	49	49	49	49	49	49	49	49	39	49	49
	Median	0.000125	0.019	0.001	***245***	0.0001	0.0005	0.0005	0.001	0.09	0.002	0.003	0.0005	0.0005	0.82	0.018
	Mean	0.000931	0.0327	0.00307	243	0.000908	0.00205	0.00123	0.00283	0.132	0.00556	0.00433	0.00328	0.00097	0.805	0.0209
	Min	< 0.00005	0.004	0.0008	170	0.00008	< 0.0002	0.0002	< 0.001	< 0.01	0.0006	< 0.001	0.0003	< 0.001	0.61	< 0.005
	Max	< 0.01	**0.13**	< 0.03	**311**	< 0.01	< 0.02	< 0.01	< 0.02	**0.63**	0.036	< 0.02	< 0.03	**0.002**	1.09	**0.074**
	25th Percentile	0.000125	0.012	0.0005	219	0.0001	0.0005	0.0005	0.001	0.03	0.001	0.002	0.0005	0.0005	0.72	0.013
	75th Percentile	0.000125	0.037	0.001	***266***	0.0001	0.0005	0.0005	0.002	0.150	0.006	0.005	0.002	0.0015	0.88	0.027
V4	n	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	Median	-	0.0521	0.00055	72.1	7.42E-05	0.00036	0.00041	0.000965	0.277	0.0418	0.000853	0.000363	0.00063	0.299	0.00338
	Mean	-	0.015	0.0005	72.8	0.0001	0.0005	0.0005	0.000615	0.245	0.038	0.00072	0.0005	0.0005	0.305	0.0025
	Min	< 0.000005	0.0019	0.00047	40	0.000016	0.000045	< 0.0001	0.00055	0.13	0.017	< 0.00002	0.000011	0.00044	0.14	0.0013
	Max	< 0.00025	**0.22**	< 0.001	103	< 0.0002	< 0.001	< 0.001	**0.002**	**0.53**	0.0854	0.002	< 0.001	**0.002**	0.398	0.009
	25th Percentile	-	0.0029	0.0005	69.4	0.00003	0.00013	0.0004	0.0005	0.197	0.0258	0.0005	0.00022	0.0005	0.285	0.00185
	75th Percentile	-	0.0577	0.00052	74.4	0.0001	0.0005	0.0005	0.00125	***0.305***	0.0429	0.001	0.0005	0.0005	0.331	0.00337
V6A	n	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
	Median	-	0.042	0.001	27	0.0001	0.0005	0.0005	0.0005	0.133	0.0071	0.0005	0.0005	0.0005	0.109	0.0165
	Mean	-	0.101	0.0011	30.9	8.19E-05	0.00037	0.000407	0.000816	0.175	0.0104	0.000453	0.000727	0.00141	0.13	0.0197
	Min	< 0.000005	0.0146	0.00091	14	0.00003	0.000032	< 0.0001	0.00038	0.076	0.004	< 0.00002	0.000359	< 0.00004	0.053	0.013
	Max	< 0.00025	**0.76**	0.003	54.4	< 0.0002	< 0.001	< 0.001	**0.003**	**0.61**	0.027	< 0.001	**0.002**	**0.015**	0.24	**0.031**
	25th Percentile	-	0.023	0.000918	22.6	5.42E-05	0.000162	0.0001625	0.0005	0.102	0.00697	0.000365	0.00049	0.000223	0.0973	0.0138
	75th Percentile	-	0.057	0.001	40.1	0.0001	0.0005	0.0005	0.00065	0.182	0.0133	0.0005	0.001	0.0005	0.172	0.0258
V27	n	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	Median	-	0.02	0.0005	26.5	0.0001	0.0005	0.0005	0.0009	0.049	0.0035	0.0005	0.0005	0.0005	0.0978	0.0257
	Mean	-	0.0392	0.000432	27.6	0.000083	0.00339	0.000365	0.00105	0.0868	0.00797	0.000546	0.000782	0.0004	0.105	0.0246
	Min	< 0.000005	< 0.005	< 0.00002	4.68	0.00004	0.000015	<0.0001	0.00062	0.009	0.00095	< 0.00002	0.000134	< 0.00004	0.02	0.016
	Max	< 0.00025	**0.16**	< 0.001	52.8	< 0.0002	**0.04**	< 0.001	**0.002**	**0.36**	0.039	< 0.001	**0.002**	< 0.001	0.211	**0.0318**
	25th Percentile	-	0.0106	0.0004	22.3	5.40E-05	4.00E-05	1.00E-04	0.00062	0.025	0.003	0.0005	0.000456	0.00031	0.087	0.022
	75th Percentile	-	0.023	0.0005	28.6	0.0001	0.0005	0.0005	0.0011	0.09	0.008	0.00061	0.00052	0.0005	0.11	0.0274

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

a *Calcium Guideline is based on effects on zooplankton, as developed in Background Benchmark Report (Minnow 2008)*

b *Strontium Guideline is based on effects on fish, as developed in Background Benchmark Report (Minnow 2008)*

Bold *Maximum Exceeds Guideline*

Bold, italics *75% and/ or Median Exceeds Guideline*

underlined *>50% of samples < Method Detection Limit (MDL);*

- *100% of samples <MDL*

Table 3.3-12. Water Quality at Vangorda Creek Receiving Water Sites, (2005-2007)

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
Water Quality Guidelines		-	-	**0.24**	**6.5 - 9.0**	**50**	**8**
V5	n	29	28	29	28	28	29
	Median	453	265	0.005	8.1	***77.8***	***9***
	Mean	472	274	0.0141	8.08	89.8	39.1
	Minimum	172	126	< 0.005	7.4	28.0	2
	Maximum	793	436	0.11	8.4	**174**	**249**
	25th Percentile	337	201	0.005	7.98	61.1	4
	75th Percentile	640	329	0.02	8.30	***116***	***46***
V8	n	39	37	39	37	38	38
	Median	514	293	0.005	8.1	***121***	1
	Mean	493	278	0.0146	8.05	123	7.70
	Minimum	174	112	< 0.005	7.3	33.3	< 1
	Maximum	781	449	0.13	8.5	**312**	**67**
	25th Percentile	339	197	0.005	8	68.1	0.5
	75th Percentile	662	371	0.02	8.20	***166***	6.25
VGMAIN	n	35	35	35	35	34	35
	Median	438	249	0.005	8.0	***129***	0.5
	Mean	452	251	0.0144	8.05	131	1.63
	Minimum	170	86	< 0.01	7.5	32.9	< 1
	Maximum	804	526	0.11	8.5	**399**	**23**
	25th Percentile	280	158	0.005	7.90	68.0	0.5
	75th Percentile	615	338	0.02	8.25	***171***	0.5

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)
BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

Bold *Maximum Meets or Exceeds Guideline*

Bold, italics *75% and/ or Median Meets or Exceeds Guideline*

underlined *>50% of samples < Method Detection Limit (MDL);*

\- *100% of samples <MDL*

Table 3.3-13. Trace Metals (Total) Concentrations at Vangorda Creek Receiving Water (2005-2007)

Parameter		AG-T mg/L	AL-T mg/L	AS-T mg/L	CA-T mg/L	CD-T mg/L	CO-T mg/L	CR-T mg/L	CU-T mg/L	FE-T mg/L	MN-T mg/L	NI-T mg/L	PB-T mg/L	SE-T mg/L	SR-T mg/L	ZN-T mg/L
Water Quality Guidelines		**0.0001**	**0.1**	**0.005**	**116[a]**	**0.00003**	**0.004**	**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.001**	**9.3[b]**	**0.03**
V5	n	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
	Median	0.000125	0.16	0.0005	63.5	0.0001	0.0005	0.0005	0.001	***0.37***	0.026	0.002	0.0005	0.0005	0.27	0.009
	Mean	0.000130	0.836	0.00122	64.8	0.00012	0.000906	0.00234	0.00301	1.41	0.0441	0.00410	0.00176	0.00117	0.259	0.0125
	Min	< 0.00001	0.024	< 0.001	30.8	0.00004	0.00027	0.0008	< 0.001	0.090	0.007	0.001	0.00052	< 0.001	0.12	0.0039
	Max	**0.0004**	**6.95**	**0.005**	101	**0.0003**	**0.005**	**0.016**	**0.018**	**11.0**	0.19	0.02	**0.01**	**0.003**	0.4	**0.046**
	25th Percentile	0.000125	0.08	0.0005	49.1	0.00010	0.0005	0.0005	0.0005	0.20	0.015	0.002	0.0005	0.0005	0.210	0.0025
	75th Percentile	0.000125	0.890	0.001	77.8	0.00010	0.0005	0.002	***0.004***	***1.46***	0.042	0.004	0.002	0.0013	0.290	0.013
V8	n	38	39	39	39	39	39	39	39	39	39	39	39	39	39	39
	Median	-	0.04	0.0005	66.5	0.0001	0.0005	0.0005	0.001	0.15	0.026	0.002	0.0005	0.0005	0.28	0.015
	Mean	-	0.172	0.00124	65.3	0.00012	0.00067	0.00088718	0.00265	0.341	0.0433	0.00242	0.00203	0.00148	0.269	0.019
	Minimum	< 0.00001	< 0.005	0.0004	26.9	0.00004	0.00012	0.0003	< 0.001	0.049	0.006	< 0.001	0.0003	< 0.0005	0.1	0.0070
	Maximum	< 0.00025	**1.37**	< 0.05	**120**	< 0.002	**0.007**	< 0.005	**0.045**	**2.13**	0.38	< 0.02	**0.04**	< 0.05	0.48	**0.064**
	25th Percentile	-	0.0155	0.0005	47.7	0.00010	0.0005	0.0005	0.0005	0.075	0.0155	0.001	0.0005	0.0005	0.190	0.0105
	75th Percentile	-	0.16	0.0005	85.2	0.00010	0.0005	0.0005	***0.002***	***0.345***	0.034	0.0025	0.0005	0.001	0.360	0.023
VGMAIN	n	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
	Median	0.000125	0.012	0.0005	60.6	0.0001	0.0005	0.0005	0.0005	0.07	0.007	0.002	0.0005	0.0005	0.24	0.019
	Mean	0.00013	0.0345	0.00056	61.3	0.00012	0.00051	0.00053	0.00244	0.111	0.0455	0.00201	0.00079	0.00063	0.246	0.0208
	Min	< 0.00025	< 0.005	< 0.001	21.2	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.002	< 0.001	< 0.001	< 0.001	0.081	0.010
	Max	**0.0003**	**0.49**	0.002	**145**	**0.0004**	< 0.001	< 0.001	**0.052**	**0.95**	0.61	0.011	**0.008**	**0.003**	0.58	**0.086**
	25th Percentile	0.000125	0.007	0.0005	38.5	0.00010	0.0005	0.0005	0.0005	0.025	0.005	0.00075	0.0005	0.0005	0.155	0.0125
	75th Percentile	0.000125	0.0315	0.0005	80.4	0.00010	0.0005	0.0005	0.001	0.12	0.0145	0.003	0.0005	0.0005	0.315	0.0235

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

a *Calcium Guideline is based on effects on zooplankton, as developed in Background Benchmark Report (Minnow 2008)*

b *Strontium Guideline is based on effects on fish, as developed in Background Benchmark Report (Minnow 2008)*

Bold *Maximum Exceeds Guideline*

Bold, italics *75% and/ or Median Exceeds Guideline*

underlined *>50% of samples < Method Detection Limit (MDL);*

\- *100% of samples <MDL*

Table 3.3-14. Pelly RSA (Rose Creek, Anvil Creek and Pelly River) Sampling Sites

Sampling Site	Site Description
Reference Locations (in Addition to LSA Reference Locations)	
FC[2]	Faro Creek, upstream of Faro West Valley Interceptor
R6[1]	Anvil Creek, upstream of Rose Creek
P1[2]	Pelly River upstream of Vangorda Site
Receiving Water Locations	
R4[1]	Rose Creek, upstream of Anvil Creek
R5[1]	Anvil Creek, downstream of Rose Creek
R11[1]/A1[2]	Anvil Creek, upstream of the Pelly River
P2[2]	Pelly River downstream of Vangorda Site
P3[2]	Pelly River upstream of Anvil Creek
P4[2]	Pelly River downstream of Anvil Creek

[1] *Water Licence Monitoring Program*

[2] *Interim Aquatic Ecosystem Monitoring Program*

Table 3.3-15. General Parameters in Anvil Creek and Pelly River Reference Locations - Regional Study Area

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
Background Benchmark		**303**	**158**	**0.03**	**6.58-8.16**	**20.3**	**3**
Water Quality Guidelines		**-**	**-**	**0.24**	**6.5 - 9.0**	**50**	**8**
FC	n	4	4	4	4	4	4
	Median	37	13.4	-	6.85	2.5	0.5
	Mean	36	13.7	-	7.04	2.28	0.875
	Minimum	29	12.2	< 0.005	6.45	1.2	< 1
	Maximum	41	16.0	< 0.005	8.01	2.9	2
	25th Percentile	35	12.7	-	6.74	2.10	0.5
	75th Percentile	38	14.4	-	7.14	2.67	0.875
P1	n	4	4	4	4	4	4
	Median	358	190	0.00338	8.08	***63.45***	2.38
	Mean	370	194	0.0025	8.26	64.9	2
	Minimum	292	154	< 0.005	7.40	55.5	< 1
	Maximum	400	216	0.006	8.39	**68.5**	5
	25th Percentile	336	169	0.0025	8.0	60.75	0.875
	75th Percentile	393	215	0.0034	8.3	***67.6***	3.5
R6	n	10	10	10	10	10	10
	Median	304	158	0.005	8.05	20.3	0.5
	Mean	298	165	0.006	8.01	27.1	0.8
	Minimum	240	132	< 0.005	7.5	19.3	< 1
	Maximum	382	261	0.02	8.3	**80.1**	2
	25th Percentile	267	147	0.0025	7.92	19.7	0.5
	75th Percentile	315	166	0.005	8.10	23.9	0.5

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

	CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)
	BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)
Bold	Maximum Meets or Exceeds Guideline
Bold, italics	75% and/ or Median Meets or Exceeds Guideline
underlined	>50% of samples < Method Detection Limit (MDL);
-	100% of samples <MDL

Table 3.3-16. Total Metals in Anvil Creek and Pelly River Reference Locations - Regional Study Area

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Sr	Zn
		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	mg/L
Background Benchmark		**<0.00005**	**0.156**	**<0.001**	**44.9**	**0.00004**	**<0.001**	**<0.001**	**0.002**	**0.246**	**0.0264**	**<0.001**	**<0.001**	**<0.001**	**0.18**	**0.0164**
Water Quality Guidelines		**0.0001**	**0.1**	**0.005**	**116[a]**	**0.00003**	**0.004**	**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.001**	**9.3[b]**	**0.03**
FC	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Median	-	0.0346	0.00009	4.09	0.0000095	0.0000185	0.0001	0.00049	0.032	0.00097	0.000225	0.000128	-	0.0263	0.00195
	Mean	-	0.0446	0.00011	4.15	0.000010	0.0000255	0.000325	0.000568	0.0385	0.00131	0.000175	0.000166	-	0.0261	0.00288
	Minimum	< 0.000005	0.0293	0.00006	3.54	0.000009	0.000015	0.0001	0.00039	0.024	0.0007	< 0.00002	0.000088	< 0.00004	0.0222	0.0015
	Maximum	< 0.000005	0.0797	0.0002	4.87	0.000013	0.00005	**0.001**	0.0009	0.066	0.00261	0.00024	0.00032	< 0.00004	0.0296	0.0061
	25th Percentile	-	0.0315	0.00007	3.82	0.000009	0.00002	0.0001	0.00045	0.0293	0.00084	0.000167	0.0001	-	0.0251	0.00173
	75th Percentile	-	0.0477	0.000125	4.42	0.000011	0.00003	0.000325	0.000607	0.0412	0.00144	0.000233	0.000194	-	0.0272	0.0031
P1	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Median	0.000004	0.0524	0.000385	*49.4*	0.0001775	0.0000735	0.0003125	0.000995	0.135	0.0163	0.00455	0.000147	0.001045	0.203	0.0183
	Mean	0.0000025	0.0318	0.000375	50.5	***0.0001705***	0.000059	0.0001	0.00089	0.123	0.0162	0.00462	0.000133	0.00107	0.212	0.0177
	Minimum	< 0.000005	0.0090	0.0003	39.9	0.00015	0.000026	< 0.0001	0.0007	0.04	0.0117	0.00406	0.00007	0.0008	0.164	0.0142
	Maximum	0.000007	0.137	0.00049	*56.8*	**0.000219**	0.00015	**0.001**	0.0015	*0.253*	0.0212	*0.0049*	0.00025	*0.00124*	*0.224*	*0.0234*
	25th Percentile	0.0000025	0.0201	0.00032	44.1	0.00016	0.000037	0.000087	0.0008	0.071	0.012	0.0044	0.00012	0.00090	0.19	0.0163
	75th Percentile	0.0000036	0.0640	0.00044	*55.8*	***0.00018***	0.000095	0.000325	0.0011	0.186	0.021	0.0048	0.00016	0.00121	0.22	0.0197
R6	n	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Median	0.000125	0.0156	0.0005	*45.1*	0.0001	0.0005	0.0005	0.0005	0.115	0.014	0.0005	0.0005	0.0006	0.137	0.0025
	Mean	0.000235	0.0291	0.00042	47.2	0.000066	0.000314	0.000745	0.000734	0.113	0.0141	0.000526	0.000334	0.000744	0.139	0.00289
	Minimum	< 0.000005	0.0067	< 0.00002	35.3	0.00001	0.000013	< 0.0001	0.00035	< 0.05	0.00512	< 0.00002	0.00002	0.0007	0.106	0.0004
	Maximum	**0.0017**	0.140	< 0.001	*77.8*	< 0.0002	< 0.001	**0.003**	**0.003**	0.18	0.0208	*0.002*	< 0.001	*0.002*	*0.25*	0.006
	25th Percentile	0.000007	0.0133	0.00045	40.9	0.00002	0.00004	0.0002	0.00045	0.093	0.0112	0.000255	0.00012	0.0005	0.1125	0.0013
	75th Percentile	0.000125	0.0257	0.00050	*48.5*	0.00010	0.00050	0.0005	0.0005	0.148	0.0178	0.0005	0.0005	0.000725	0.1400	0.00437

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)

BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)

a Calcium Guideline is based on effects on zooplankton, as developed in Background Benchmark Report (Minnow 2008)

b Strontium Guideline is based on effects on fish, as developed in Background Benchmark Report (Minnow 2008)

Bold Maximum Meets or Exceeds Guideline

italics Value Meets or Exceed Background Benchmark

underlined >50% of samples < Method Detection Limit (MDL);

\- 100% of samples <MDL

Table 3.3-17. General Parameters in Rose Creek, Anvil Creek, and the Pelly River Regional Study Area Receiving Water

Parameter		Conductivity - Lab µs/cm	Hardness mg/L	Ammonia mg/L	pH - Field	Sulphate mg/L	TSS mg/L
Water Quality Guidelines		**-**	**-**	**0.24**	**6.5 - 9.0**	**50**	**8**
P2	n	4	4	4	4	4	4
	Median	354	189	0.01	8.06	***62.1***	3.63
	Mean	366	195	0.01	7.95	62.8	3
	Minimum	294	153	< 0.005	7.69	54.5	< 1
	Maximum	390	214	0.026	8.63	**68.2**	**8**
	25th Percentile	338	170	0.002	7.85	60.6	0.875
	75th Percentile	383	213	0.024	8.16	***64.2***	5.75
P3	n	4	4	4	4	4	4
	Median	346	182	0.0045	7.57	***57.2***	3.63
	Mean	355	187	0.00	7.47	57.9	3
	Minimum	293	156	< 0.005	7.17	53.3	< 1
	Maximum	380	200	0.007	8.16	**59.8**	**8**
	25th Percentile	335	169	0.002	7.39	56.4	2.38
	75th Percentile	365	200	0.006	7.64	***58.8***	4.25
P4	n	4	4	4	4	4	4
	Median	346	178	0.0095	7.91	***57.0***	3.125
	Mean	361	180	0.00525	8.04	60.6	2.5
	Minimum	271	142	< 0.005	7.16	45.4	< 1
	Maximum	390	209	0.025	8.41	**61.2**	7
	25th Percentile	331	165	0.002	7.80	56.4	0.875
	75th Percentile	375	193	0.012	8.15	***61.1***	4.75
R4	n	10	10	10	10	10	10
	Median	383	199	0.018	7.95	***79.6***	0.5
	Mean	393	203	0.0190	7.85	89.9	0.9
	Minimum	238	117	< 0.005	7.27	26.4	< 1
	Maximum	514	262	0.042	8.4	**127**	3
	25th Percentile	340	180	0.011	7.62	75.6	0.5
	75th Percentile	472	246	0.02	8.11	***122***	1
R5	n	4	4	4	4	4	4
	Median	275	150	-	8.1	26.6	0.5
	Mean	296	177	-	8.0	38.8	1.13
	Minimum	252	135	< 0.01	7.5	21.7	< 1
	Maximum	383	272	< 0.01	8.3	**80.3**	3
	25th Percentile	266	140	-	7.95	24.3	0.5
	75th Percentile	305	187	-	8.15	41.0	1.13
R11	n	6	6	6	6	6	6
	Median	311	165	0.0125	7.95	48.3	0.5
	Mean	315	179	0.0142	7.83	51.4	1.33
	Minimum	245	135	< 0.01	7.4	38.6	< 1
	Maximum	383	290	0.03	8.2	**81.9**	4

	25th Percentile	284	140	0.005	7.6	42.5	0.5
	75th Percentile	351	184	0.02	8.0	***50.0***	1.63

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

	CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)
	BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)
Bold	Maximum Meets or Exceeds Guideline
Bold, italics	75% and/ or Median Meets or Exceeds Guideline
underlined	>50% of samples < Method Detection Limit (MDL);
-	100% of samples <MDL

Table 3.3-18. Total Metals in Rose Creek, Anvil Creek, and the Pelly River Regional Study Area Receiving Water

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Sr	Zn
		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	mg/L
Water Quality Guidelines		**0.0001**	**0.1**	**0.005**	**116**[a]	**0.00003**	**0.004**	**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.001**	**9.3**[b]	**0.03**
P2	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Median	-	0.0557	0.0003675	49.0	0.000178	0.00008	0.0001625	0.00107	0.144	0.0177	0.00464	0.000159	0.0010275	0.207	0.0185
	Mean	-	0.0413	0.000365	50.5	***0.000179***	0.000076	0.00015	0.00105	0.143	0.0163	0.00474	0.000171	0.00106	0.2145	0.0177
	Minimum	< 0.000005	0.0093	0.0002	39.5	0.00015	0.000038	< 0.0001	0.00088	0.041	0.0114	0.00419	0.000106	0.0008	0.165	0.0149
	Maximum	< 0.000005	**0.131**	0.00054	55.6	**0.000204**	0.00014	0.0003	0.0013	0.247	0.0267	0.0049	0.000189	**0.00119**	0.234	0.0238
	25th Percentile	-	0.0260	0.00028	44.2	0.00017	0.000039	0.000087	0.00098	0.0673	0.0126	0.0046	0.0001	0.0009	0.192	0.0168
	75th Percentile	-	0.0710	0.00045	55.3	***0.00019***	0.00012	0.00022	0.0011	0.219	0.0214	0.0048	0.0002	0.0012	0.2295	0.0194
P3	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Median	-	0.0608	0.00036	49.1	0.0001165	0.000083	0.0006375	0.00105	0.121	0.0152	0.00346	0.000116	0.0008875	0.1935	0.0113
	Mean	-	0.0296	0.000375	49.9	***0.0001195***	0.000055	0.0001	0.00101	0.0975	0.0156	0.00346	0.000081	0.000885	0.197	0.0123
	Minimum	< 0.000005	0.0069	0.0002	40.9	0.000082	0.000032	< 0.0001	0.00079	0.027	0.0095	0.00233	0.000073	0.0008	0.171	0.0063
	Maximum	< 0.000005	**0.177**	0.00049	55.8	**0.000145**	0.00019	0.0023	0.0014	0.261	0.0201	0.0046	0.00023	0.00098	0.209	0.0145
	25th Percentile	-	0.0115	0.00030	44.3	0.00010	0.000037	0.000087	0.00080	0.0443	0.0115	0.0028	0.000074	0.0009	0.18975	0.0092
	75th Percentile	-	0.0788	0.00044	54.8	***0.00013***	0.00010	0.00065	0.0013	0.174	0.0192	0.0041	0.000123	0.0009	0.20075	0.0144
P4	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Median	-	0.0426	0.0003825	48.0	0.0001283	0.000066	0.000225	0.0010175	0.118	0.018725	0.00330	0.000208	0.000895	0.19275	0.0125
	Mean	-	0.0315	0.0004	48.8	***0.000123***	0.000065	0.000075	0.00096	0.119	0.01855	0.00334	0.000202	0.0009	0.202	0.0124
	Minimum	< 0.000005	0.0103	0.0002	38.2	0.00009	0.000033	< 0.0001	0.00085	0.036	0.0111	0.00268	0.000168	0.0007	0.145	0.0078
	Maximum	< 0.000005	0.097	0.00053	56.0	**0.000177**	0.0001	0.0007	0.0013	0.199	0.0267	0.00383	0.00026	**0.00108**	0.222	0.0175
	25th Percentile	-	0.0156	0.00032	43.9	0.000097	0.000033	0.000050	0.00093	0.0517	0.0136	0.0030	0.0002	0.0008	0.18325	0.0100
	75th Percentile	-	0.0585	0.00046	52.8	***0.00015***	0.000097	0.00025	0.001	0.185	0.0236	0.0036	0.0002	0.0009	0.2115	0.0149
R4	n	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Median	0.000125	0.007	0.0005	59.6	0.0001	0.0005	0.0005	0.0005	0.0905	0.117	0.00091	0.0005	0.0005	0.208	0.0126
	Mean	0.000125	0.0107	0.000421	60.3	0.000071	0.000385	0.00043	0.000594	0.0866	0.239	0.00101	0.000410	0.0006	0.206	0.0126
	Minimum	< 0.000005	0.0046	< 0.00002	34.6	0.00001	0.000045	0.0001	0.0005	0.047	0.017	0.0005	0.000129	< 0.00004	0.125	< 0.005
	Maximum	**0.0006**	0.0209	< 0.001	77.6	**0.00006**	< 0.001	< 0.001	0.00103	0.17	0.938	0.00203	< 0.001	**0.002**	0.26	0.025
	25th Percentile	0.000007	0.0051	0.000238	52.8	0.000032	0.000208	0.0005	0.0005	0.0472	0.0462	0.00057	0.000389	0.000493	0.191	0.0065
	75th Percentile	0.000125	0.018	0.0005	72.6	0.0001	0.0005	0.0005	0.000583	0.11	0.35	0.001	0.0005	0.0005	0.24	0.0154
R5	n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Median	0.000125	0.018	-	41.9	-	-	-	0.0005	0.11	0.028	-	-	0.00075	0.12	0.0025
	Mean	0.000244	0.0208	-	50.4	-	-	-	0.000625	0.104	0.0373	-	-	0.00075	0.153	0.00363
	Minimum	< 0.00025	0.017	< 0.001	36.3	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.016	< 0.001	< 0.001	< 0.001	0.11	< 0.005
	Maximum	**0.0006**	0.03	< 0.001	81.5	< 0.0002	< 0.001	< 0.001	< 0.001	0.17	0.077	< 0.001	< 0.001	< 0.001	0.26	0.007
	25th Percentile	0.000125	0.017	-	38.5	-	-	-	0.0005	0.0888	0.0183	-	-	0.0005	0.11	0.0025
	75th Percentile	0.000244	0.0217	-	53.8	-	-	-	0.00063	0.125	0.047	-	-	0.001	0.162	0.00362
R11	n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.021	0.0005	48.2	-	-	-	-	0.08	0.0195	-	-	0.0005	0.15	0.0025
	Mean	0.00025	0.0262	0.00067	52.6	-	-	-	-	0.075	0.024	-	-	0.00075	0.167	0.004
	Minimum	< 0.00025	0.007	< 0.001	38.3	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.005	< 0.001	< 0.001	< 0.001	0.12	< 0.005
	Maximum	**0.0009**	0.061	< 0.001	85.9	< 0.0002	< 0.001	< 0.001	< 0.001	0.12	0.059	< 0.001	< 0.001	**0.002**	0.28	0.008
	25th Percentile	0.000125	0.0115	0.0005	40.8	-	-	-	-	0.0363	0.00925	-	-	0.0005	0.132	0.0025

	Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	Sr	Zn
75th Percentile	0.000125	0.0343	0.000875	54.3	-	-	-	-	0.113	0.0312	-	-	0.0005	0.167	0.00512

Note: statistics calculated setting results <MDL equivalent to 1/2 MDL

	CCME Guideline - Water Quality Guideline shown is based on CCME Guidelines for Aquatic Life, as developed in Background Benchmark Report (Minnow 2008)
	BC - WQG - Water Quality Guideline is based on the British Columbia Water Quality Guideline for freshwater, as developed in Background Benchmark Report (Minnow 2008)
a	Calcium Guideline is based on effects on zooplankton, as developed in Background Benchmark Report (Minnow 2008)
b	Strontium Guideline is based on effects on fish, as developed in Background Benchmark Report (Minnow 2008)
Bold	Maximum Exceeds Guideline
Bold, italics	75% and/ or Median Exceeds Guideline
underlined	>50% of samples < Method Detection Limit (MDL);
-	100% of samples <MDL

Table 3.3-19. Pelly River Sampling Sites – Pelly River Aquatic Effects Monitoring Program

Sampling Site	Site Description
Pelly Aquatic Effects Monitoring Program[1]	
PB	Pelly River, upstream of Blind Creek
P1	Pelly River, upstream of Anvil Creek (upstream of IAEMP P3)
P1A	Pelly River, downstream of Anvil Creek (downstream of IAEMP P4)

[1] Sample sites illustrated in Figure 3.3-19 (map provided by Access Consulting Group).

4. Aquatic Organisms and Habitat

The Anvil/Rose Creek and Vangorda Creek watersheds affected by the Faro Mine Complex have an area of 980 km^2 and 90 km^2 respectively and are tributaries to the Pelly River. To put this in perspective the Pelly River watershed has a total drainage area of 51,000 km^2 and the Anvil/Rose Creek and Vangorda Creek drainages represent approximately 2% and 0.2% of the total Pelly River drainage area. A broad watershed ecosystem perspective is needed to capture a key issue identified: the transport of pollutants and toxic substances from the mining site and downstream effects on water quality and aquatic resources.

The major water quality issues arising from past mining activities involve heavy metals such as copper, zinc and lead that are toxic to aquatic resources in high concentrations but are normally found in lower concentrations in the natural environment. As well there is considerable connectivity of salmon and other aquatic resources between the Anvil/Rose and Vangorda Creek systems and the broader watershed. The Pelly River watershed has been classified as a higher sensitivity watershed in the development of the new placer mining regime based mainly on the relatively high level of utilization by adult salmon and salmon spawning and relatively good water quality (low turbidity).

The overall abundance and availability of habitat types within the Pelly watershed is characterised as follows: 4% of the total stream length is classified as the highest sensitivity migration and spawning habitat for adult Chinook salmon (*Oncorhynchus tshawytscha*); 24% is classified as moderate sensitivity Chinook rearing habitat; and 61% is classified as low sensitivity freshwater fish habitat. These are important factors to consider when assessing the risk of potential mining impacts on fish habitat in the Anvil/Rose Creek and Vangorda Creek drainages and the brooder risk to salmon and freshwater fish in the Pelly River watershed.

Aquatic resources baseline data presented and discussed here include sediment quality, benthic invertebrates (community species diversity and abundance, presence and abundance of pollution sensitive species and metal concentrations in tissues), fish (species abundance and distribution and metal concentrations in tissues) and fish habitat.

An extensive aquatic database describing metals in stream sediments, metals in fish tissues, abundance and diversity of benthic invertebrates and fish species utilization exists for the Anvil/Rose Creek watershed dating back to the early 1970's and Vangorda Creek watershed dating back to the early 1990's. Some caution is necessary when trying to interpret data trends extending over three decades, especially where the data compatibility is heavily dependent on consistency of sampling and analytical techniques used.

4.1 Aquatic Study Area

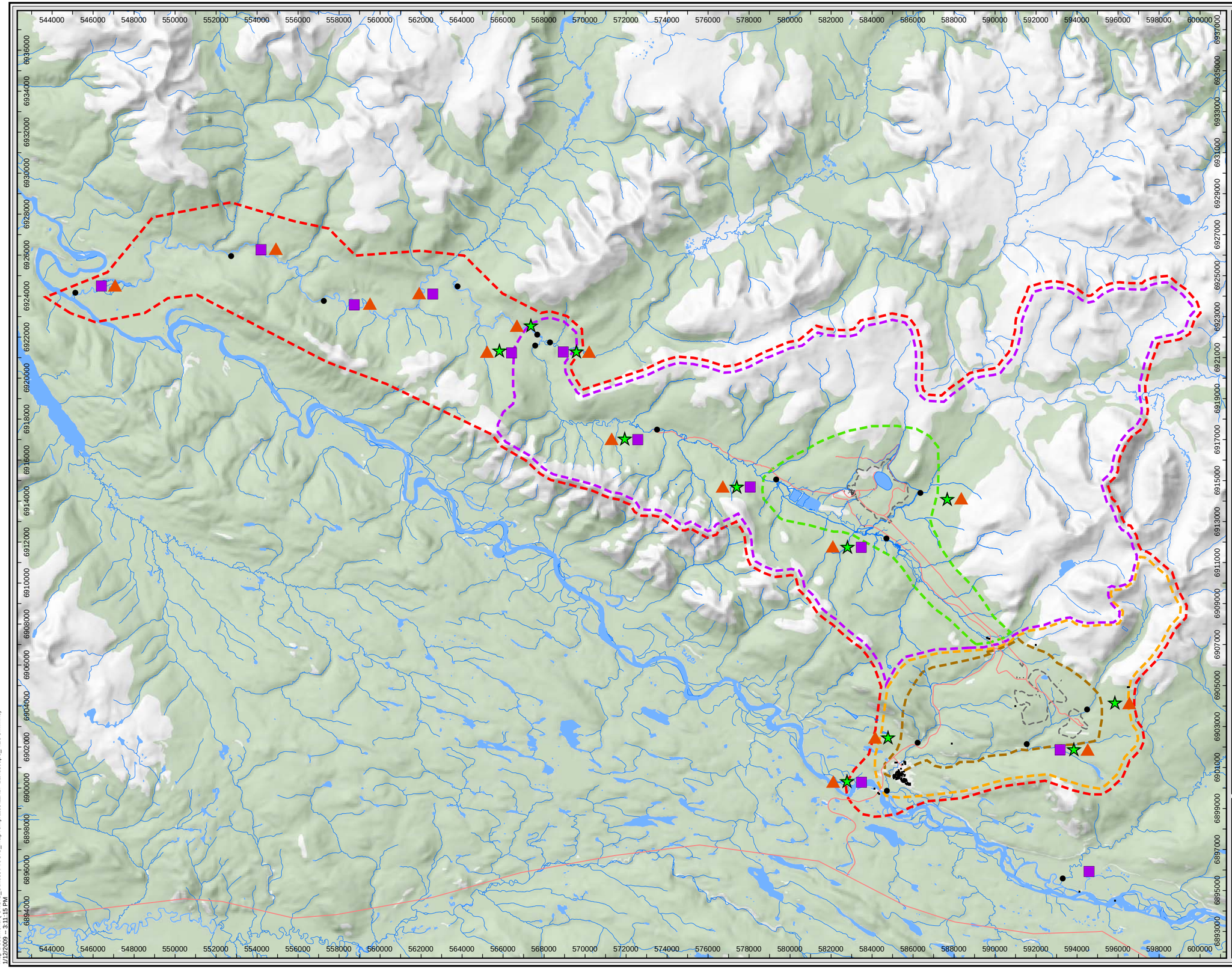
The local and regional study areas for aquatic resources are based on watershed boundaries and include both the Anvil/Rose Creek and Vangorda Creek watersheds as shown in Figure 2.1-1. The Anvil/Rose and Vangorda watersheds are separate and unique and have distinct characteristics in terms of hydrology, morphology, geology and drainage area, as well as past and continuing impacts from mining activities. Watershed characteristics are summarized in Table 4.1-1. Consequently, baseline data for each watershed is presented and discussed separately.

The local and regional study areas for aquatic resources are determined largely by downstream water quality and thus are the same as those for surface water quality and described in Section 3.3 and illustrated on Figure 4.1-1. The regional study area includes the Vangorda Creek drainage down to the Pelly River and the Anvil/Rose Creek drainage to the confluence with the Pelly River. The drainage area of Anvil Creek, which includes Rose Creek drainage, is 980 km^2.

Some consideration must also be given to potential impacts to the Pelly River in areas below the discharge points of these tributaries. Several studies have been completed on the receiving waters of this area of the Pelly River (Selkirk First Nation 2005, 2006, 2007) Some fish data from Blind Creek is also presented. Blind Creek is an important Chinook salmon spawning stream which is a tributary to the Pelly River upstream from Faro and is used as a reference watershed.

Most of the aquatic resource studies in the local and regional study areas have been completed as routine sampling required under the water licenses and other studies have occurred on a less routine basis for other purposes. Sample site locations are illustrated on Figure 4.1-1. Metals in stream sediment data and benthic invertebrate community data exists from 1973 to 2007, while fish presence and metals in fish tissue data exists from 1974 to 2007. Metals in benthic invertebrate tissue data were collected in 2002 and 2006.

Table 4.1-2 outlines the aquatic resource studies that have been completed within the study areas. In addition, studies have been carried out in the Pelly River by Selkirk First Nation during 2004-06 through the Pelly River Aquatics Effects Assessment and through the Interim Aquatic Ecosystem Monitoring Program in 2007.



Legend

- Benthic Invertebrate
- Fish Sampling
- Stream Sediment
- Sampling Locations
- Roads
- Pits
- Regional Study Area
- Rose Creek Local Study Area
- Vangorda Local Study Area
- Rose Creek Watershed
- Vangorda Watershed
- Surface Water
- Buildings

Basemapping from Yukon Territory Government

N W E S

Kilometers

0 2 4 6 8

1:175,000

UTM Zone 8N, NAD 83

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Environmental Assessment of the Closure and Remediation Plan for the Faro Mine Complex

Aquatic Resources Study Area

April 2009
Project 107403 - 80649

AECOM

Figure 4.1-1

Map Document: (O:\GIS_Utilities\ArcGIS_MapTemplates\11x17-Landscape_AECOM.mxd)
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Table 4.1-1. Characteristics for Vangorda Creek and Anvil/Rose Creek Watersheds

Characteristic	Vangorda Creek Watershed	Anvil/(Rose) Creek Watershed
Drainage Area (km^2)	90	980 (340)
Change in Elevation (m)	1000	(750)
Steam Order	3	(3)
Area Drained	South slope of Mount Mve	(Southeast slopes of Anvil Range Mountains)
Empties into	Pelly River	Pelly River (Anvil Creek)

Table 4.1-2. Aquatic Resource Studies Completed

Study Topic	Watershed	Study Date	Reference
Metals in stream sediment	Rose	1973	Hoos & Holman (Env. Can), 1973
Metals in stream sediment	Rose	1985	Godin & Osler (Env. Can), 1985
Metals in stream sediment	Vangorda	1993	Laberge, 1993
Metals in stream sediment	Vangorda	1996	Davidge (Env. Can.), 1996
Metals in stream sediment	Vangorda	1996	Laberge, 1996
Metals in stream sediment	Vangorda	1997	Laberge, 1997
Metals in stream sediment	Vangorda	1999	Laberge, 1999
Metals in stream sediment	Rose	1999	Env. Can. Unpublished
Metals in stream sediment	Vangorda	2001	Laberge, 2001
Metals in stream sediment	Rose, Vangorda	2002	Gartner Lee, 2003a
Metals in stream sediment	Vangorda	2003	Laberge, 2003
Metals in stream sediment	Rose	2004	Laberge, 2004
Metals in stream sediment	Vangorda	2005	Laberge, 2005
Metals in stream sediment	Rose	2006	Laberge, 2006
Metals in stream sediment	Vangorda	2007	Laberge, 2007
Metals in stream sediment	Rose (Anvil)	2006	Selkirk First Nation, 2007
Metals in stream sediment	Vangorda	2007	
Metals in stream sediment	Anvil, Blind, Pelly	2004, 05. 06	Selkirk First Nation 2005, 06, 07
Benthic invertebrate studies are outlined in Table 3.3-1.			
Fish presence, metal in fish tissue	Rose	1974	S.A. Baker, 1979
Fish presence, metal in fish tissue	Rose	1975	S.A. Baker, 1979
Fish presence, metal in fish tissue	Rose, Vangorda	1975	Mtl. Engineering Co., 1976
Fish presence, metal in fish tissue	Rose	1976	S.A. Baker, 1979
Fish presence, metal in fish tissue	Vangorda	1977	Mtl. Engineering Co., 1978
Fisheries impact of Rose diversion	Rose	1981	K. Weagle, 1981a
Arctic grayling survey	Rose	1981	K. Weagle, 1981b
Fisheries	Rose	1986	Leverton & Associates, 1986
Fish presence and habitat	Vangorda	1987	P.A. Harder & Associates, 1987
Fish spawning survey	Rose	1988	P.A. Harder & Associates, 1988
Fish production and overwintering	Vangorda	1989	P.A. Harder & Associates, 1989a,b
Fish habitat, production and feeding	Rose	1989 / 1990	P.A. Harder & Associates, 1991a,b,c,d
Fish feeding, growth and population	Vangorda	1990	P.A. Harder & Associates, 1992
Fish habitat, metal in fish tissue	Rose	1992	P.A. Harder & Associates, 1993a,b
Fish habitat use	Vangorda	1996	P.A. Harder & Associates, 1996
Metal in fish tissue		1997	Yukon Territorial Government
Fish habitat associated with FWSD	Rose	2000	Gartner Lee Ltd., 2000
Fish habitat, some fish presence and metals in fish tissue	Rose, Vangorda	2002	Gartner Lee Ltd., 2003
Fish habitat and presence	South Fork Rose, FWSR	2004	White Mountain, 2005a
Fish habitat, presence, metal in tissue	Rose , Vangorda	2004	White Mountain, 2004
Fish habitat and presence	South Fork Rose, FWSR	2005	White Mountain, 2006a
Fish habitat, presence, metal in tissue	Rose, Vangorda	2005	White Mountain, 2005b
Fish habitat and presence	South Fork Rose, FWSR	2006	White Mountain, 2007a
Fish habitat, presence, metal in tissue	Rose, Vangorda	2006	White Mountain, 2006b
Fish habitat and presence	South Fork Rose, FWSR	2007	Laberge, 2008
Fish habitat, presence, metal in tissue	Rose, Vangorda	2007	White Mountain, 2008
Fish habitat, presence, metal in tissue	Anvil	2004-2005	Selkirk First Nation 2005, 2006

4.2 Stream Sediment Quality

Stream sediment samples have been collected from various sites in and near the Faro Mine Complex for several decades. Chemical analysis was performed on the portion of the sediment that passed through a 100 (0.15 mm) mesh screen. All data examined are the means of triplicates (except for the 1983 data which are means for six samples).

4.2.1 Vangorda Creek Watershed

4.2.1.1 Historic Sediment Quality

Sediment sampling and analyses for metals have been conducted every two years at four sites on Vangorda Creek since 1993 as required by the Water Licence. The concentrations of copper, lead and zinc have been examined and discussed in annual and compilation reports. These three metals are found in the ore deposits, can be toxic to aquatic organisms at high concentrations and have sediment quality guidelines available for comparison. These data have been summarized and graphed along with the recent data in Table 4.2-1 and Figure 4.2-1.

The sites have been arranged in the tables and graphs as they occur geographically. V1 is the uppermost site and represents the reference site. V27 is located below all mine inputs and represents the near field site. Both V5 and V8 are far field sites.

The 1993, 1995, 1997 and 1999 (historical data) results for Vangorda Creek sediments indicate that the highest arsenic, copper, lead and zinc concentrations are in sediments from the impacted site V27. Metal concentrations at site V5 on the West Fork are the lowest and comparable to reference site V1 results, while concentrations at the creek mouth (V8) are between the results of sites V27 and V5. All samples exceeded the Interim Sediment Quality Guidelines (ISQG) for arsenic and most also exceeded the Probable Effects Level (PEL). Copper levels exceeded the 35.7 µg/g ISQG for some sample results at all of the sites. Lead levels exceeded the 91.3 µg/g PEL in the V27 and V8 sediments, while zinc levels exceeded the 315 µg/g PEL in all V27 and some V8 samples. Increasing levels of the metals at site V27 over time is an evident data trend.

4.2.1.2 Recent and Current Sediment Quality

Minnow Environmental Inc (2007) examined all the data collected from the Vangorda Watershed from 1993 to 2005. Statistical evaluation of the data spatially and temporally, identified that the key indicators of mine influence on sediment chemistry were arsenic, lead and zinc. More recent stream sediment samples were collected in July 2007. The concentrations of these metals, as well as copper, are included in Table 4.2-1 and Figure 4.2-1.

Current metal concentrations (2001 to 2007) in the stream sediments have been relatively stable at V1, V5 and V8 with a gradual reduction in lead and zinc concentrations at V8. Although metal concentrations have been significantly greater at V27 than at the other sites, the concentrations of the metals have been decreasing steadily since peaking in 2001, with some fluctuation of zinc.

All samples exceeded the ISQG for arsenic, with the PEL also exceeded in all V27 samples and some of the V1 samples (Table 4.2-1). Concentrations of arsenic in the stream sediments at the far field sites are similar to the reference site and appear to be a natural element found in the Vangorda Creek watershed.

Copper concentrations in the stream sediments at V27 have been decreasing in recent years and are approaching background levels.

Lead concentrations in the stream sediments at V5 have typically been lower than the reference site V1. Significantly higher levels of lead have been documented at V27, peaking in 2001. Concentrations have decreased drastically since then, although they are greater than concentrations in the sediments at V1, V5 and V8. Lead concentrations at V8 continue to exceed the ISQG.

Zinc concentrations in the stream sediments have frequently exceeded the ISQG at V1 and V8, and have exceeded the PEL at V27. Levels appear relatively stable over time at V1, V5 and V8, and appear to display a decreasing trend at V27.

There have been no mine related inputs to the Vangorda Creek system since 2005. Analysis was completed on the fine grained and easily transported sediment, and it would appear that this material has been gradually mobilized through the system. The documented high concentrations of metals at V27 during the 1990s have either not yet mobilized to V8, or have mobilized to the Pelly River.

4.2.2 Anvil/Rose Creek

4.2.2.1 Historical Data

Stream sediment samples have been collected sporadically and inconsistently in the Rose Creek watershed with the first collection occurring in 1973. It was not until 2004 that monitoring the quality of stream sediments became a licensed requirement. Samples have been collected from a total of eleven sites within the Anvil/Rose Creek drainage, ranging from upstream on the North Fork of Rose Creek to Anvil Creek at the mouth near the confluence with the Pelly River. The sites have been arranged in the tables and graphs with the reference sites (R6, R7, and R1) at the beginning followed by the near and far field sites as they occur downstream.

The 1973, 1983, 1996 and 1999 (historical data) results for Rose Creek sediments indicate that copper concentrations exceed the 35.7 ug/g ISQG in most impacted areas and some reference area samples (Table 4.2-2, Figure 4.2-5). Lead concentrations in sediment exceed the 91.3 µg/g.

PEL in most impact and reference area samples. Some zinc concentrations exceed the 123 µg/g ISQG while the remainder exceed the 315 µg/g PEL at impact and reference area samples. Spatial trends in the data set are not apparent and temporal trends indicate highest values for the three metals in 1983 samples from the impacted area (following a 1975 tailings spill into Rose Creek) as compared to 1973 and 1996 values. However, very high concentrations of arsenic, lead, mercury and zinc were also documented in 1983 at R6, a reference site for Anvil Creek, leading to speculation on the accuracy of these analyses. Concentrations of these metals in the sediments at R6 since 1983 have been constantly much lower.

The stream sediments at R2, the near field site, consistently had the highest concentrations of the metals examined with all samples exceeding the ISQG for all metals, and the PEL for arsenic, lead and zinc.

4.2.2.2 Recent Data

Minnow Environmental Inc (2007) examined all the data collected from the Anvil/Rose Creek Watershed from 1973 to 2006. Statistical evaluation of the data spatially and temporally, identified that the key indicators of mine influence on sediment chemistry of this watershed were arsenic, lead, manganese and zinc. Summarized data for cadmium and mercury have also been included in Table 4.2-2 and Figure 4.2-5. There are no guidelines for manganese but since this metal exceeded background concentration by the greatest magnitude, it has been identified as a parameter to monitor (Minnow 2007).

A comparison of spatial and temporal sediment data and trends moving downstream from the site R2 closest to the Faro mine site on Rose creek down to site A1 on Anvil Creek near the Pelly River is presented in Figure 4.2-2. While there is some variation in the data there is clear evidence of a declining trend in metals in sediments moving from the near field sites on Rose Creek downstream to the Pelly River for all metals except for Cadmium. At A1 near the Pelly River concentrations are at or below ISQG and PEL guideline levels and at reference site levels for all metals. Cadmium shows no obvious trends and it is believed that high levels of this metal in the natural environment mask any influences from mining for this metal.

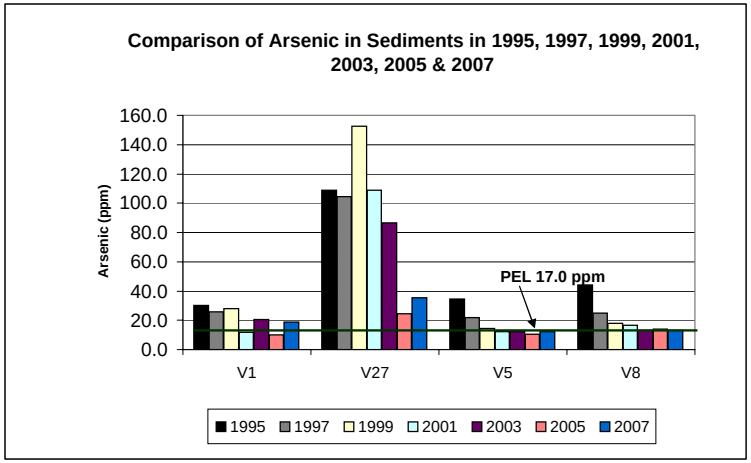
The recent data (2002, 2004, 2005 and 2006) for arsenic are generally stable at the sites with the stream sediments at R2, R3 and R4 having the greatest concentration (except for an outlier in 2005 at R5). Arsenic levels appear to be decreasing and levelling off at R2, R3 and R4 approaching background levels.

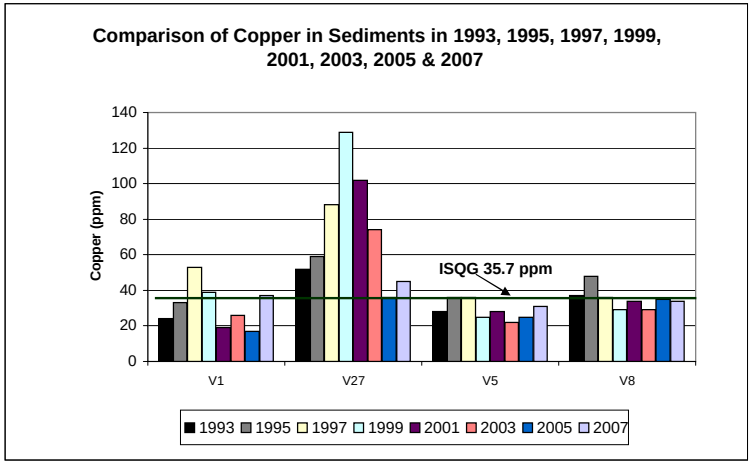
The recent data (2002, 2004, 2005 and 2006) indicates that lead and zinc levels continue to be greatest at the near field site, R2, and gradually decrease progressively downstream. Lead and zinc have been relatively low at the reference sites R6 and R7, however the ISQG has occasionally been exceeded at R1. Lead and zinc levels appear to be decreasing over time at the impacted sites R2, R3 and R4.

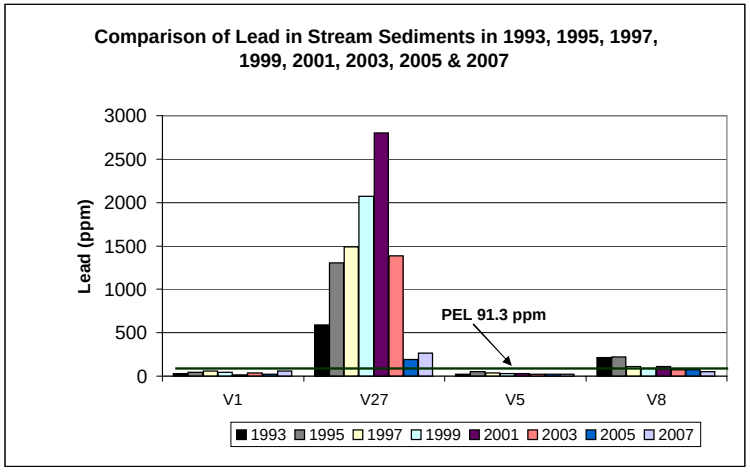
Cadmium, mercury and manganese concentrations are greater than the reference sites, however cadmium levels at R6 are quite similar to the other sites.

Sediment sampling was conducted by Selkirk First Nation at a number of sites on the Pelly River during 2004, 2005, and 2006. A comparison of levels of copper, lead and zinc in sediments at site P1 (control site upstream of Anvil Creek and site P1A (effected site downstream of Anvil Creek) revealed little or no differences in concentrations of these metals in sediments between the two Pelly River sites. However, Figures 4.2-2 through 4.2-4 show that concentrations at the Pelly River sites were generally at or lower that concentrations of these metals in the Anvil Creek sites (Selkirk First Nation 2007).

Figure 4.2-1: Temporal comparison of average sediment metal concentrations at Vangorda Creek monitoring stations, 1993 to 2007







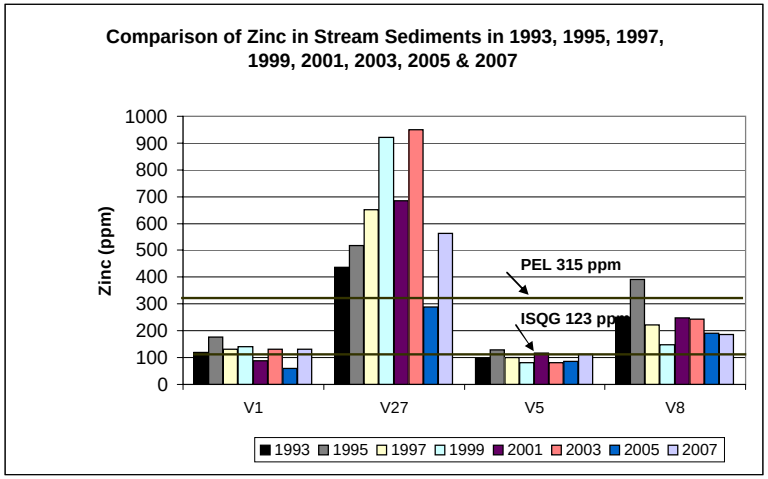


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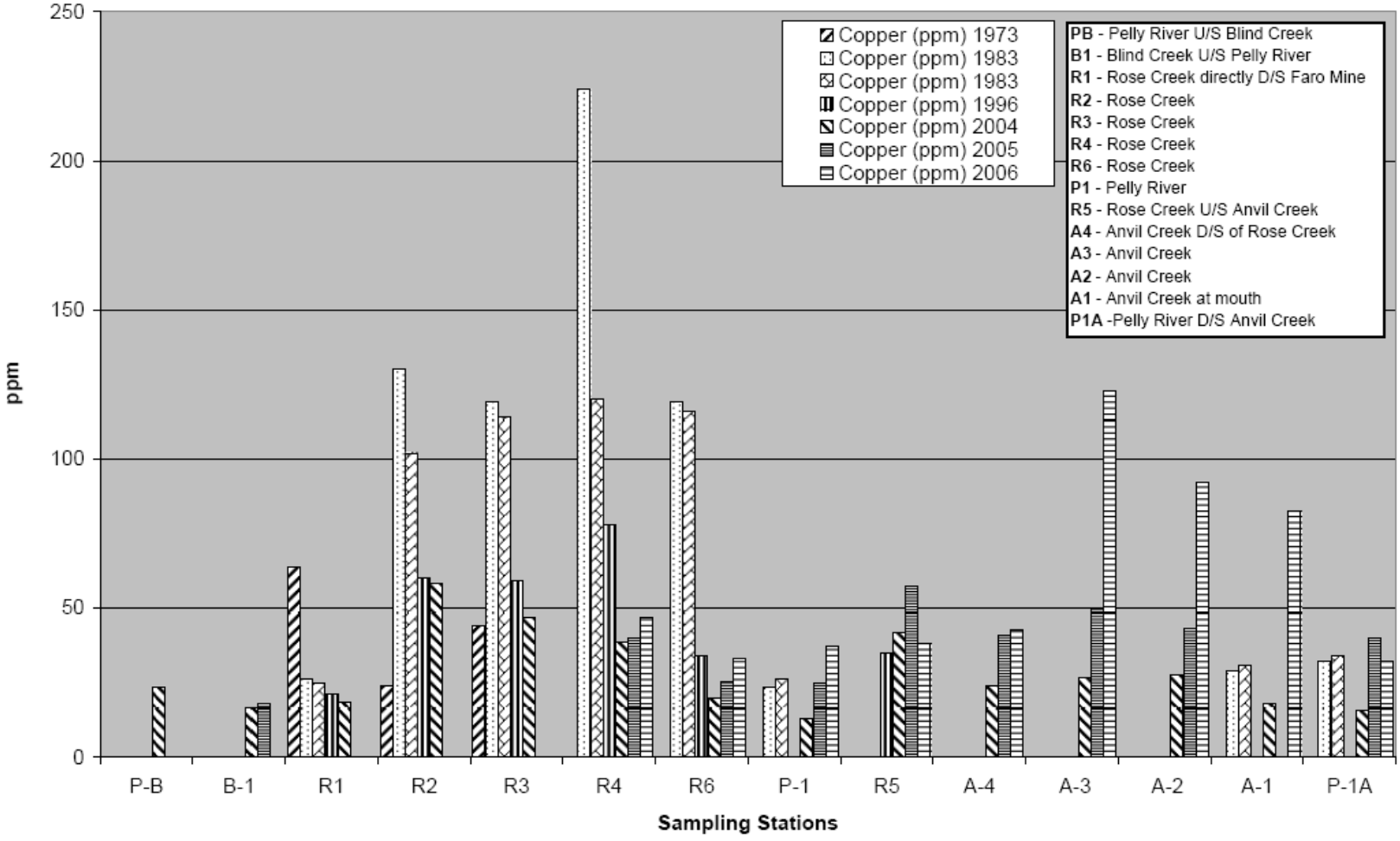
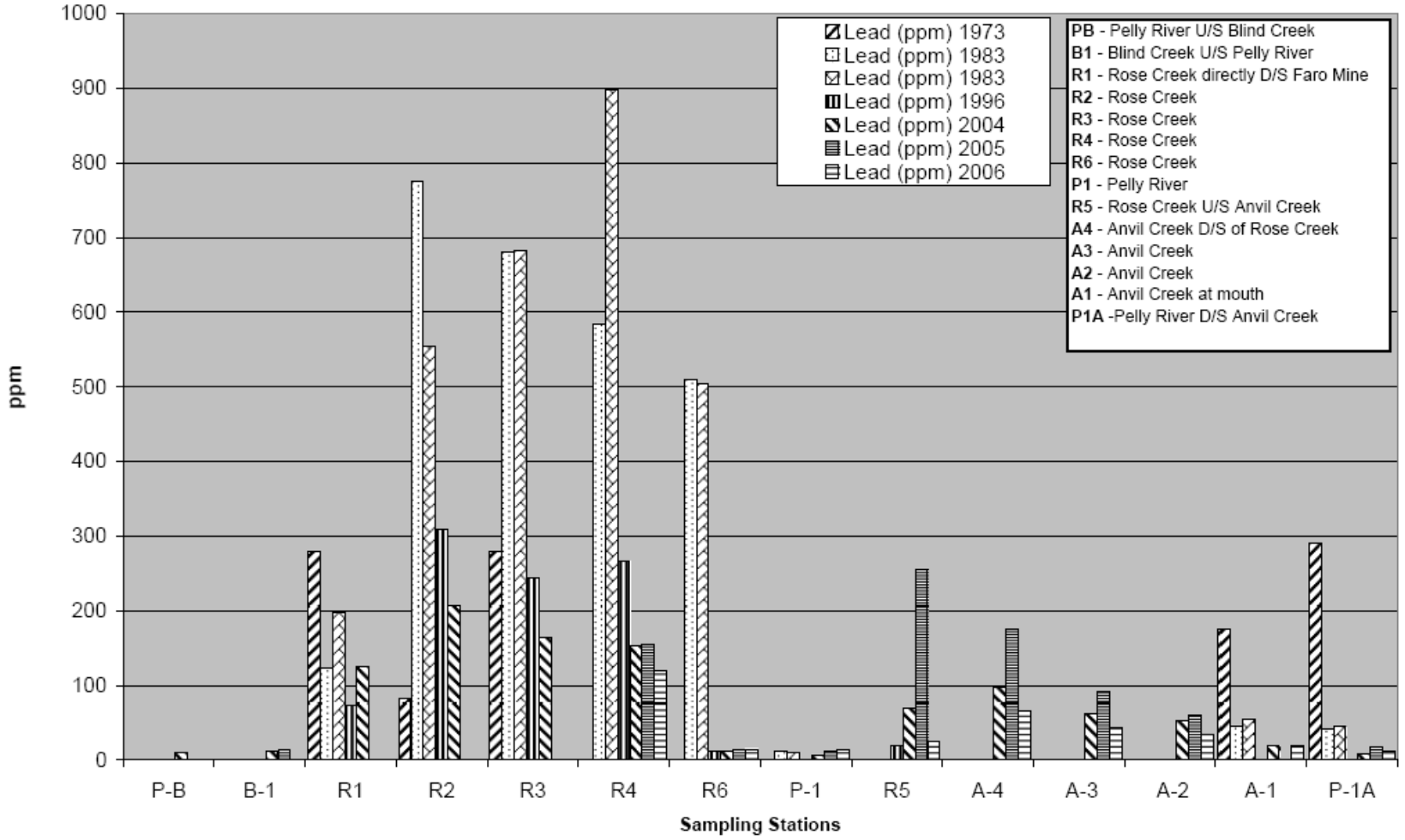
Figure 4.2-2. Copper Concentrations in Sediments, Trend by Site and Year



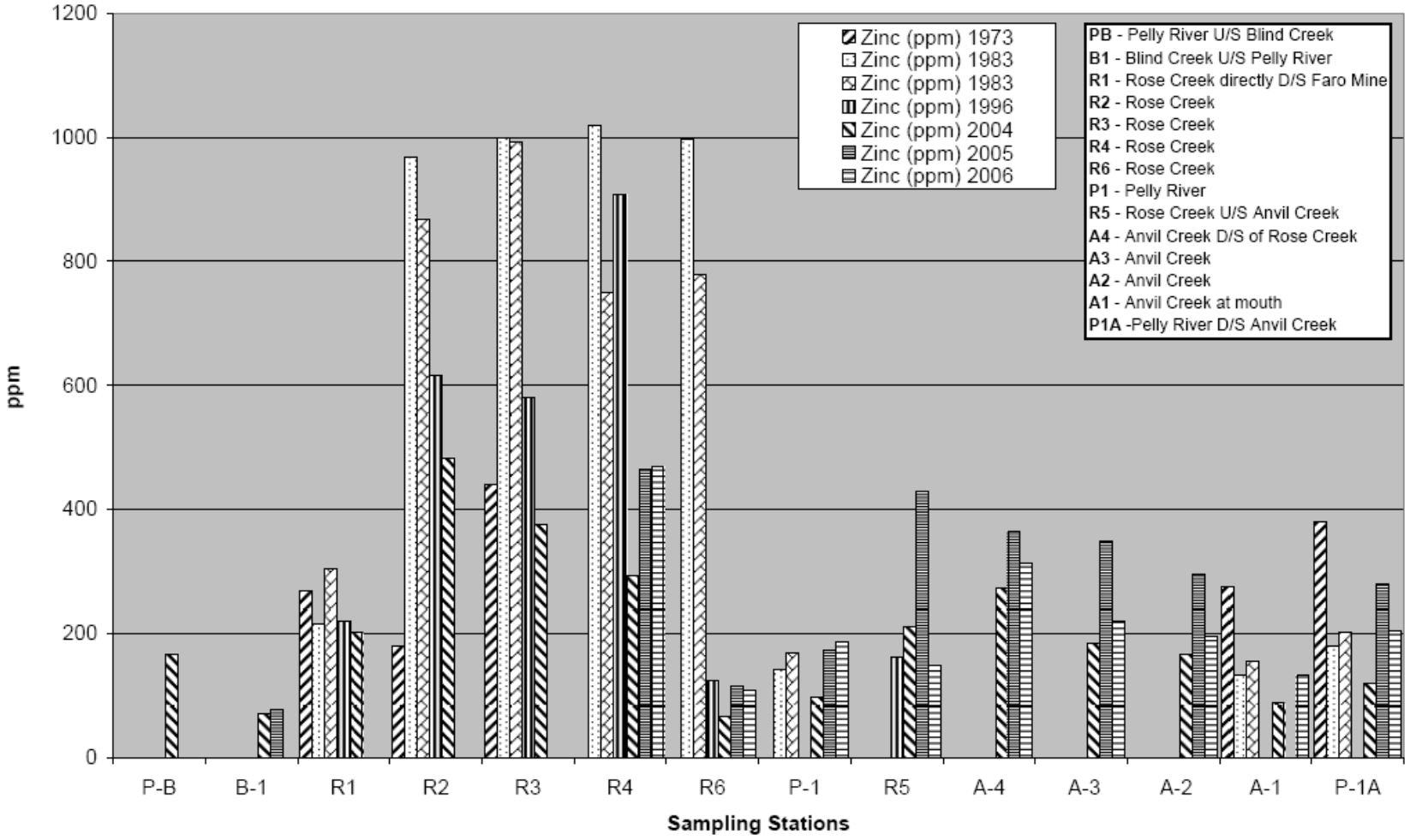
Source: Selkirk First Nation, 2005

Figure 4.2-3. Lead Concentration in Sediments, Trend by Site and Year



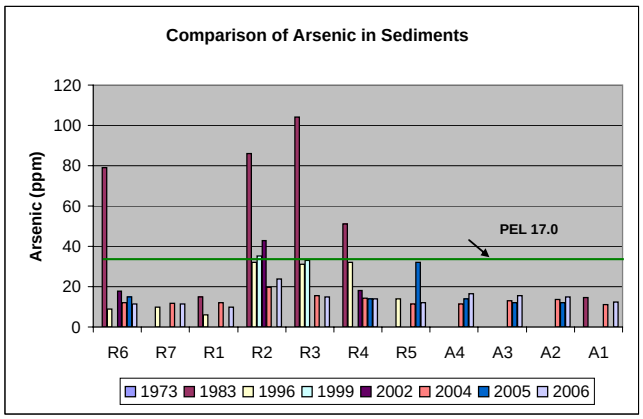
Source: Selkirk First Nation, 2005

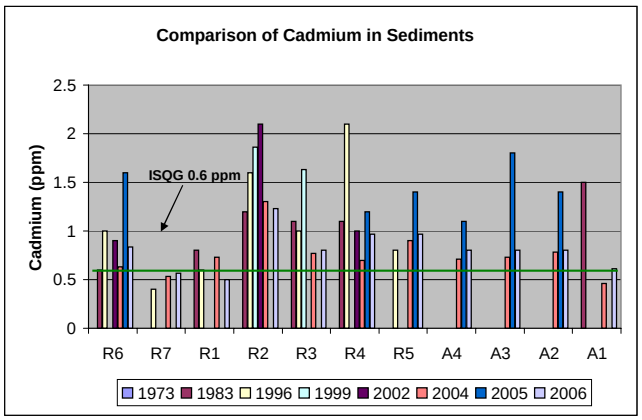
Figure 4.2-4. Zinc Concentration in Sediments, Trend by Site and Year

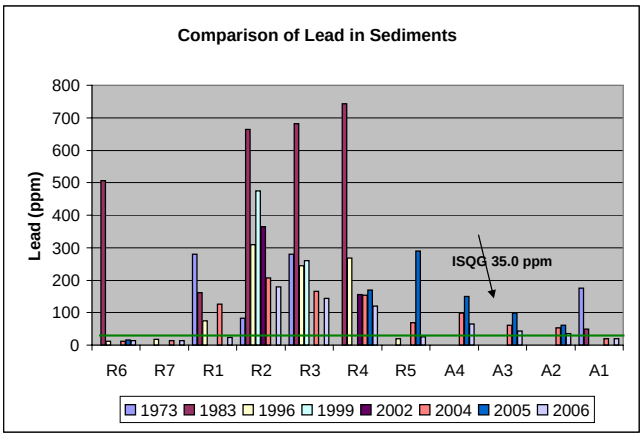


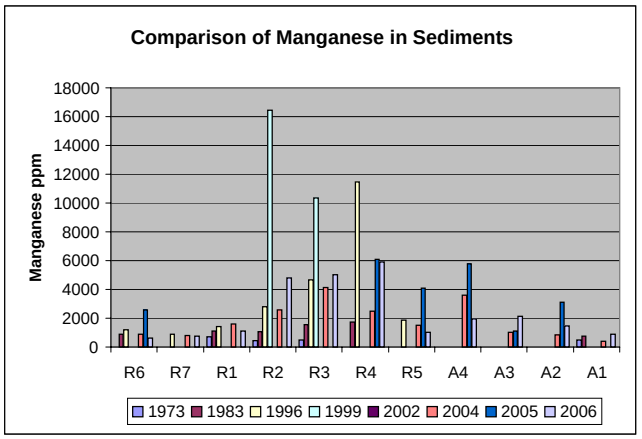
Source: Selkirk First Nation, 2005

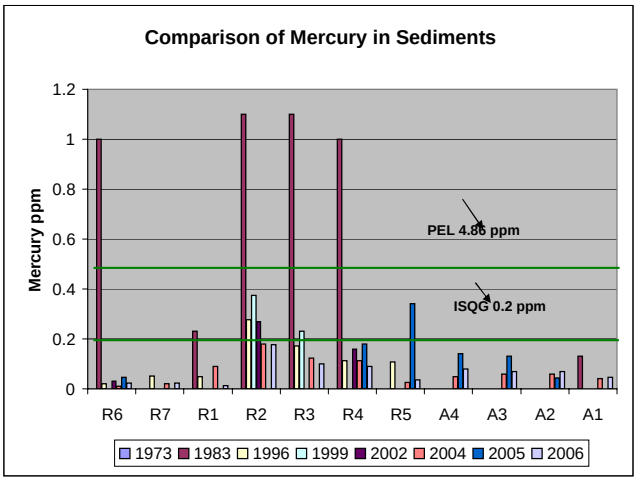
Figure 4.2-5: Temporal comparison of average sediment metal concentrations at Rose and Anvil Creek monitoring stations, 1973 to 2006











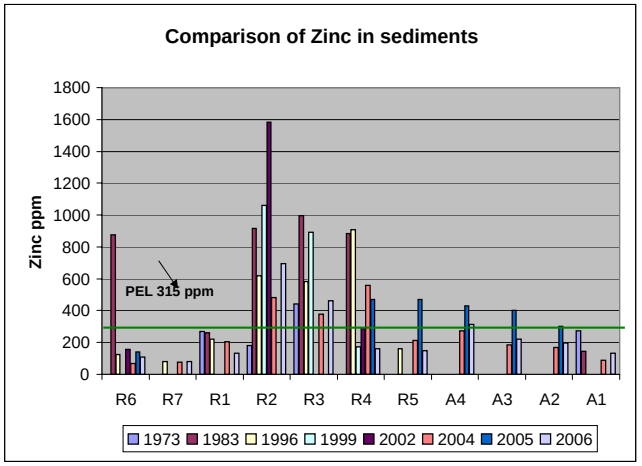


Table 4.2-1. Selected Metal Concentrations in the Stream Sediments of the Vangorda Creek Watershed

Station	Year	Metal (mg/kg)			
		Arsenic	Copper	Lead	Zinc
V1	1993	not done	24	30	120
	1995	**30**	33	**43**	**177**
	1997	**26**	**53**	**58**	**132**
	1999	**28**	**39**	**45**	**141**
	2001	**12**	19	18	88
	2003	**21**	26	**37**	**132**
	2005	**10**	17	19	60
	2007	**19**	**37**	**62**	**131**
V27	1993	not done	**52**	**587**	**436**
	1995	**109**	**59**	**1305**	**519**
	1997	**105**	**88**	**1492**	**652**
	1999	**152**	**129**	**2069**	**921**
	2001	**109**	**102**	**2802**	**868**
	2003	**87**	**74**	**1383**	**951**
	2005	**24**	**36**	**188**	**288**
	2007	**36**	**36**	**269**	**564**
V5	1993	not done	28	23	98
	1995	**34**	**36**	**52**	**129**
	1997	**22**	**36**	35	100
	1999	**15**	25	30	81
	2001	**12**	28	32	116
	2003	**12**	22	25	80
	2005	**10**	25	21	86
	2007	**12**	31	25	113
V8	1993	not done	**37**	**214**	**251**
	1995	**44**	**48**	**218**	**391**
	1997	**25**	**36**	**114**	**221**
	1999	**18**	29	**89**	**148**
	2001	**17**	34	**110**	**248**
	2003	**13**	29	**74**	**243**
	2005	**14**	35	**75**	**192**
	2007	**13**	34	**51**	**187**
ISQG		5.9	35.7	35.0	123
PEL		17.0	197.0	91.3	315

*Note: ISQG = Interim freshwater Sediment Quality Guidelines, in **bold** where exceeded*

*PEL = Probable Effects Level in **bold** and shaded where exceeded*

Table 4.2-2. Selected Metal Concentrations in the Stream Sediments of the Rose Creek Watershed

Station	Year	Metal (mg/kg)						
		Arsenic	Cadmium	Copper	Lead	Manganese	Mercury	Zinc
R6	1973							
	1983	**79.0**	**0.6**	**116.0**	**83.0**	901	**1.0**	877
	1996	**9.0**	**1.0**	34.0	11.0	1222	0.02	**125**
	1999							
	2002	**17.7**	**0.9**	29.3	30.0		0.03	**155**
	2004	**12.2**	**0.6**	20.0	11.0	890	0.01	66
	2005	**15.0**	**1.6**	31.0	16.0	2600	0.05	**140**
	2006	**11.3**	**0.8**	33.0	14.7	634	0.02	109
R7	1973							
	1983							
	1996	**10.0**	0.4	14.0	18.0	887	0.05	82
	1999							
	2002							
	2004	**11.9**	0.5	17.3	14.7	809	0.02	78
	2005							
	2006	**11.3**	0.6	17.3	14.7	745	0.02	81
R1	1973			**64.0**	**280.0**	700		**270**
	1983	**15.0**	**0.8**	25.6	**161.0**	1122	**0.23**	**260**
	1996	**6.0**	0.6	21.0	**74.0**	1419	0.05	**221**
	1999							
	2002							
	2004	**12.1**	**0.7**	18.3	**125.3**	1590	0.09	**203**
	2005							
	2006	**10.0**	0.5	10.0	22.7	1123	0.01	**131**
R2	1973			24.0	**83.0**	460		**180**
	1983	**86.0**	**1.2**	**116.0**	**665.0**	1053	**1.10**	**918**
	1996	**32.0**	**1.6**	**60.0**	**310.0**	2808	**0.28**	**617**
	1999	**35.1**	**1.9**	**122.6**	**475.7**	16430	**0.37**	**1060**
	2002	**42.7**	**2.1**	**82.7**	**364.0**		**0.27**	**1583**
	2004	**19.6**	**1.3**	**58.3**	**207.3**	2577	0.18	**482**
	2005							
	2006	**23.7**	**1.2**	**60.7**	**178.7**	4797	0.18	**694**
R3	1973			**44.0**	**280.0**	490		**440**
	1983	**104.0**	**1.1**	**117.0**	**682.0**	1550	**1.10**	**996**
	1996	**31.0**	**1.0**	**59.0**	**244.0**	4665	0.17	**581**
	1999	**33.0**	**1.6**	**85.5**	**261.0**	10340	**0.23**	**890**
	2002							
	2004	**15.6**	**0.8**	**46.7**	**165.3**	4151	0.12	**376**
	2005							
	2006	**15.0**	**0.8**	**46.3**	**143.0**	5040	0.10	**464**
R4	1973							
	1983	**51.0**	**1.1**	**172.0**	**742.0**	1723	**1.00**	**885**
	1996	**32.0**	**2.1**	**78.0**	**267.0**	11466	0.11	**908**
	1999							
	2002	**18.0**	**1.0**	**44.3**	**156.0**		0.16	**171**
	2004	**14.2**	**0.7**	**38.7**	**153.7**	2483	0.11	**294**
	2005	**14.0**	**1.2**	**48.0**	**170.0**	6100	0.18	**560**
	2006	**14.0**	**1.0**	**47.0**	**120.0**	5927	0.09	**470**
R5	1973							
	1983							
	1996	**14.0**	**0.8**	35.0	20.0	1855	0.11	**161**
	1999							
	2002							
	2004	**11.4**	**0.9**	**42.3**	**69.3**	1518	0.03	**212**

Station	Year	Metal (mg/kg)						
		Arsenic	Cadmium	Copper	Lead	Manganese	Mercury	Zinc
	2005	**32.0**	**1.4**	**78.0**	**290.0**	4100	**0.34**	**470**
	2006	**12.0**	**1.0**	**38.3**	24.7	1014	0.04	**149**
A4	1973							
	1983							
	1996							
	1999							
	2002							
	2004	**11.5**	**0.7**	24.0	**98.0**	3580	0.05	**274**
	2005	**14.0**	**1.1**	**42.0**	**150.0**	5800	0.14	**430**
	2006	**16.4**	**0.8**	**42.6**	**65.6**	1937	0.08	**313**
A3	1973							
	1983							
	1996							
	1999							
	2002							
	2004	**13.0**	**0.7**	26.8	**62.0**	1020	0.06	**184**
	2005	**12.0**	**1.8**	**58.0**	**99.0**	1100	0.13	**400**
	2006	**15.7**	**0.8**	**122.7**	**44.3**	2140	0.07	**221**
A2	1973							
	1983							
	1996							
	1999							
	2002							
	2004	**13.6**	**0.8**	27.5	**52.9**	862	0.06	**167**
	2005	**12.0**	**1.4**	**44.0**	**61.0**	3100	0.04	**300**
	2006	**14.8**	**0.8**	**92.4**	34.8	1455	0.07	**195**
A1	1973			**100.0**	**175.0**	500		**275**
	1983	**14.7**	**1.5**	30.0	**50.0**	745	0.13	**145**
	1996							
	1999							
	2002							
	2004	**11.0**	0.5	18.0	19.4	381	0.04	90
	2005							
	2006	**12.3**	**0.6**	**82.7**	20.1	872	0.05	**133**
ISQG		5.9	0.6	35.7	35.0		0.2	123
PEL		17.0	3.5	197.0	91.3		0.486	315

*Note: ISQG = Interim freshwater Sediment Quality Guidelines, in **bold** where exceeded*

*PEL = Probable Effects Level in **bold** and shaded where exceeded*

4.3 Benthic Invertebrates

Benthic invertebrates include insects, crustaceans, aquatic worms and molluscs that reside in and on stream bottoms. Benthic invertebrate community structures are often used as measure of ecosystem health. Impacts to watercourses such as substrate composition, water flows and, in particular, water and sediment quality can affect benthic organisms. Sampling has been conducted at the following stations in the Rose Creek and Vangorda Creek watersheds:

6. R1 - Rose Creek south fork d/s of FWSD Reservoir, a reference site
7. R2 - Rose Creek at confluence of diversion channel and tailings outlet
8. R3 - Rose Creek between tailings and Anvil Creek
9. R4 - Rose Creek at confluence with Anvil Creek
10. R5 - Anvil Creek d/s of Rose Creek
11. R6 - Anvil Creek u/s of Rose Creek, a reference site
12. R7 - North Fork of Rose Creek, a reference site
13. V1 - Vangorda Creek upstream of diversion, a reference site
14. V5 - Vangorda Creek west fork downstream of mine activity
15. V27 - Vangorda Creek downstream of mine activity
16. V8 - Vangorda Creek at mouth

Sampling was initiated at some of these sites in 1973 within the Anvil/Rose Creek watershed and in 1975 within the Vangorda Creek watershed. From 1988 (Rose Creek) and 1991 (Vangorda Creek) benthic invertebrate population monitoring has been conducted at each of the applicable sites every second year as per the requirements of the water licences. Artificial substrates were used for the majority of the sampling events, allowing consistency across much of the data set. Triplicate samples were collected at each site during each sampling event and the results pooled to report community structure. A summary of the benthic invertebrate projects and the methods used are provided in Table 4.3-1.

Sampling results have been summarized in terms of abundance (total number of organisms) and richness (number of taxa), as a means of comparing the benthic invertebrate community health over time and throughout the watersheds.

A limited benthic invertebrate sampling program was conducted by Selkirk First Nation during 2004, 2005, and 2006 on Anvil Creek and at two sites on the Pelly River upstream and downstream of Anvil Creek. However because of differences in methodology, the results are not directly comparable to the established sampling programs on Vangorda Creek and Rose Creek.

4.3.1 Vangorda Creek Watershed

Similar to the sediment data, sites have been arranged in the tables and graphs as they occur geographically.

4.3.1.1 Historical Data

The historical data encompasses the years 1976, 1980, 1990, 1991, 1993, 1995, 1997 and 1999. Community populations were very low in 1976, 1980, 1991 and 1999 at all sites (Table 4.3-2 and Table 4.3-1). Populations were considerably greater in 1993, 1995 and 1997, with V27 seeing a significant increase in abundance. Although the metal concentrations in the stream sediments at V27 during these years exceeded the PEL, which should create adverse effects to the biotic community, there is no evidence of detrimental effects in terms of numbers of organisms. The reference site V1 generally had the lowest population per sampling period.

The diversity of the communities did not range as much during the years and there was not a great deal of difference between each site (Figure 4.3-2).

4.3.1.2 Recent and Current Data

The current and recent data include samples collected in 2001, 2003, 2005 and 2007. These data have been included in Table 4.3-2, Figure 4.3-1 and Figure 4.3-2. Community populations have continued to fluctuate in recent years with V5 showing a significant increase in abundance. Population numbers continue to be lowest at the reference site V1. The low productivity at V1 is probably a function of the habitat here rather than the quality of the water or substrate.

The diversity of the benthic invertebrate community (number of taxa represented) is considered a first order measure of aquatic health. The diversity of the benthic communities at all of the sites is increasing over time in the Vangorda Creek watershed. The communities at the near field site, V27, have similar or greater population numbers and diversity than at the reference site V1, indicating that mine-related effects have had little or no effect on the biota here.

The community structure is also an important indicator of the health of the aquatic environment at a site. In recent years one or more of the pollution sensitive insect orders Ephemeroptera, Plecoptera or Trichoptera have dominated the community at V27 (Burns 2007). Minnow (2007) performed various statistics on the benthic data collected from Vangorda Creek and found that the percent EPT (pollution intolerant Ephemeroptera, Plecoptera and Trichoptera) was significantly greater at the near field site V27 than at any other station. The other sites did have representatives of these organisms but not to the degree as V27. The high proportion of EPT at V27 would also indicate that any mining-related activities have had little or no long-term impact on the biological productivity and aquatic health of Vangorda Creek.

4.3.2 Rose Creek Watershed

4.3.2.1 Historical Data

The historical data covers the period from 1974 to 1998. Populations were very low in the early years from 1974 to 1980. Not all sites have been sampled consistently and it was not until 1980 that R4 was sampled for the first time. Within this limited data set populations ranged from 3 at R3 in 1974 to 547 at R6 in 1975. Abundance increased from 1981 to 1992 with a range of 32 individuals at R3 in 1988 (all sites had low populations in 1988) to 5,903 organisms at R4 in 1986. There were some population explosions during the

period 1994 to 1998. The highest population occurred at R3 in 1994 with a total of 54,875 individuals and the lowest was also at R3 in 1996 with 144 individuals. R1 also saw a population boom in 1998 with a total of 50,808 individuals collected (Table 4.3-3).

In general terms the historic data shows that populations were very depressed from 1974 to 1980, gradually recovered from 1981 to 1992, and exhibited very high populations in 1994 and 1998 at some of the sites, including the impacted site of R3 (Figure 4.3-3).

The species diversity of the benthic communities generally followed the same trend as the abundance data. Diversity, or the number of species groups or taxa represented in the benthic community, increased during the early to mid 1980s, then declined at all sites from 1988 to 1992. Diversity increased at all sites in 1994 and remained high up to 2000 (Table 4.3-4, Figure 4.3-4). Generally per sample period, the community at R1 had the greatest diversity.

4.3.2.2 Recent and Current Data

To reflect current conditions at the Rose Creek site, the data for the years 2000, 2002, 2004 and 2006 were examined. Population numbers increased significantly during this period at several of the sites although numbers did fluctuate between year and site (Table 4.3-3 and Figure 4.3-3). The community at R5 had the highest population in 2000 and 2002. The greatest abundance was documented at R1 in 2004 and at R2 in 2006. Several other sites also had high populations during each of these years. Populations in the tens of thousand did not occur at any of the sites until 1994 but became fairly frequent from 1998 on.

The benthic communities at all of the sites have become much more diverse in recent years (Table 4.3-4, Figure 4.3-4). Diversity ranged from 36 species groups or taxa to 60 during the studies conducted from 2000 to 2006. The community at R1 continued to be the most diverse of the sites during this time period. The community at the reference site, R7, was typically the least diverse in recent years.

To further characterize the recent Rose Creek data, the percentage of Ephemeroptera, Plecoptera and Trichoptera (EPT) (insects that are typically sensitive to chemical pollution) were calculated (Table 4.3-5). The proportion of EPT did fluctuate somewhat, although overall the %EPT in the exposure areas (R2, R3 and R4) was greater than in the reference areas (R1, R6 and R7). Although R1 had the highest diversity, it usually had a lower proportion of sensitive organisms than the mine exposed sites R2, R3 and R4.

Benthic invertebrate data collected in 2006 by Selkirk First Nation for Anvil Creek sites using comparable sampling methods, shows similar abundance and diversity to Rose Creek sites with a high abundance of pollution sensitive taxa (Selkirk First Nation, 2007 Table 6). The diversity and abundance of benthic invertebrates for the two Pelly River sites, and the abundance of pollution sensitive taxa were much lower than for the Anvil/Rose Creek system. However, the values for the Pelly River sites were comparable to each other. The relatively low abundance and diversity of benthic invertebrates is likely due in part, to the differences in stream order and morphology as the Pelly is a much larger river.

The above data shows that the benthic communities at all the sites are healthy and robust and suggests that there are minimal, if any, mine influenced impacts to the stream biota in Rose Creek downstream of the tailings facility from 2000 to 2006.

4.3.3 Metals in Benthic Invertebrates

Benthic invertebrates were collected for the analysis of metals in tissue around the Faro Mine Complex for the first time in 2002. The analysis was initiated to determine the extent to which metals were accumulating in the benthic invertebrates (benthos) and thus the pathway for bioaccumulation in aquatic vertebrates, slimy sculpin (*Cottus cognatus)* and Arctic grayling (*Thymallus arcticus)*. While most metals do not biomagnify between trophic levels, small invertebrates tend to accumulate greater concentrations of metals than large invertebrates, and therefore, early-life stage fish (which eat smaller invertebrates) may be exposed to a larger dose of metals than adults (which eat larger invertebrates; Fareg *et al* 1998). Benthos were collected at the regular benthic monitoring sites R2, R4, R6 and V8.

Table 4.3-6 outlines the results of selected metals (arsenic, cadmium, copper, mercury, lead and zinc) in benthic invertebrate tissue.

Concentrations of copper, mercury and lead are highest in benthos collected from site R2, while concentrations of arsenic and cadmium are the highest in benthos collected from the reference site R6. This correlates with the 2002 stream sediment results where sediment collected from R2 also contained the highest concentrations of copper, mercury and lead. Zinc concentrations are similar in benthos collected from R2 and V8. This does not correlate with the 2002 sediment sample results where the zinc concentration in V8 sediment is lower than R2 sediment.

During aquatic studies conducted on tributaries to the Pelly River by the Selkirk First Nation, benthic invertebrates were collected for metal analysis at sites A1, A2, A3 and A4 in 2004, 2005 and 2006. As there was no analysis on benthic tissues from any Rose Creek sites in 2004 and 2005, no correlation of this data can be accomplished. In 2006, benthic invertebrates were collected for metal analysis from R4, R5 and R6. Only benthos from R6 had been analyzed for metals previously. However, the tissues in 2002 were analyzed as wet weight, whereas in 2006, the data was reported as dry weight. The lab did not report the percent moisture, so these two data sets cannot be compared. The 2006 data is presented in Table 4.3-7. Details of the studies can be found in the individual study reports for 2004, 2005, 2006 (Selkirk First Nation 2005, 2006, 2007).

The highest cadmium concentrations were again found in the benthos from the reference site R6. Concentrations were considerably lower in the main stem of Anvil Creek but increased progressively downstream. The lowest concentrations of lead and zinc were documented in the benthos from the reference site R6. Zinc concentrations were approximately double in the main stem of Anvil Creek and were similar in the benthos at the other sites. The highest arsenic and lead concentrations were reported in the benthos collected from R5. Copper and mercury concentrations did not range much in the benthos tissues at the sites.

Figure 4.3-1: Community Abundance Over Time in Vangorda Creek

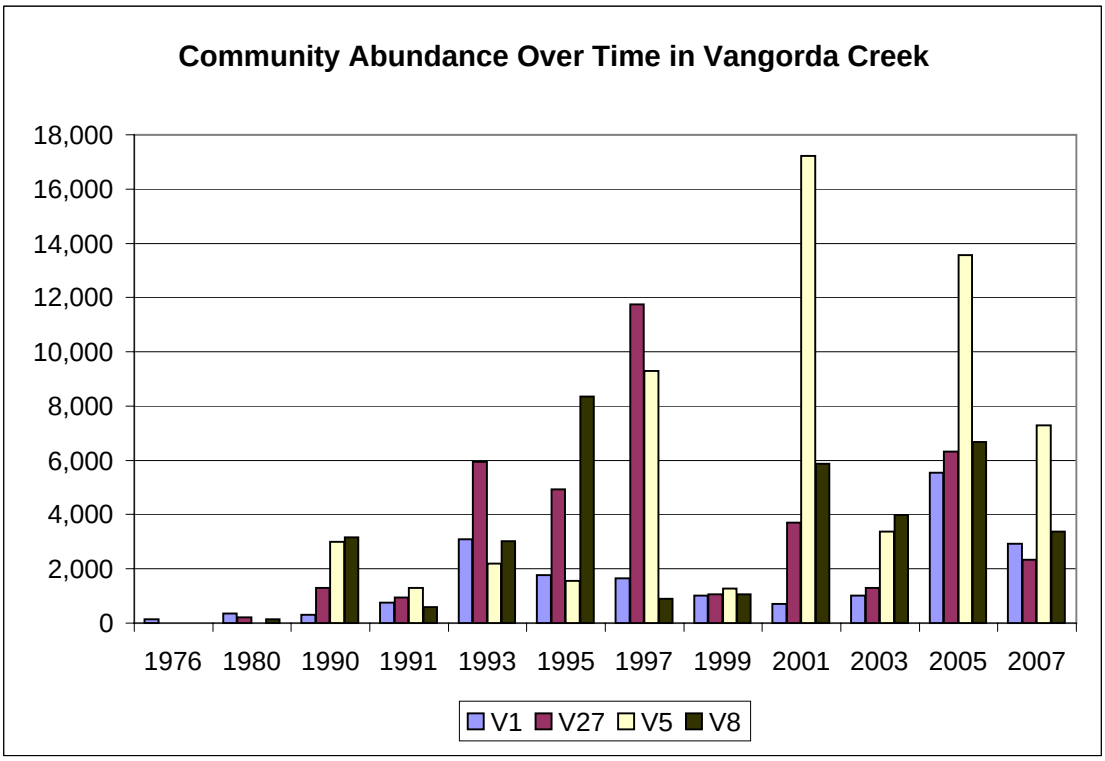


Figure 4.3-2: Community Diversity Over Time in Vangorda Creek

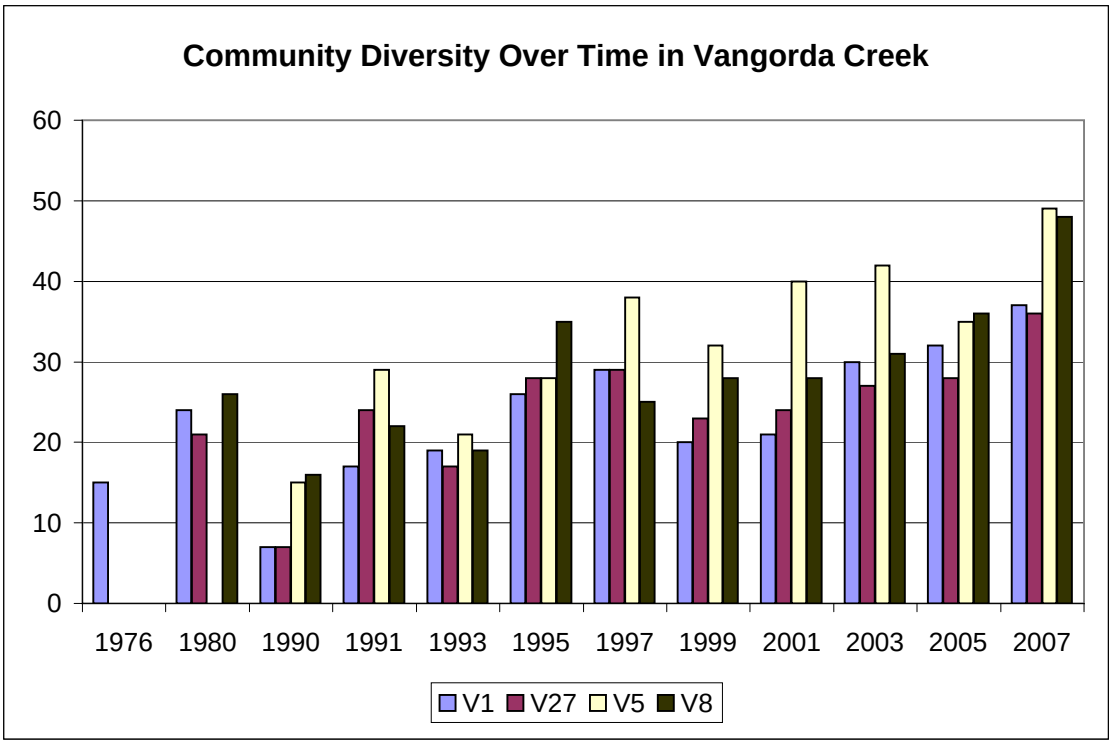


Figure 4.3-3: Community Abundance at the Rose Creek Sites Over Time

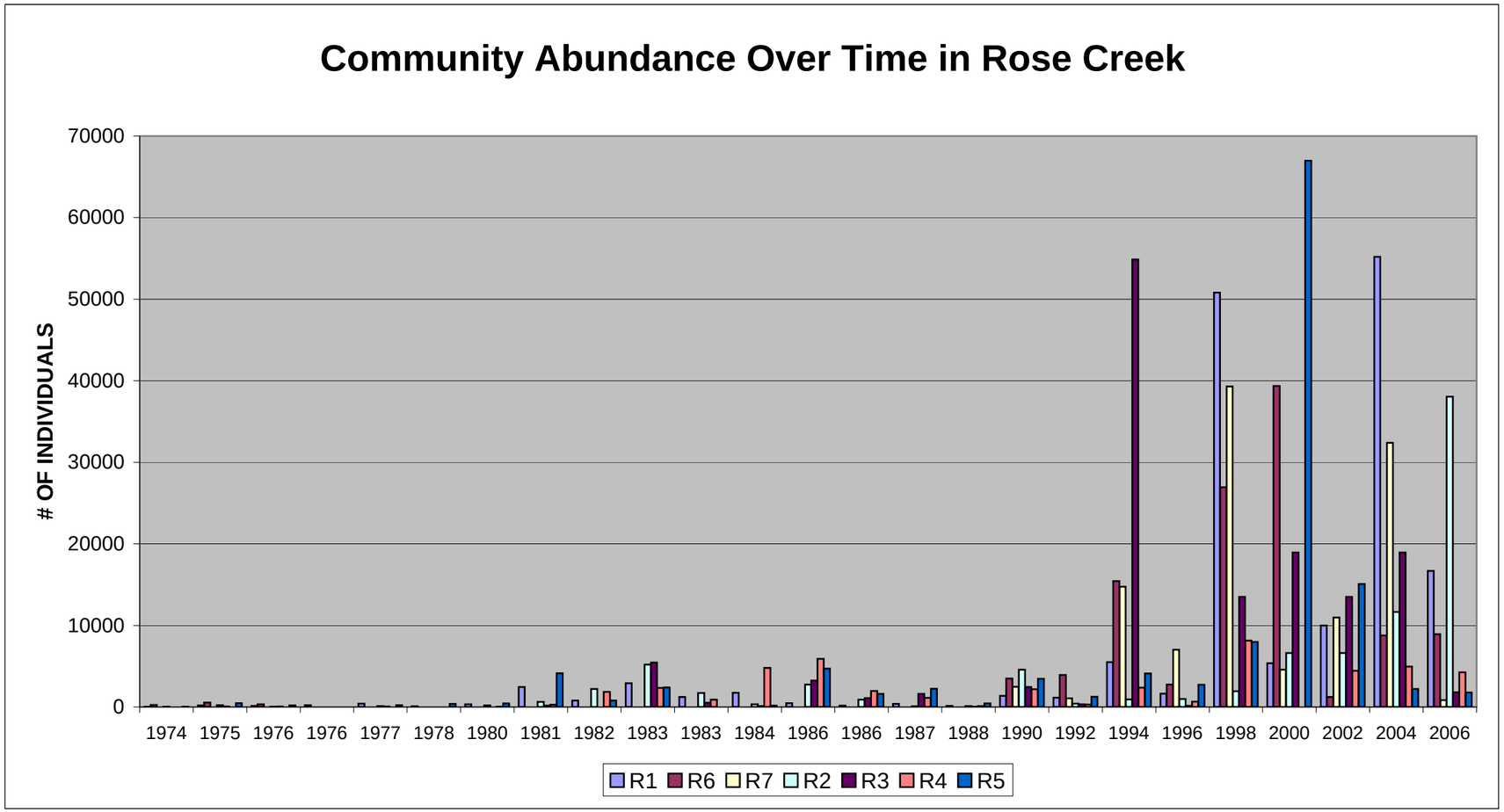


Figure 4_3_3.xls

Figure 4.3-4: Community Diversity at the Rose Creek Sites Over Time

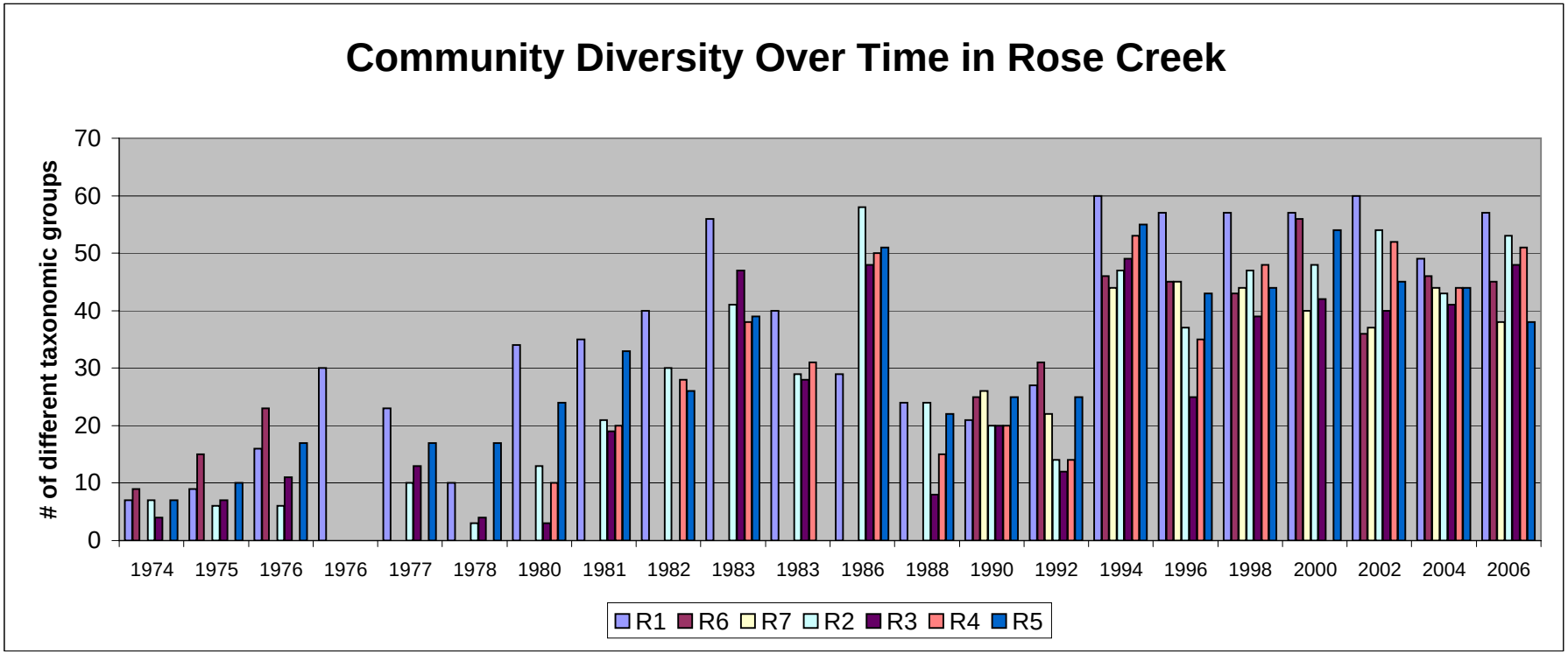


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Table 4.3-1. Summary of Studies and Methods used in Benthic Invertebrate Community Assessments and Tissue Analysis

Reference	Year Sampled	Stations	Sampler	Replicates/station	Incubation or collection dates	mesh size	Taxonomy
Hoos and Holman 1973	1973	R1-R3, R5, R11	1 square foot circular sampler	3	Sept 17-21, 1973	not specified	genus
Baker 1979	1974-1976	R1-R4, R6, R11 and Pelly River	chrome-plated baskets with rocks	3	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)	August 1975	not specified	Partially to family
Weagle 1981a	1977	R1-R4, R6, R11 and Pelly River	chrome-plated baskets with rocks	3	August 18 to Oct 5, 1977	100 microns (surber)	genus
Weagle 1981a	1978	R1-R4, R6, R11 and Pelly River	Surber	3	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	Aug 14-15 to Sept 17-18, 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	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	September 7-October 8, 1982	100 um (surber)	genus/species
Godin and Osler 1985	1983	R1-R6, R11, and Pelly River	Baskets with rocks 1-8 cm diameter	3	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	Aug 19/20 to Oct 13/14, 1983	100 um (drift net)	genus/species
Leverton and Associates 1987	1986	R2-R5 (see comment re: R1)	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	July 14 to August 27, 1986	not specified	genus/species
Burns 1989	1988	R1-R5	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Aug 5 to Sept 21-22, 1988	sieved through 300 micron mesh bucket	genus/species
Burns 1989	1988	R6, V8 and Blind Creek	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Aug 5 to Sept 21-22, 1988	sieved through 300 micron mesh bucket	genus/species

Reference	Year Sampled	Stations	Sampler	Replicates/station	Incubation or collection dates	mesh size	Taxonomy
Burns 1991	1990	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Aug 22/24 to	sieved through 300 micron mesh bucket	genus
Harder and Associates 1991d	1990	V8 and Blind Creek	baskets with clean substrata; no details provided	3	July 29 to Sept. 5, 1990	sieved through 300 micron mesh bucket	family/genus
Harder and Associates 1992	1990	V1, V5, V27, V8, Blind and Buttle Creeks	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	installed July 18-19, 1990, for five weeks	sieved through 300 micron mesh bucket	not specified
Harder and Associates 1993a,b	1992	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	July 8/10 to Aug 16/17, 1992	sieved through 300 micron mesh bucket	family/genus
Burns 1994	1994	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Installed late July and retrieved after about five weeks	sieved through 300 micron mesh bucket	genus/species
Burns 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 dia. Filled with gravel (2-15cm dia)	3	Installed late July and retrieved after about five weeks	sieved through 300 micron mesh bucket	genus/species
Burns 1997, 1999, 2001, 2002b, 2004, 2006	1996, 1998, 2000, 2002, 2004, 2006	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Installed late July and retrieved after about five weeks	sieved through 300 micron mesh bucket	genus/species
Access, Laberge and White Mountain	2004	A1 - A4	Surber and Kick net	3		300 microns	genus/species
Access, Laberge and White Mountain	2005	A1 - A4	Surber and Kick net	3		300 microns	genus/species
Access, Laberge and White Mountain	2006	A1 - A4, R5, R6	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia), kick net	3	Installed late July and retrieved after about five weeks		genus/species

Table 4.3-2. Community Abundance and Diversity at the Vangorda Creek Sites Over Time

Year	V1		V27		V5		V8	
	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity
1976	136	15						
1980	350	24	216	21			133	26
1990	300	7	1,299	7	2,985	15	3,162	16
1991	763	17	953	24	1,298	29	594	22
1993	3,090	19	5,952	17	2,193	21	3,024	19
1995	1,758	26	4,929	28	1,550	28	8,340	35
1997	1,663	29	11,751	29	9,291	38	904	25
1999	1,025	20	1,061	23	1,284	32	1,061	28
2001	707	21	3,698	24	17,232	40	5,867	28
2003	1,025	30	1,301	27	3,377	42	3,989	31
2005	5,534	32	6,329	28	13,570	35	6,687	36
2007	2,918	37	2,338	36	7,279	49	3,385	48

Table 4.3-3. Community Abundance at the Rose Creek Sites over Time

Year	R1	R2	R3	R4	R5	R6	R7
1974	25	33	3		24	247	
1975	182	213	65		466	547	
1976	137	32	45		190	328	
1976	215						
1977	398	99	47		226		
1978	74	5	8		375		
1980	333	191	6	37	434		
1981	2,457	634	166	274	4,126		
1982	784	2,193		1,856	777		
1983	2,906	5,187	5,436	2,336	2,401		
1983	1,226	1,709	517	907			
1984	1,736	320	101	4,780	161		
1986	469	2,736	3,250	5,903	4,702		
1986	156	911	1,083	1,973	1,605		
1987	374	93	1,619	1,106	2,226		
1988	128	115	32	116	425		
1990	1,373	4,564	2,455	2,175	3,470	3,477	2,467
1992	1,141	400	321	312	1,263	3,911	1,053
1994	5,489	920	54,875	2,366	4,115	15,431	14,756
1996	1,629	991	144	666	2,726	2,741	7,029
1998	50,808	1,945	13,491	8,148	7,974	26,944	39,292
2000	5,368	6,611	18,929		66,975	39,344	4,574
2002	9,988	6,611	13,491	4,430	15,088	1,232	10,965
2004	55,191	11,639	18,929	4,964	2,206	8,759	32,380
2006	16,685	38,042	1,808	4,252	1,768	8,934	838

Table 4.3-4. Community Diversity at the Rose Creek Sites Over Time

Year	R1	R2	R3	R4	R5	R6	R7
1974	7	7	4		7	9	
1975	9	6	7		10	15	
1976	16	6	11		17	23	
1976	30						
1977	23	10	13		17		
1978	10	3	4		17		
1980	34	13	3	10	24		
1981	35	21	19	20	33		
1982	40	30		28	26		
1983	56	41	47	38	39		
1983	40	29	28	31			
1986	29	58	48	50	51		
1988	24	24	8	15	22		
1990	21	20	20	20	25	25	26
1992	27	14	12	14	25	31	22
1994	60	47	49	53	55	46	44
1996	57	37	25	35	43	45	45
1998	57	47	39	48	44	43	44
2000	57	48	42	na	54	56	40
2002	60	54	40	52	45	36	37
2004	49	43	41	44	44	46	44
2006	57	53	48	51	38	45	38

Table 4.3-5. Percentage of Pollution Sensitive EPT (Ephemeroptera, Plecoptera, Trichoptera) at Rose Creek Sites

Site	2000	2002	2004	2006	Average
R6	20.6	18.3	40.5	23.0	25.6
R7	15.5	11.1	14.4	24.3	16.3
R1	14.4	19.8	22.6	17.2	18.5
R2	38.1	26.3	21.1	49.2	33.7
R3	81.9	11.6	39.8	23.3	39.2
R4		25.1	22.8	50.1	32.7
R5	30.6	15.5	14.3	42.5	25.7

Notes: Due to high water the samplers at R4 could not be retrieved from R4 in 2000.

Table 4.3-6. Summary of Metal Concentrations in Benthic Invertebrate Tissue (wet weight µg/g), 2002

Creek	Site	Arsenic	Cadmium	Copper	Mercury	Lead	Zinc
Rose Creek	R2	0.35	0.075	12.8	0.011	6.42	50.6
Rose Creek	R4	0.25	0.055	4.7	0.006	3.14	34.2
Anvil Creek	R6	1.32	0.141	4.7	0.007	1.35	39.4
Vangorda Creek	V8	0.30	0.117	4.8	0.009	1.86	50.8

Table 4.3-7. Summary of Metal Concentrations in Benthic Invertebrate Tissue (dry weight µg/g), 2006

Creek	Site	Arsenic	Cadmium	Copper	Mercury	Lead	Zinc
Anvil Creek	R6	1.3	8.9	48.3	0.6	3.4	299
Rose Creek	R4	<1	1.0	52.2		5.9	681
Anvil Creek	R5	4.8	1.0	57.5	0.9	12.0	374
Anvil Creek	A4	2.0	2.0	51.6	0.8	7.7	671
Anvil Creek	A3	1.9	2.7	64.5	0.4	7.3	552
Anvil Creek	A2	2.5	3.2	47.1	0.4	4.0	509
Anvil Creek	A1	2.0	6.0	56.0	0.5	6.1	614

4.4 Fish

4.4.1 Vangorda Creek

4.4.1.1 Fish Habitat

The Vangorda/Grum area of the Faro Mine Complex is situated within the Vangorda Creek watershed. Vangorda Creek contains two upper branches that meet to form the main stem plus a major tributary called the West Fork. The mainstem has been diverted around the various pits and dumps, and the mine haul road crosses this branch. The mine access road crosses the West Fork in three locations and a culvert under the Town of Faro access road crosses the main stem. Lower Vangorda Creek, upstream of the confluence with the Pelly River, is low gradient (1.5% to 2.7%) with large gravels, cobbles and boulders. Some spawning habitat is available in this section and rearing and the pools and in-stream cover offer summer habitat. This habitat provides excellent rearing habitat for Chinook salmon and moderate rearing for grayling and sculpin. The Habitat Suitability Classification developed for the Pelly River watershed by the new Placer Mining Regime classifies the lower section of Vangorda Creek up to the first fork as moderate-moderate sensitivity Chinook salmon rearing habitat based on gradient, proximity to natal areas and water quality. Moderate over wintering habitat is provided for Chinook and sculpin (see Table 4.4-4).

The culvert under the Town of Faro access road and waterfalls just upstream are barriers to upstream fish movement. The channel gradient becomes progressively steeper upstream (4% in the mid-section and 6% in the headwaters) with larger substrate and log debris from adjacent burn areas (Harder 1987).

4.4.1.2 Fish Presence

The absence of fish in the West Fork of Vangorda Creek and the upper Vangorda Creek is likely due to the presence of impassable barriers located near the Town of Faro (Minnow 2007): perched culvert preventing fish passage and a steep natural cataract/waterfall. The reach near the licensed site V8 on lower Vangorda Creek has been investigated for fish assessments from 2004 to 2007. Slimy sculpin, Arctic grayling, Chinook salmon, burbot (*Lota lota*), round whitefish (*Prosopium cylindraceum*) and longnose sucker (*Catostomus catostomus*) have been documented here.

Chinook salmon fry are present in large numbers in lower Vangorda Creek each year from the spring or early summer where they rear until outmigration in the fall. These fish are migrating from spawning grounds, including Blind Creek.

The reach at V8 has been assessed annually from 2004 to 2007 as a licensed requirement as part of the Aquatic Life Sampling and Testing Program (White Mountain 2004, 2005a,b, 2006a,b, 2007, 2008). Fish sampling involved single pass electrofishing and baited minnow traps. Fish habitat and presence are documented and fish are collected for the analysis of metals in their tissues. The summaries of the electro-fishing and minnow trapping results conducted each August are provided in Table 4.4-1 and Table 4.4-2 respectively. Catches in Table 4.4-1 have been expressed by unit of effort as the number of fish recorded per 100 seconds shocking time. Catches in Table 4.4-2 have been expressed by capture/trap/24 hours. Minnow traps were also set at Blind Creek as a reference. Slimy sculpin, juvenile Chinook salmon and to some extent

burbot are readily captured in minnow traps while grayling and other species are seldom captured. Electro-fishing is an effective capture method for all species. Electro-fishing has not been conducted at Blind Creek as the assessment coincides with Chinook spawning activity during August.

Of all species captured, Chinook salmon juveniles form by far the greatest densities. Densities were lower in 2006 and this corresponds with escapement numbers for adult Chinook salmon from the year proceeding the year of capture (White Mountain, 2007). For the first time, numerous two and three year old (age estimated by weight) juvenile Chinook salmon were recorded in Blind Creek during the 2007 assessment (White Mountain, 2008).

Sub-adult and adult Arctic grayling densities appear to be increasing over time (Table 4.4-1), and are a common presence in lower Vangorda Creek, whereas slimy sculpin appear to be slightly decreasing. Both sculpin and burbot are uncommon in this reach. However short term trends in fish species presence and abundance may vary for many reasons including environmental conditions and sample sizes and thus are not very informative and should be regarded with caution. Slimy sculpin are a relatively sedentary species and may spend their entire lives in the same section of stream and thus may be considered a true resident species.

Relatively high fish species diversity and density in lower Vangorda Creek, compared to reference areas (Blind Creek), suggests there are no current adverse effects from mine-related influence on local fish populations (Minnow, 2007).

4.4.2 Anvil/Rose Creek Watershed

4.4.2.1 Historical Fish Habitat

Most of the Faro Mine Complex is located within the Rose Creek watershed, and construction and operations have altered the creek in the following way:

- diversion of Faro Creek around the Faro Pit to enter the north fork of Rose Creek, rather than flowing directly into the main stem of Rose Creek;
- diversion of the main stem (reach 3) around the tailings impoundment facilities;
- creation of the pumphouse pond at the junction of the north and south forks;
- two alternative routes for the lower 500 m of the North Fork – one is the original channel with a series of excavated ponds, with a culvert at the upstream end preventing upstream fish migration and the other is a boulder-lined channel;
- construction of the Fresh Water Supply Dam (FWSD) converting approximately 1,500 m length of stream habitat into lake habitat;
- creation of a barrier on the south fork of Rose Creek through the installation of hanging culverts just downstream of the FWSD spillway;
- a fish migration barrier on the North Fork at the haul road crossing; and
- fish migration barriers on the South Fork at the haul road and mine road crossings.

4.4.2.2 Existing Fish Habitat

The established reaches on the Rose Creek watershed are generally described in Figure 3.3-2, where reach 1 is identified by the fish sampling site numbered R1. The only recent alteration to fish habitat has been the dewatering of the freshwater reservoir and associated FWSD decommissioning in November/December 2003. The South Fork of Rose Creek has more or less resumed its flow in its original channel since dewatering. Fish habitat assessments have been conducted annually on established reaches on Rose Creek and on stream reaches of South Rose Creek associated with the former reservoir, dam breach section and downstream from the breach construction area since the summer of 2004. For the later three reaches (1 to 3) are within the dewatered reservoir, one reach (4) includes the area of the breach and just downstream, another reach (5) extends below the construction zone into the wetland complex and a final reach was assessed below the diversion canal to the water quality and flow site, X14 (Figure 3.3-1). This final reach is assessed annually as it is the location where all fish removed from the freshwater reservoir prior to breaching of the dam were released. The descriptions of each reach are provided in Table 4.4-3.

Minnow (2007) examined all the fish studies completed at the Faro Mine Complex and summarized the habitat requirements and habitat availability of Arctic grayling, Chinook salmon and slimy sculpin in Rose and Vangorda watersheds (Table 4.4-4). The North Fork of Rose Creek (R7) and the South Fork of Rose Creek (R1) were found to have excellent rearing habitat for Arctic grayling. The South Fork of Rose Creek (R1) provided excellent spawning, rearing and overwintering habitat for slimy sculpin.

The summary of fish habitat requirements and availability within the Anvil/Rose Creek system and lower Vangorda Creek in Table 4.4-4 are based in part on the reporting of P.A. `Harder & Associates (1987, 1988, 1989a,b, 1991a,b,c,d, 1992 1993a,b, 1996) and field assessments by Gartner Lee during July and August of 2002 (GLL 2002c). This was added to by field habitat surveys conducted annually during 2004-2007 as part of the aquatic life sampling program (White Mountain 2004, 2005a,b, 2006a,b, 2007, 2008).

4.4.2.3 Fish Presence

As at lower Vangorda Creek, slimy sculpin, Arctic grayling, Chinook salmon, burbot, round whitefish and longnose sucker have been captured in the Anvil/Rose Creek watershed. Slimy sculpin were generally the most commonly encountered species, found at most of the sites on most of the occasions, and frequently occurred in the highest densities. Arctic grayling also are common throughout the watershed and is the only species that has been fished for sport. Fishing had been popular in the freshwater reservoir and in the pumphouse pond. High numbers of juvenile Chinook salmon were found in the lower reaches of Anvil Creek up to the confluence with Rose Creek during 2004 and 2005 (Table 4.4–6 and 4.4-8) and in recent years in low numbers as far upstream as R1 (juveniles only) (Tables 4.4-5 and 4.4-7).

The Habitat Suitability Map for the Pelly River watershed developed by the federal Department of Fisheries and Oceans in 2008 as the basis for the Watershed Authorization for Placer mining in the Pelly River watershed, classifies the lower section of Anvil Creek up to the confluence of Rose Creek an area of special consideration based on the historic presence of adult Chinook salmon and salmon spawning. In 2005, six adult salmon were observed at site A4 which is 18km upstream from the confluence of the Pelly River. Rose Creek and Anvil Creek beyond the confluence are classified as low-moderate sensitivity salmon rearing

habitat. This Habitat Suitability Map is available on the Yukon Placer Secretariat website (http://www.yukonplacersecretariat.ca/).

Minnow (2007) examined fish studies from 1989 to 2005 and concluded that the relatively high fish species diversity and density at areas immediately below the tailings facility discharge (Station R2) in Rose Creek relative to reference areas and to areas in lower Anvil Creek during the recent biological studies, suggest that mine-related activities were not adversely affecting utilization of the Anvil/Rose Creek system by fish populations.

Electro-fishing, minnow trapping and angling have been the primary methods for collecting fish. Sites on Rose Creek, as well as one on Anvil Creek, have been assessed annually since 2004 as a licensed requirement, referred to as the Aquatic Life Sampling and Testing Program. Fish habitat and presence are documented and fish are collected for the analysis of metals in their tissues each year. Fish capture data as it relates to electro-fishing and minnow trapping results for 2004 to 2007 have been summarized in Table 4.4-5 and Table 4.4-7 respectively, for these long established sites on the Rose Creek system. Adult grayling have been caught at all sites by angling (Table 4.4-10). As well, Selkirk First Nation conducted assessments on fish populations on Anvil Creek during 2004 and 2005 using electrofishing (Table 4.4-7), minnow trapping (Table 4.4-8) and angling (Table 4.4-9) sampling methods (Selkirk First Nation 2006).

As well Selkirk First Nation conducted fisheries assessments on Anvil Creek during 2004 and 2005 using electrofishing, minnow trapping and angling sampling methods (Selkirk First Nation 2006). Their assessments indicated that slimy sculpin were the most widely distributed and abundant species at all sites on the Anvil/Rose Creek watershed (Selkirk First Nation 2006). As previously mentioned, slimy sculpin are a sedentary species and may spend their entire life cycle in a small section of stream thus probably the best fish species indicator of environmental health. The data presented in Tables 4.4-10 and 4.4-12 indicates that levels of heavy metals in slimy sculpin tissue where significantly higher, especially for zinc and lead, then in Arctic grayling tissue which may reflect differences in diet but also more extensive exposure throughout their entire life cycle. There is also evidence that a related sculpin species, the mottled sculpin (*Cottus bairdi*), is one of the more sensitive aquatic species to elevated zinc concentrations. Thus the abundance of slimy sculpin at all sites, including the most impacted sites on Rose Creek, may be further evidence of aquatic health of the system.

All life stages of Arctic grayling occur at the Rose Creek sites during the open water season. Habitat is limited for adults at R1, however juveniles are found here more frequently than at the other Rose Creek sites. Burbot occur at all sites, but have only been caught in minnow traps at R2 on Rose Creek. Lake chubb (*Couesius plumbeus)* and round whitefish were captured by electrofishing at sites A1 and A2 on Anvil Creek.

Juvenile Chinook salmon were captured by electro-fishing and minnow trapping at the Rose Creek sites (none at R6, Anvil Creek) in low numbers in 2004 and 2005, but have been absent since. No salmon aged one year or more have been documented in the Rose Creek drainage during these assessments, however significant numbers of 1+ juvenile Chinook were captured by minnow trapping at lower sites A1 and A2 on Anvil Creek during 2004 and 2005 (Table 4.4-8).

Arctic grayling and burbot densities have decreased at R1 since 2004 (Table 4.4-5 and Table 4.4-7). Large numbers of grayling and burbot were removed from the freshwater reservoir prior to breaching of the dam in late 2003, and it is likely that remnant populations remained in the creek after dewatering and have slowly reduced in numbers since (White Mountain, 2007).

Fish utilization in the reaches within the dewatered reservoir and downstream have been assessed annually since 2004 as part of the adaptive management strategy for the breach project. Table 4.4-11 and 4.4-12 summarize the electro-fishing and minnow trapping data respectively, for these reaches of the South Fork of Rose Creek for 2004 to 2007.

Densities of Arctic grayling tend to be lower in the reaches in the dewatered reservoir compared to downstream in the physically unaltered reach. The wide distribution and low catch numbers of burbot, as was the case in all assessments, suggest continued stability in use as rearing habitat of juvenile populations in the assessment area. The wide distribution of slimy sculpin throughout the reaches and similar catch statistics suggest some stability of populations within this area. These three species have historically been documented in the freshwater reservoir prior to dewatering and in the South Fork of Rose Creek (Gartner Lee 2003b). Their continued presence since dewatering indicates success in the re-establishment of the channel and habitat in this section of the South Fork of Rose Creek.

4.4.3 Metals in Fish Tissue

Fish tissues have been analyzed over the years from the Rose and Vangorda watersheds to assess whether the Faro Mine Complex has influenced fish tissue quality. The analysis of metals in fish tissue has been carried out in 1975, 1976, 1977, 1989, 1992, 1997, 2002, 2004, 2005, 2006 and 2007 within the regional aquatic study area and reference sites in Anvil and Blind Creeks. These data have been summarized for slimy sculpin whole body tissue (Table 4.4-13, Arctic grayling muscle tissue Table 4.4-14 and Arctic grayling liver tissue Table 4.4-15. In each table the data have been compared with the wildlife consumption benchmark, and also the with the human consumption benchmark in Table 4.4-14 (Arctic grayling muscle).

Overall the tissue data suggests that mining activities have had only minor influences on the quality of fish tissue in the Rose-Anvil and Vangorda Creek systems (Minnow, 2007).

Table 4.4-1. Comparison of Electro-fishing Results from August Sampling of V8 on Vangorda Creek, 2004 to 2007

Site	Year	Grayling sub ad. & adult	Grayling juvenile	Sculpin adult	Sculpin fry	Burbot	Chinook Salmon juvenile	Round Whitefish
V8	2004	1.08	0.59	0.69	0	0	16.60	0
	2005	0.30	0	0.49	0	0	18.62	0
	2006	1.02	0	0.26	0	0.13	4.99	0
	2007	2.58	2.57	0.22	0	0.11	15.45	0.11

Arctic grayling and slimy sculpin were classified as to life history stage using general visual size criteria

Table 4.4-2. Comparison of Minnow Trap Results from August Sampling V8 on Vangorda Creek, 2004 to 2007

Site	Year	Arctic Grayling	Slimy Sculpin	Burbot	Juvenile Chinook Salmon 0+	Juvenile Chinook Salmon 1+
V8	2004	0.00	0.00	0.00	79.28	0.00
	2005	0.00	0.00	0.00	17.89	0.00
	2006	0.00	0.00	0.00	11.78	0.00
	2007	0.00	0.00	0.00	34.59	0.00
B1	2004	0.00	0.13	0.00	75.76	0.53
	2005	0.11	0.32	0.00	55.90	0.32
	2006	0.00	0.00	0.21	9.36	0.34
	2007	0.00	0.00	0.00	13.92	4.80

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

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 (ºC)	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

Table 4.4-4. Summary of Arctic Grayling, Chinook Salmon and Slimy Sculpin Habitat Requirements and Habitat Availability within the Anvil/Rose Creek System (Minnow 2007)

Species	Habitat Requirements			Habitat Availability Rating					
	Spawning (S)	Rearing (R)	Overwintering (OW)	Upper Anvil Creek (R6 Reference)	North Fork Rose Creek (R7 Reference)	South Fork Rose Creek (Station R1)	Lower Rose Creek (Station R2, R3, R4)	Lower Anvil Creek (Stations R5, A1 to A4)	Lower Vangorda Creek (Station V8)
Arctic grayling (*Thymallus arcticus*)	Small gravel- or rock-bottomed stream-runs at 0.3 m to 0.8 m depth, often near inlet/outlet of ponds and lakes; males territorial	Fry occupy shallow, quiter waters of stream edges and side channels; older fry and/or juveniles may migrate from hatching grounds to deeper pools and ponds with suitable cover, therefore both rocky-bottomed streams and silt-covered ponds important habitats	Deepwater habitats including lakes & ponds mainly [adults], but also deep pools with ample instream cover (e.g., vegetative debris, undercut banks, large cobble and boulder substrate) in streams and/or rivers [adults and juveniles]; adults relatively tolerant of low oxygen (i.e., winter hypoxia) conditions	Poor S, R & OW (lack of side channels and deep water)	Moderate S, OW habitat; Excellent R	Moderate S, Excellent R, Poor OW	Moderate S, OW Poor R	Moderate S, R, OW	Poor S, OW Moderate R
Chinook salmon (*Oncorhynchus tshawytscha*)	Larger tributaries with relatively large substrate (25 to 305 mm diameter) and deep water (0.3 m to 9.5 m deep) near riffles (water velocity from 0.25 m/s to 2.25 m/s); large redds constructed	Young fry are found primarily along the sides of pools and near the cover of over-hanging banks. Older fry increase their distance from cover and tend to occupy greater water depths and velocities which are sheltered from current.	In small streams, deeper pools with ample instream cover (e.g., vegetative debris, undercut banks, large cobble and boulder substrate) required; fry often migrate out of smaller tributaries in the fall	Poor S, R & OW (? based on low numbers observed)	NA (no access)	Poor S, R & OW (? based on low densities observed)	Poor S, R & OW (? based on low numbers observed)	Poor S Moderate R, OW	Poor S Excellent R Moderate OW
Slimy Sculpin (*Cottus cognatus*)	Rock-bottomed run-habitat of streams, or rocky areas of lakes	Gravel and rock-bottomed areas of streams and lakes; juveniles may occupy areas with smaller substrate and water velocities (e.g., stream edge and side channels) relative to adults	Same as rearing habitat, but often in proportionately deeper waters; species exhibits limited seasonal migration	Unknown S, OW Poor R	Moderate S, R, OW	Excellent S, R, OW	Moderate S,R & OW at R2; Poor S, R and OW at R3 and R4	Moderate S, R, OW	Moderate S, R, OW

Table 4.4-5. Comparison of Electro-fishing Results from August Sampling of the Regular Stream Reaches of Rose Creek, 2004 to 2007

Site	Year	Grayling Sub ad. & Adult	Grayling Juvenile	Sculpin Adult	Sculpin Fry	Burbot	Chinook Salmon Juvenile	Round Whitefish
R1	2004	0.36	1.80	3.47	0	0.24	0.36	0.12
	2005	0	1.53	4.83	0	0.24	0	0
	2006	0	0	1.75	0	0	0	0
	2007	0	0.34	3.09	0.11	0	0	0
R2	2004	0.27	0	15.65	1.10	0.27	0	0
	2005	1.81	0.11	8.60	0.79	0.79	0.23	0
	2006	0	0	4.22	0.55	0.08	0	0
	2007	0	0.18	5.12	0.18	0	0	0
R4	2004	0.11	0	2.86	0	0	0	0
	2005	0.57	0	4.31	0.58	0	0	0
	2006	0	0.10	8.37	5.10	0	0	0
	2007	0.11	0.68	11.12	0	0.11	0	0
R6	2004	0.11	0	2.86	0.11	0	0	0
	2005	0	0	4.21	0.10	0	0	0
	2006	0	0	6.29	1.28	0.26	0	0
	2007	0	0	5.02	0	0.18	0	0

Note:
The site at R6 was moved 800 m upstream in 2006.
Catches have been expressed by unit of effort as the number of fish recorded per 100 seconds shocking time

Table 4.4-6. Comparison of Electrofishing Results from August Stream Sampling of Regular Stream Reaches on Anvil Creek, 2004 and 2005

Site	Year	Grayling Sub ad. & Adult	Sculpin Adult	Sculpin Fry	Chinook Salmon Juvenile	Other Species
A1	2004	0	12.12	0	1.73	0.08 LC
	2005	0	9.36	0	4.56	0
A2	2004	0	15.96	3.19	15.13	0
	2005	0.49	8.63	0	2.96	0.12 RWF
A3	2004	0	12.84	abundant	1.05	0
	2005	0.41	7.65	0	0	0
A4	2004	0	6.74	0	0.42	0
	2005	0.49	7.15	0.16	0.16	0

Note:
Catches have been expressed by unit of effort as the number of fish recorded per 100 seconds shocking time.
LC = Lake chubb.
RWF = Round White Fish.

Table 4.4-7. Comparison of Minnow Trap Results from August Sampling of the Regular Stream Reaches of Rose Creek, 2004 to 2007

Site	Year	Arctic Grayling	Slimy Sculpin	Burbot	Juvenile Chinook Salmon 0+	Juvenile Chinook Salmon 1+
R1	2004	0.16	0.49	0.00	0.16	0.00
	2005	0.28	0.28	0.00	0.00	0.00
	2006	0.16	0.16	0.00	0.00	0.00
	2007	0.00	0.00	0.00	0.00	0.00
R2	2004	0.00	0.15	0.15	0.84	0.00
	2005	0.00	0.34	0.67	0.84	0.00
	2006	0.15	0.15	0.00	0.00	0.00
	2007	0.00	0.39	0.19	0.00	0.00
R3	2004	0.00	0.00	0.00	0.51	0.00
	2005	0.00	0.31	0.00	0.00	0.00
	2006	0.00	0.28	0.00	0.00	0.00
	2007	0.11	1.37	0.00	0.00	0.00
R4	2004	0.00	0.00	0.00	0.51	0.00
	2005	0.00	0.31	0.00	0.00	0.00
	2006	0.00	0.28	0.00	0.00	0.00
	2007	0.11	1.37	0.00	0.00	0.00
R6	2004	0.00	0.00	0.00	0.00	0.00
	2005	0.00	0.21	0.00	0.00	0.00
	2006	0.00	0.20	0.00	0.00	0.00
	2007	0.00	0.25	0.00	0.00	0.00

Note: 0+ = young of the year, 1+ = juveniles one year and older
The site at R6 was moved 800 m upstream in 2006.
Catches have been expressed by capture/trap/24 hrs.

Table 4.4-8 Comparison of Minnow Trap Results from August Sampling of the Regular Stream reaches of Anvil Creek, 2004 and 2005

Site	Year	Arctic Grayling	Slimy Sculpin	Juvenile Chinook Salmon 0+	Juvenile Chinook Salmon 1+
A1	2004	0	0.55	38.90	0
	2005	0	0	8.67	0
A2	2004	0	0.22	31.82	0
	2005	0	0.31	1.10	0
A3	2004	0	0.85	8.72	1.06
	2005	0.13	0.80	0.13	0.13
A4	2004	0	0.61	6.58	0
	2005	0	0.58	0.12	2.09

Note: 0+ = young of the year, 1+ = juveniles one year and older
Catches have been expressed by capture/trap/24 hrs

Table 4.4-9. Comparison of Angling Efforts and Catches from August Investigations of the Regular Stream Reaches of Anvil Creek, 2004

Sample Site	Year	Effort	Catch	Catch Per Unit Effort (# Fish/60 Minutes)
A1	2004	225 minutes	3 Arctic grayling	0.80
A2	2004	30 minutes	0	0
A3	2004	10 minutes	7 Arctic grayling	42.00
A4	2004	100 minutes	10 Arctic grayling	6.00

Table 4.4-10. Comparison of Angling Efforts and Catches from August Investigations of the Regular Stream Reaches of Rose Creek, 2004 to 2007

Sample Site	Year	Effort	Catch	Catch Per Unit Effort (#Fish/60 Minutes)	Comment
R1	2004	30 minutes	2 Arctic grayling	4.00	
	2005	45 minutes	4 Arctic grayling	5.30	
	2006	190 minutes	9 Arctic grayling	2.84	Ag mostly sub. Ad
	2007	90 minutes	9 Arctic grayling	6.00	
R2	2004	30 minutes	7 Arctic grayling	14.00	caught u/s and d/s of discharge
	2005	105 minutes	0	0	observe 0 Ag
	2006	180 minutes	5 Arctic grayling	1.67	well dispersed
	2007	110 minutes	5 Arctic grayling	2.73	
R4	2004	10 minutes	0	0	
	2005	30 minutes	5 Arctic grayling	10.00	
	2006	50 minutes	6 Arctic grayling	7.20	u/s of site
	2007	40 minutes	12 Arctic grayling	18.00	
R6	2004	30 minutes	2 Arctic grayling	4.00	
	2005	50 minutes	1 Arctic grayling	1.20	
	2006	50 minutes	3 Arctic grayling	3.60	
	2007	40 minutes	12 Arctic grayling	18.00	

Note:
The site at R6 was moved 800 m upstream in 2006.

Table 4.4-11. Comparison of Electro-fishing Results from August Sampling of Stream Reaches of Rose Creek Associated with the Former Reservoir, Dam Breach Section, and Downstream from the Breach Construction Area, 2004 to 2007

Site	Reach	Species	Density (capture/100 sec)			
			2004[1]	2005[1]	2006[1]	2007[2]
Former reservoir	1	Arctic grayling	1.00	1.84	0.30	0.14
		burbot	0.36	0.12	0.10	0
		slimy sculpin	0.68	0.86	0.64	0.98
	2	Arctic grayling	0.23	0.24	0	0.14
		burbot	0	0	0	0
		slimy sculpin	4.28	3.30	7.11	3.59
	3	Arctic grayling	0.26	0.07	0	1.34
		burbot	0.58	0.21	0.03	0
		slimy sculpin	2.02	5.50	4.22	2.28
Dam breach section	4	Arctic grayling	1.28	0.28	0.06	0.75
		burbot	0.37	0.14	0.06	0.13
		slimy sculpin	0.64	0.14	0.49	0.40
Downstream of breach construction area	5[2]	Arctic grayling	2.96	5.13	2.00	1.12
		burbot	0.23	0	0	0
		slimy sculpin	0.56	1.84	3.41	0.70
		round whitefish	0	0.17	0.41	0

[1] based on 2 pass block net electrofishing technique.
[2] based on 1 pass electro-fishing technique.
**life history stages of fish in samples not determined*

Table 4.4-12. Comparison of Minnow Trapping Results from Combined June and August Sampling of Stream Reaches of Rose Creek Associated with the Former Reservoir, Dam Breach Section, and Downstream from the Breach Construction Area, 2004 to 2007

Site	Reach	Species	Density (capture/trap/24 hr)			
			2004	2005	2006	2007
Former reservoir	1	Arctic grayling	0	0.62	0	0.08
		burbot	0.12	0.07	0.09	0.08
		slimy sculpin	0.12	0.21	0	0.25
	2	Arctic grayling	0.12	0.08	0	0
		burbot	0.06	0.17	0.42	0.18
		slimy sculpin	0	0.08	0	0.53
	3	Arctic grayling	0	0.19	0	0
		burbot	0	0.09	0	0.08
		slimy sculpin	0.06	0	0	0.08
Dam breach section	4	Arctic grayling	1.04	0.65	0	0
		burbot	0	0.20	0	0.15
		slimy sculpin	0	0	0.10	0.15
Downstream of breach construction area	5	Arctic grayling	0.15	0.17	0	0.33
		burbot	0.14	0.17	0.20	0.16
		slimy sculpin	0	0	0	0
	X-14	Arctic grayling	0	0.08	0	0
		burbot	0.14	0	0	0
		slimy sculpin	0.14	0	0	0.07

Table 4.4-13. Summary of Slimy Sculpin Whole Body Tissue Metal Concentrations (mg/kg ww), Rose-Anvil and Vangorda Creek systems, 1975 to 2007

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
	2006										
	2007	0.1	0.1	0.1	<0.1					0.15	0.1
Cadmium	1997		0.077	0.227						0.133	0.349
	2002		0.030							0.117	0.453
	2004	0.072	0.011	0.051	0.062	0.045	0.086	0.073	0.199	0.108	0.184
	2005	0.076	0.050	< 0.05	<0.05	0.066	0.064	0.096	0.260	0.085	0.180
	2006	0.058	0.040	0.03	0.04					0.06	
	2007	0.04	0.020	<0.02	0.03					0.07	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
	2006	0.56	0.72	0.56	0.41					0.61	
	2007	0.78	0.85	0.68	0.66					0.78	0.92

Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
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
	2006	<0.1	<0.1	<0.1	<0.1					<0.1	
	2007	<0.1	<0.1	0.2	0.2					<0.1	0.1
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	30.8	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
	2006	8.2	16.7	19.7	37.0					11.1	
	2007	18.2	22.4	84.5	61.7					14.3	7.81
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
	2006										
	2007										
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
	2006	27.2	33.0	49.6	44.5					23.7	
	2007	32.7	28.3	48.5	54.4					28.1	0.2

Value exceeds respective wildlife consumption benchmark (0.28 mg/kg for Arsenic; 4.9 mg/kg for lead)

Table 4.4-14. Summary of Arctic Grayling Muscle Tissue Metal Concentrations (mg/kg ww), Rose-Anvil and Vangorda Creek Systems, 1975 to 2007

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
	2006										
	2007	<0.6	<0.1	<0.1	<0.1					<0.1	<0.1
Cadmium	1992		< 0.1								
	1997		0.013	0.013						0.038	0.093
	2002		< 0.005	0.010						0.011	0.351
	2004	<0.005	0.015	0.097	<0.005		0.019	0.006		0.032	0.033
	2005	< 0.05	0.050		0.830	0.062	0.068	0.062	0.075	0.090	0.167
	2006	< 0.02	< 0.02	< 0.02	< 0.02					< 0.02	0.030
	2007	<0.02	<0.02	<0.02	<0.02					0.020	<0.02
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
	2006	0.27	0.35	0.5	0.37					0.25	0.29
	2007	0.55	0.48	0.43	0.48					0.31	0.25
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
	2006	< 0.1	< 0.1	< 0.1	< 0.1					< 0.1	< 0.1
	2007	<0.1	<0.1	<0.01	<0.1					<0.1	<0.01
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
	2006	0.52	0.83	1.38	0.8					0.30	0.26
	2007	0.33	0.47	0.34	0.48					0.36	0.29
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
	2006										
	2007										

Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
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
	2006	5.1	6.2	6.7	6.4					6.1	6.8
	2007	4.4	4.1	5.1	4.8					4.7	4.5

Value exceeds respective either human or wildlife consumption benchmark (Arsenic - 0.20 mg/kg, 0.56 mg/kg, 0.28 mg/kg for human toddler, human child and wildlife, respectively; Mercury - 0.07 mg/kg for human toddler)

Table 4.4-15 Summary of Arctic Grayling Liver Tissue Metal Concentrations (mg/kg ww), 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

Value exceeds respective wildlife consumption benchmark (0.28 mg/kg for Arsenic; 4.9 mg/kg for lead; 0.45 mg/kg for mercury)

5. Terrestrial Resources

5.1 Vegetation

5.1.1 Introduction

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 and industrial development in particular has the potential to affect vegetation ecosystem health.

The objectives of the vegetation baseline assessment for the Closure and Remediation Plan for the Faro Mine Complex (the Project) are to identify the current condition of vegetation components of the ecosystem, including:

- Composition and cover of vegetation associations at a local scale; and
- Levels of contaminants from the Faro Mine Complex in vegetation in the region.

5.1.2 Regional Setting – Vegetation

The Faro Mine Complex is located within the Yukon Plateau-North Ecoregion, in the Boreal Cordillera Ecozone of the Yukon (Environment Canada, 2005). The region consists of rolling uplands, small mountain groups, and nearly level tablelands dissected by U-shaped valleys. A prominent valley called the Tintina Trench traverses the ecoregion from southeast to northwest. The mine complex lies within the zone of discontinuous, widespread permafrost, wherein Turbic Cryosolic and Eutric Brunisolic soils predominate and occasional pockets of Dystric Brunisols occur on coarse-textured morainal and glaciofluvial materials. Vegetation is predominantly white spruce with willow, dwarf birch, ericaceous shrubs, and occasionally, lodgepole pine. Poorly drained lowland sites consist of black spruce, scrub willow, birch, and mosses. Subalpine areas are vegetated with alpine fir, lodgepole pine, mountain avens, dwarf willow, birch, ericaceous shrubs, graminoid species, and mosses (Environment Canada, 2005).

5.1.3 Data Sources

Data sources for the LSA are primarily field data collection, 1:10,000 scale black and white aerial photos and a 1:20,000 colour ortho photo of the area. The 2007 draft revegetation program conducted by EDI was consulted for additional information regarding natural communities within the LSA (EDI, 2008). Data sources for contaminant accumulation in vegetation in the RSA are the results of the Faro Mine Complex – Terrestrial Effects Study: Investigation into Metal Concentrations in Vegetation, Wildlife and Soils, prepared for Deloitte & Touche Inc. on behalf of the Faro Mine Closure Planning Office by Gartner Lee Limited September 2006.

References for plant species identification and nomenclature include: Flora of the Yukon Territory (Cody, 2000), Plants of Northern British Columbia (Mackinnon et. al, 1999) and Plants of the Western Boreal Forest and Aspen Parkland (Johnson et. al, 1995).

5.1.4 Baseline Description

5.1.4.1 Local Study Area

Local Study Area Baseline Data Collection Methods

During the summer of 2007, representative vegetation associations were surveyed in order to describe their composition and develop vegetation map units. The characteristic composition and cover of species in each association was determined through standardized plot sampling in representative areas. A preliminary vegetation map of the area was then developed at a scale of 1:20,000, using aerial photography flown in July 2003. Map units for the LSA vegetation associations map were designed to link to the existing Sheep Mountain studies (Staniforth, 1998), taking into consideration that modifications of the Sheep Mountain associations were undertaken to better represent the vegetation in the project LSA (Figure 5.1-1). Many potential associations are not identified for this project as they were too small to map or there was a lack of clarity in their delineations.

The vegetation sampling density for LSA mapping was guided by the British Columbia Terrestrial Ecosystem Mapping (TEM) inventory standards for 1:20,000 scale mapping (Resource Inventory Committee 1998). These guidelines provide a previously evaluated sampling strategy that is scientifically accurate and efficient, particularly for collecting data in remote locations with limited access. Data collection identified in these guidelines includes 5% detailed vegetation plots, 20% ground plots and 75% visual calls to confirm map polygon identifications.

During the 2007 vegetation field survey of the Faro LSA, 17 ground plots and 59 visual calls were inventoried (Figure 5.1-2). A list of the sites surveyed in 2007 and their corresponding vegetation associations are presented in Appendix A.

Baseline descriptions are developed for each mapped vegetation association, including plant species composition, terrain and general soils characteristics, e.g., site moisture and nutrient regime, based on field data. No specific soil characterizations were undertaken during this investigation, however supporting information on surficial geology and soils was utilized from the *Anvil Range Mining Complex Additional Borrow Studies 2005/06 Task 17a* report done by SRK Consulting (2006c).

Local Study Area Baseline Conditions

The LSA baseline conditions are generally described in relation to each issue (vegetation abundance and diversity and vegetation health), and more specifically for the VECs associated with those issues.

Vegetation Association Descriptions

Thirteen vegetation associations and the project footprint have been identified and mapped within the LSA of the project. Their distributions are shown in Figure 5.1-2. The abundance of each vegetation association and the abiotic features in the LSA are present in Table 5.5-1. The white spruce/willow vegetation association covers the largest area at 3657.4 ha (45%) of the LSA. Detailed descriptions of the vegetation associations including their component vegetation species and a representative photo are presented in Appendix B. A list of vegetation species observed during the 2007 and 2008 field surveys is presented in Appendix C.

Ecozones

Vegetation associations throughout the mapped LSA vary according to elevation, soil drainage, aspect and disturbance (Oswald et al., 1983). Due to the mountainous nature of the LSA, elevation is a prominent element in determining vegetation associations. The LSA can be divided into two zones; the boreal zone and the subalpine zone.

Boreal Zone

The boreal zone contains forested, low elevation valley bottoms and low-lying terrain (Deloitte & Touche and Gartner Lee, 2003a). Most waterbodies and wetlands are associated with this zone, which dominates the majority of the study area below 1200 m. This area was extensively glaciated, leaving morainal and glacio-fluvial deposits (Staniforth, 1998), and contains a large number of associations linked to terrain variation and fire.

Subalpine Zone

In the 2004 to 2008 Water License Renewal Environmental Assessment Report (Deloitte & Touche Inc., 2003), it is stated that; “the subalpine zone refers to the zone between the relatively closed-canopy forests in the boreal zone and the dwarf shrub, herb and non-vegetated rock areas in the alpine zone. The subalpine zone represents a broad gradient between low and high elevation conditions. It is dominated by tall shrub vegetation with scattered spruce and fir forests at its lower limits, grading into lower stature shrub and herb communities at upper elevations.” This zone begins at roughly 1200m and is noted as beginning higher on southern aspects than on northern ones (Oswald *et al.*, 1983).

Rare or Threatened Plant Species

The current regulatory lists for rare and threatened species; “Wild Species 2005: The General Status of Species in Canada” (CESCC 2006) identifies and ranks threats to plant populations on consideration of the following factors; population size, number of occurrences, geographic distribution, trend in population, trend in distribution, threats to population and threats to habitat. Rare and threatened plants include species ranked as “may be at risk” and “at risk”. A third risk category, “sensitive”, includes species not currently at risk or rare, but species that may be vulnerable to impacts to populations. Status rank categories are presented in Table 5.1-2. There are currently 227 “sensitive” vascular plant species in the Yukon, 249 “may be at risk” and none that are “at risk” (see Appendix D).

The Yukon Conservation Data Centre under NatureServe Canada documents ranks and tracks populations of rare plant species, but does not assign a “threat or risk” status. Status rank categories, based on rarity, are

presented in Table 5.1-3. There are currently 185 “S1” vascular plant species in the Yukon, 147 “S2” species and 59 “S3” species (see Appendix E).

At the federal level, species determined to be at risk (endangered, threatened or of special concern) by COSEWIC undergo a regulatory review process administered under the *Species at Risk Act* (*SARA*) (CESCC 2006; CWS, 2005) for listing in Schedule 1 of the Act. There is currently one SARA-listed plant in the Yukon, Baikal sedge *(Carex sabulosa)*, however it is restricted to sand dunes in south/ southwest Yukon.

In August 2008, surveys for rare, threatened and sensitive vascular plants were undertaken in selected areas adjacent to waste rock piles that will be recontoured and new disturbance to natural vegetation is planned. No species identified as rare, threatened or sensitive were found during the survey. See Appendix F for the full report on the 2008 Faro Mine Site Rare Plant Survey. Further rare plant surveys will be required for other areas of new project footprint once these areas are spatially defined.

Introduced Plant Species

A number of introduced plant species are present in the Faro Mine Complex area. A survey for introduced species has not been done but there are a number of records from field surveys in support of the mapping, revegetation planning and the rare plant survey (Table 5.1-4) (see Appendix C for a vegetation species list for the project). Additional introduced species occurrences are likely in disturbed areas of the mine complex and in currently reclaimed areas where seed mixes were used.

5.1.4.2 Regional Study Area Baseline Vegetation Health

Vegetation Health Background

As a result of concern with respect to the potential for elevated metal concentrations to occur in vegetation, soils and wildlife near the Faro Mine Complex, a Terrestrial Effects Study was completed by Gartner Lee Ltd. (GLL) and Associates in 2006. The overall objective of the Terrestrial Effects Study was to gather data that could be used to better understand the distribution and movements of elevated elemental concentrations in the terrestrial environment. This information has been used for the human and ecological risk assessment (HHERA) .. The specific objectives of the Terrestrial Effects Study were to:

- characterize the spatial distribution of elevated elemental concentrations;
- determine if deposition is ongoing;
- improve characterization of elemental concentrations in reference materials;
- investigate elemental concentrations in vegetation and mineral licks;
- investigate elemental concentrations in wildlife tissues;
- determine specific sources of elemental lead, and
- determine elemental concentrations in ambient air.

The findings of this study with respect to vegetation health are presented in the following sections. Although the Terrestrial Effects Study was designed to provide an understanding of the spatial extent, timing and

concentrations of elements in the terrestrial environment near the Faro Mine Complex, the HHERA of the Project Proposal deals with the significance of these findings in terms of human health and ecological risk.

Vegetation Health Baseline Data Collection

Several interrelated environmental parameters were examined to obtain the data needed for the terrestrial effects assessment. The study design applicable to vegetation health is summarized below. Further detail on study design and methods is contained in the GLL *et al* 2006 report.

Background sampling was conducted near Swim Lake, approximately 9 km to the southeast of the Vangorda pit, to establish background "reference" levels for metals concentrations in soils and vegetation. These background sampling locations are shown in Figure 5.1-3 along with the other sampling locations.

Characterization of the Spatial Distribution of Elevated Elemental Concentrations

To isolate the effects of airborne deposition from mineralization, the spatial distribution of elevated elemental concentrations was determined, primarily by sampling lichens. Lichens (*Cladina spp*.) were selected as the indicator species because they are long-lived, non-deciduous and depend entirely on airborne material and precipitation for nutrients and are therefore unaffected by the mineralization of underlying soils. Soils are also perennial accumulators and provide an additional record of cumulative airborne deposition; however, elemental concentrations in mineral soils can also be influenced by natural mineralization and glacial transport. Soil sampling was therefore conducted to:

- confirm the results of lichen sampling, and
- detect naturally elevated elemental concentrations (i.e., unrelated to the mine) in local surficial materials.

Timing of Deposition of Mine-Related Dust

Initial studies conducted in 2002 (C.E. Jones & Associates Ltd. 2003) indicated that elemental deposition occurs in the study area from operations at the mine but did not provide information about its timing. Studies were conducted in 2004 and 2005 to determine if deposition is ongoing. This study component was designed to determine if measured elemental concentrations are at their maxima or will continue to increase into the future. Moss bags were used to determine if airborne deposition is ongoing and its timing.

Elemental Concentrations in Vegetation and Mineral Licks

Selected plant species were collected in the study area to determine the uptake of various elements by vegetation used by wildlife (e.g., forage species) or humans (e.g., medicinal use or ingestion). However, elemental concentrations in vascular (i.e., rooting) vegetation can be influenced by both pre-existing mineralization (elemental uptake via root systems) and by airborne elemental deposition (through deposition on plant surfaces and uptake through surface soil). To distinguish between these sources and ensure that elevated concentrations were not erroneously attributed to mine operations, soils were collected, subsampled and analyzed where plants important to wildlife or humans were collected. Soil was also collected at mineral licks because wildlife using licks may consume soils either directly or indirectly through the ingestion of soils while foraging, providing a potential secondary source of elemental uptake. These study

components provide information about elevated metal concentrations in the human and wildlife food chains and will assist in predicting potential impacts on local land-users from elevated metal concentrations resulting from care and maintenance operations at the mine.

Sources of Elevated Lead Concentrations

Potential mechanisms for the dispersal of elements in the Faro Mine Complex study area include windblown dusts and a historic spill of tailings into Rose and Anvil Creeks, which drain portions of the Faro Mine Complex. The potential for lead from naturally occurring and outside sources to affect the study area required that local "background" levels were distinguishable from those resulting from the Faro Mine Complex. Lead (Pb) isotope tracing was used to determine the origin of lead in samples of dust, soils and moss bags from the study area. The analysis was conducted to:

- Identify and quantify ore deposit leads in dusts and soils from the Faro Mine Complex,
- Distinguish and quantify lead from mine ores and from long-range lead sources in airborne dust at locations on and off of the mine site, and
- Determine whether tailings from a historic spill are present in the floodplains of Rose and Anvil Creek below the mine.

Vegetation Health Baseline Conditions

The information collected in the terrestrial environment shows that past operations at the Faro Mine Complex have resulted in metal concentrations in the mine area that are greater than the reference/background levels. For example, lead concentrations near the mine are up to 450 times those at reference sites and the lead isotope analysis indicates that the majority of the lead deposited in the study area was from mine ores. The concentrations of metals that originated from the mine site are generally higher near the mine and decline with distance from the mine. Deposition of some metals from the mine site is still occurring in the immediate area, mostly during the snow-free period. Metal concentrations that were greater than the reference/background levels were detected in plants, small mammals and other wildlife in the area.

The discussion of the results for each component of this study is presented below.

Characterization of the Spatial Distribution of Elevated Elemental Concentrations

Because lead is the least mobile of the "heavy" metals (as opposed to zinc, which can be highly mobile in both soils and plants), it likely represents the best historical record of elevated elemental levels resulting from operations at the Faro Mine Complex. Lead in lichen tissue was therefore considered the principal indicator of the spatial distribution of elevated elemental levels from the Faro Mine Complex. High lichen lead levels in the integrated 2002 / 2004 / 2005 data set are evidence of significant mine-generated accumulations. Some lead levels near the Faro tailings impoundment / mill complex were 150-450 times baseline values.

The zone of elevated concentrations (Figure 5.1-4) extends to the Blind Creek Valley / Swim Lake basin to the southeast (1-10 km from the Grum / Vangorda mine areas), to the Pelly River Valley to the southwest (5-10 km from the mine site) and a minimum of 20 to 25 km from the mine complex up the North Fork Rose Creek drainage. Elevated concentrations of elements also extend a minimum of 40 to 50 km from the mine

complex down the Rose / Anvil / Pelly drainages; however, the 1975 tailings dam breach may have contributed to the extent of the area of impact in this direction. Lichen lead levels measured at several locations in the study area are higher than published reference levels for lichens, and are comparable to some of the higher levels documented worldwide in vascular vegetation at sites contaminated with lead. Although the area sampled for lichens was expanded in the 2004 and again in 2005, the maximum spatial extent of elevated lichen-lead concentrations could not be determined for all directions from the mine.

Soils were also examined to determine if elevated elemental levels could be attributed wholly or partly to the influence of underlying mineralized soils. Although patterns for lead and zinc in surface soils are similar to those for lichens, no similar pattern exists in subsurface organic or mineral soils. Furthermore, there is no apparent relationship between concentrations in underlying materials and surface horizons. These findings support the hypothesis that the spatial pattern of elevated elemental levels has been caused by deposition from the Faro Mine Complex and cannot be attributed to natural effects that predate mining.

The lead isotope analysis of dust, soil and moss samples from the study area further supports the conclusion that elevated elemental levels are caused by the mine. In addition, sequential extractions performed on a subset of soil samples indicate that substantial fractions of total lead concentrations exist in a weakly complexed form, which becomes relatively mobile when associated compounds decompose or degrade. The implications are that lead deposited from the mine site is not environmentally inert. Instead, it can be expected to have some mobility through plant uptake and leaching through to lower soil horizons, where it will likely become more permanently fixed. Following is a summary of results.

High Elevation Relative to Reference Levels – Lead and Arsenic. Maximum lead and arsenic concentrations in areas affected by the mine were 450 and 250 times the Swim Lake maximum, respectively. Equivalent-to-reference levels were reached to the southwest of the mine site, across the Rose mountain range, and around the perimeter of the study area from the southeast to north. 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 Faro mine area. The total area in which lead concentrations in lichens are at least 3 times the observed Swim Lake maximum is approximately 769 km2 (76,900 ha).

Moderate Elevation Relative to Reference Levels – Zinc, Copper, Iron, Silver, and Thallium. Maximum concentrations of these elements in areas affected by the mine 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 mine areas, to the northeast along the exposed (mine-side) slopes of Mount Mye, and to the southwest along the exposed slopes of Rose Mountain. Elevated elemental levels generally extend to the northeast along North Rose Creek, to the north up and past Mount Aho, and to the northwest down the Rose Creek valley.

Low Elevation Relative to Reference Levels – Barium, Chromium, Mercury, Nickel, and Selenium. Maximum concentrations for most of these elements in mine-affected areas were three to nine times the Swim Lakes maxima and 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 concentrations of these elements are associated with the Faro Mine Complex. Concentrations of these elements, however, are either within reported Yukon reference ranges for lichens (antimony and cobalt), or are similar to other high levels in the study area that appear to be unrelated to the presence of the mine (cadmium).

No Elevation Relative to Reference Levels – Boron, Molybdenum, Titanium, Vanadium, Aluminum, Beryllium, Calcium, Magnesium, Manganese, Phosphorus, Potassium, Silicon, Sodium, Tellurium, Tin and Uranium. Elevated 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 operations at the Faro Mine Complex.

Timing of Deposition of Mine-Related Dust

The exposure of moss bags for different time periods from August 2004 to August 2005 indicated that mine-generated deposition for a number of elements is ongoing. Lead had the highest amount of deposition and the pattern was generally similar to that for accumulated lead levels in lichens (i.e., elevated levels are concentrated in the vicinity of the tailings impoundment / mill complex and northwest down the Rose Creek valley). The results of the moss bag monitoring program indicate that over the study period, deposition occurred primarily between August and November, and again between late January and mid-August. This suggests that deposition occurs primarily during the snow-free period.

Concentration patterns of elements other than lead in moss bags are somewhat different from the observed cumulative patterns recorded for lichens. For example, arsenic has the second highest cumulative elemental concentration in lichens relative to reference levels but there appears to be little current deposition. In contrast, barium and nickel accumulations in lichens are low but these elements were among those with high levels of deposition in moss bags. Furthermore, aluminum, manganese, silicon, and uranium levels were elevated in moss bags but there was no evidence of mine-generated accumulations in lichens. Disparities between observed cumulative elemental elevation and current elemental deposition suggest that:

- the contribution of current mine-site elemental dust sources is different than historical contributions, due to different operational and closure conditions; and / or
- the period monitored by moss bag exposure does not reflect the entire range of conditions that have contributed to cumulative elemental elevation in the study area.

Moss bags are useful indicators of current airborne deposition and can also provide a general indication of where sources of deposition are located. However, they do not indicate specific sources or provide empirical measurements of ambient elemental concentrations in the air. Consequently, lead isotope analysis and ambient air-sampling using mini-vols was conducted in 2005.

Elemental Concentrations in Vegetation and Mineral Licks

High Elevation Relative to Reference Levels – Lead. Lead concentrations for all plant species groups were greatly elevated in the zone immediately adjacent to the tailings impoundment / mill complex, which indicates that the presence of 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 above reference ranges. There are no reference levels for comparison for 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 for berries to 20 times for forbs. In most zones affected by the mine, zinc levels in forbs, willow, mushroom and bear roots exceeded documented Yukon background ranges.

Low Elevation Relative to Reference Levels – Copper, Nickel, Silver, Mercury and Thallium. These elements all 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. It should be noted, however, that for lichens, there was no conclusive evidence of a link between elevated nickel levels and the Faro Mine Complex.

There is some evidence that concentrations of antimony, arsenic, barium, cadmium, chromium, cobalt, iron and mercury are elevated in northern rough-stemmed mushrooms, bear root and tree sap collected in mine-affected areas compared to Swim Lake or Yukon reference levels. Most notably, maximum arsenic concentrations in northern rough-stemmed mushroom and tree sap in mine-affected areas were 11 times reference levels and maximum iron concentration in tree sap was 22 times reference levels.

Soil samples were collected from two mineral lick sites, one in the vicinity of the Faro Mine Complex (Mineral Lick Site 2) and one within a reference area (Mineral Lick Site 1). The analysis of soils collected at Mineral Lick Site 2, which is within lichen lead zone 2, indicates that there is potential for the ungulates to consume soils containing 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.

Sources of Elevated Lead Concentrations

The results of the lead isotope study indicate that ore from the Faro Mine Complex is by far the most important source of lead deposition in the study area. Although lead from the ore is mixed with non-ore lead in some areas, lead from the ore is widespread in the study area and often comprises over 90% of that found in both soils and moss bags. Lead from Faro Mine Complex ores is also comprises 60 to 90% of the lead found in soils at sampling sites in the Anvil Creek floodplain.

Lead that occurs in floodplain soils is probably largely the result of the tailings dam breach, which occurred in 1975. Moss bag sampling indicated that mine ores are the source of almost 100% of the lead that is currently being deposited in the study area.

Moss bags at all sampling sites contained lead from mine ores. Such sites included those near the Town of Faro and in the Swim Lake reference area; however, lead concentrations in moss bags in those areas were low.

Vegetation Baseline Summary

Vegetation Cover Baseline Summary

A 81.2 km^2 vegetation LSA was established to map the distribution and diversity of vegetation associations in the Project area. The LSA includes the area within a 1 km wide buffer around the Faro Mine Complex, infrastructure and road corridors. A vegetation map of the area was developed at a scale of 1:20,000, using aerial photography and field data.

Vegetation associations in this mountainous area include forested and wetland associations in the low elevation valley bottoms and low-lying terrain of the boreal zone, below 1200 m. The boreal zone contains a number of associations linked to morainal and glacio-fluvial terrain and influenced by fire. Closed forests of white spruce/willow cover the largest portion 45% of the LSA. There are small areas of pine, mixed coniferous-deciduous and deciduous forests. Also present are shrub associations of dwarf birch and willow. Poorly drained lowland sites support dwarf birch, willow, sedge and graminoid associations. The areas of the LSA above 1200 m are in the subalpine zone, which is dominated by tall shrub vegetation. Scattered open spruce and fir forests occur at the lower limits, grading into lower stature shrub, herb and lichen communities at upper elevations.

Native vegetation has historically been removed from a 1612.7 ha (16.1km2) area by the development of the Faro Mine Complex.

In August 2008, surveys for rare, threatened and sensitive vascular plants were undertaken in selected areas at the foot of waste rock piles that will be recontoured and new disturbance to natural vegetation is planned. No species identified as rare, threatened or sensitive were found during the survey. Further rare plant surveys will be required for other areas of new project footprint once these areas are spatially defined.

Vegetation Health Baseline Summary

The results of the terrestrial effects study for the Faro Mine Complex show clearly that the presence of the mine has resulted in elevated concentrations of several elements both at the mine site and in the surrounding area. For example, lead concentrations in lichens near the mine were up to 450 times those in reference samples. A lead isotope analysis showed that a large proportion of the lead found in terrestrial media in the study area is from mine ores; this is the case for 61 to 100% of the dusts and soils collected from the study area, and 65 to 90% of the soils collected along Anvil Creek. In addition, the study showed that over 90% of the lead currently being deposited in the study area is from mine ores. Thus, very little of the deposited lead is transported from outside sources. Other lines of evidence confirm that the mine is the principal source of elevated elemental concentrations. Geo-statistical analyses indicated that most elements had distinct patterns of elevated concentrations, with the highest levels occurring near the mine and decreasing as distance from the mine increased. The analysis of soils indicated that elemental

concentrations in vegetation and surficial soils were not related to the degree of mineralization in underlying soil horizons.

The area affected by some elements is large. For example, concentrations of lead are elevated in an area that is known to be at least and which is probably greater than 1,760 km2. The study, however, was unable to delineate the entire area in which concentrations of some elements are elevated despite expanding the sampling program in 2004 and again in 2005. For example, the limit of deposition for lead is not known for the area to the northwest and northeast, which includes the Rose, Anvil and Pelly drainages, although it is believed to extend 40 or 50 km from the mine. Similarly, the limit of elevated lead concentrations is unknown in the area to the north and east of the mine; however, the data suggest that lead concentrations in this area are likely to approach background levels approximately 20 km away. In contrast, lead is known to decline to background levels approximately 5 to 10 km to the south of the Faro Mine Complex complex.

Although the mine appears to be the source of almost all elevated elements detected in the study area, two distinct sources are associated with the mine and mining operations. The mine itself is the source of most elemental deposition; however, a breach of the tailings dam in 1975 resulted in the deposition of tailings along watercourses to the northwest of the mine site. These tailings deposits, which occur discontinuously, may provide a secondary source of water- and air-borne deposition, which could extend the area affected by elevated elemental concentrations. Moreover, there is potential for the affected area to continue to expand as a result of the fluvial and airborne transport of tailings materials.

The presence of elevated elemental concentrations in plants consumed by humans and animals indicates that these elements are entering the environmental food chain and also have the potential to be incorporated into the human food chain.

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6915000 6912500 6910000 6907500 6905000 6902500

Petly River

Vangorda Creek

Prepared by: CA

Date Revised: April 3, 2009

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Vegetation\107403_C1_Fig_5.1-1_VegClassification_01Apr09.mxd

Map Sources/Notes:
Base data obtained from the Yukon Department of Environment, Information Management & Technology Branch.
National Topographic Database (NTDB) provided by the Government of Canada, Natural Resources Canada at 1:50,000 scale.
Survey sites provided by AECOM Canada Ltd.
Vegetation classification conducted by AECOM Canada Ltd from aerial photography at 1:10,000 scale.
Local study area delineated by AECOM Canada Ltd.

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N W E S

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Kilometers

1:75,000
UTM Zone 8N, NAD 27

Legend

Existing Features
- Road
- Local Study Area

Hydrological Features
- Watercourse
- Waterbody
- Project Footprint

Survey Sites (2007)
- Visual Calls
- Ground Plots

Vegetation Classification
- B/Fa
- B/L/Fa
- B/W
- Dd
- Gr
- Mx
- Pl
- S/W
- Sw/Fm
- Sw/W
- W/B
- W/S
- W/Sw

Faro Mine Closure
Fermeture de la mine Faro

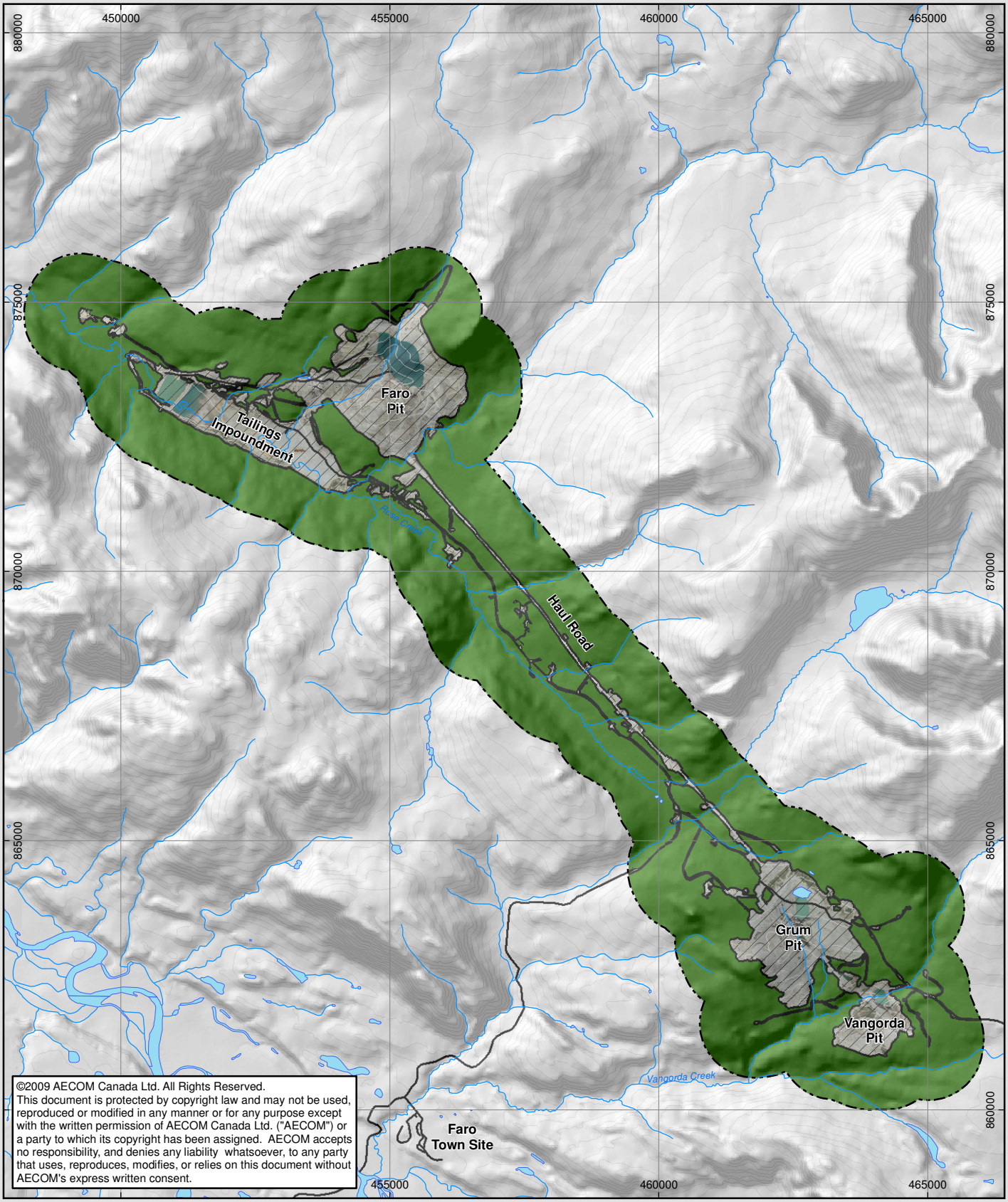
Faro Mine Complex Closure and Reclamation

Vegetation Associations and 2007 Survey Sites

March, 2009

AECOM

Figure 5.1-1



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Map Sources/Notes:
National Topographic Database (NTDB) provided by the Government of Canada, Natural Resources Canada at 1:50,000 scale.
Hillshade imagery obtained from the Yukon Department of Environment, Information Management & Technology Department.
Orthophoto produced from 1:40,000 aerial photography (Aug. 9, 2003)
Local study area delineated by AECOM Canada Ltd.

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Kilometers
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Yukon Albers

Legend

Existing Features
- Community
- Road

Elevation Contours
- Contour interval (100m)

Boundaries
- Project Footprint
- Local Study Area

Hydrological Features
- Watercourse
- Waterbody

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

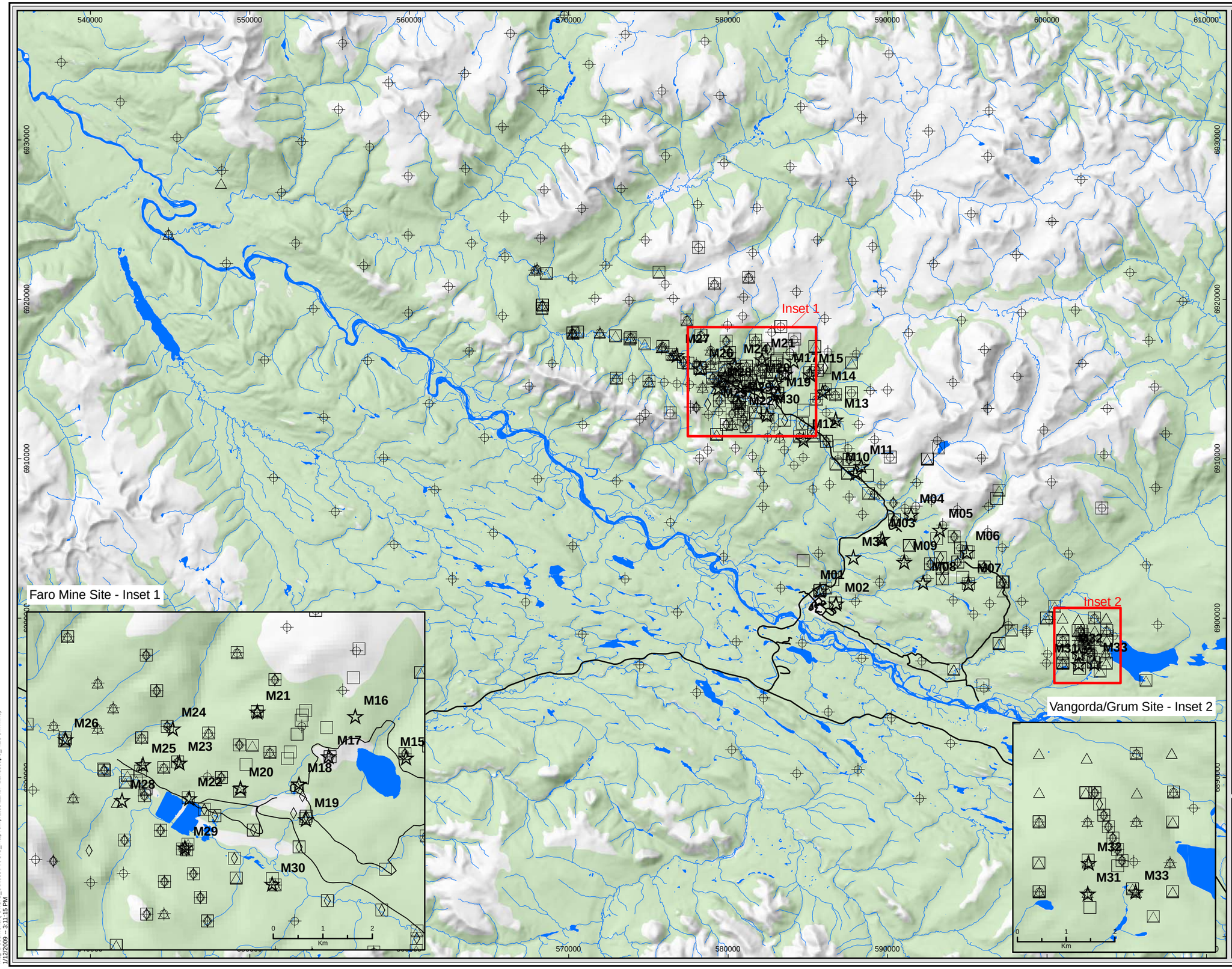
Local Study Area and Project Footprint

March, 2009

AECOM

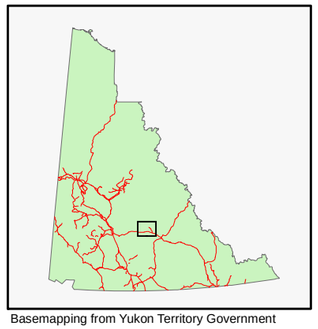
Figure 5.1-2

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Vegetation\107403_C1_Fig_5.1-2_LSAProjectFootprint_01Apr09.mxd Prepared by: CA Project: 107403 (80642-1)
Date Revised: April 2, 2009



Legend

- 2002, 2004, & 2005 Lichen Sample Locations
- 2004 & 2005 Soil Sample Sites
- Moss Bag Sampling Sites
- 2004 & 2005Vegetation Including: Berries, Labrador Tea, Willows, Forbs, Grasses, Horsetails, Mushrooms, Bear Roots, Tree Sap
- 2002 Vegetation Including: Background, Potential Mine-Affected, Tailings Transects, and Reference Sampling Points
- Roads



Basemapping from Yukon Territory Government

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Kilometers
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UTM Zone 8N, NAD 83

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Faro Mine Complex
Closure and Reclamation Project

Elements in Vegetation and Soil Studies, Sampling Locations, 2002, 2004, and 2005

April 2009
Project 107403 - 80649

AECOM

Figure 5.1-3

Map Document: (O:\GIS_Utilities\ArcGIS_MapTemplates\11x17-Landscape_AECOM.mxd)
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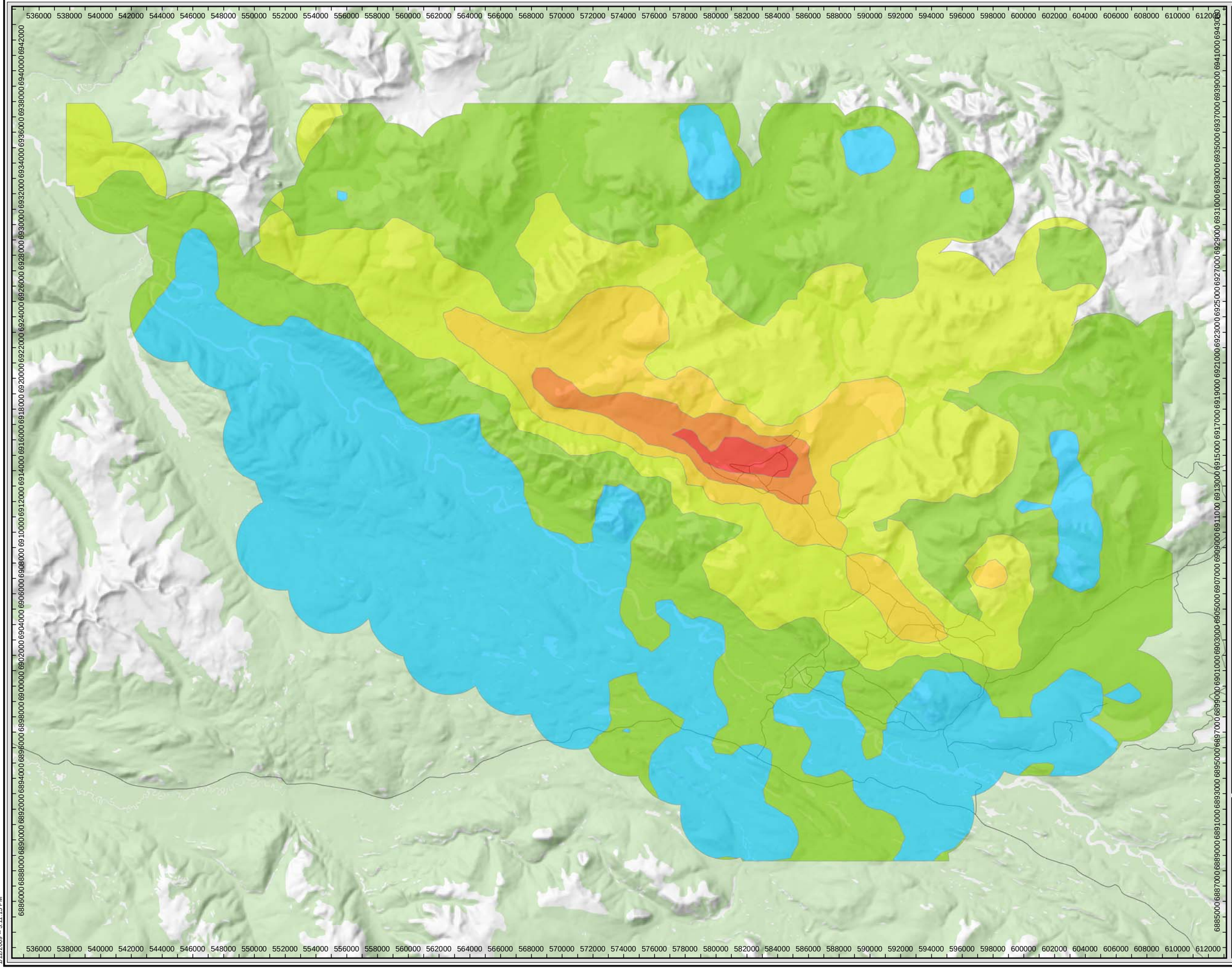

Basemapping from Ontario Ministry of Natural Resources
Orthophotography:

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Kilometers
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UTM Zone 8N, NAD 83

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Environmental Assessment of
the Closure and Remediation Plan
for the Faro Mine Complex

Standard Geostatistical Kriging of Lead in Lichen

April 2009
Project 107403 - 80649

AECOM

Figure5.1-4

Map Document: (O:\GIS_Utilities\ArcGIS_MapTemplates\11x17-Landscape_AECOM.mxd)
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Table 5.1-1. Faro Mine Closure Project LSA Vegetation Associations Baseline Area

Vegetation Association	LSA Map Code	LSA Baseline Area	
		Area (ha)	% of LSA
Sedge/Willow	S/W	54.6	0.7
Willow/Sedge	W/S	254.7	3.1
Willow/White Spruce	W/Sw	326.0	4.0
Willow/Dwarf Birch	W/B	182.2	2.2
Dwarf Birch/Willow	B/W	232.2	2.9
Dwarf Birch/Lichen/Subalpine Fir	B/L/Fa	357.8	4.4
Dwarf Birch/Subalpine Fir	B/Fa	279.9	3.4
White Spruce/Willow	Sw/W	3657.4	45.0
White Spruce/Feathermoss	Sw/Fm	105.1	1.3
Pine	Pl	52.4	0.6
Mixed Coniferous-Deciduous	Mx	682.0	8.4
Deciduous	Dd	276.6	3.4
Graminoid	Gr	49.3	0.6
Project Footprint	PF	1612.7	19.9
LSA Total Area		**8122.8**	**100.0**

Table 5.1-2. General Status Rankings for Vascular Plants

General Status Categories*	
At Risk	Species for which a formal detailed risk assessment (COSEWIC assessment or territorial equivalent) had been completed and that have been determined to be at risk of extirpation or extinction (i.e., endangered or threatened).
May be at Risk	Species that may be at risk of extinction or extirpation, and are therefore candidates for detailed risk assessment. These species are ranked with the highest priority for COSEWIC or jurisdictional consideration.
Sensitive	Species which are not at risk of extinction or extirpation but may require special attention or protection to prevent them from becoming at risk. These species are ranked with a medium priority for further consideration.
Secure	Species which are not at risk or sensitive. These species have the lowest priority for further consideration.
Undetermined	Species for which insufficient information, knowledge, or data is available to reliably evaluate their general status.
Not Assessed	Species which are known or believed to be present, but which have not been examined.
Exotic	Species that have been moved beyond their natural range as a result of human activity.
Accidental	Species occurring infrequently and unpredictably, outside their usual range.

** Canadian Endangered Species Conservation Council (CESCC) 2006. Wild Species 2005: The General Status of Species in Canada.*

Table 5.1-3. NatureServe Yukon's Status Ranks for Rare Species

Status Categories *	
S1	5 or fewer occurrences or only a few remaining individuals
S2	6-20 occurrences or with many individuals in fewer occurrences
S3	21-100 occurrences may be rare and local throughout its range, or in a restricted range (may be abundant in some locations or may be vulnerable to extirpation because of some factor of its biology)
S4	Apparently secure under present conditions, typically > 100 occurrences but may be fewer with many large populations; may be rare in parts of its range, especially peripherally
S5	Demonstrably secure under present conditions, > 100 occurrences but may be rare in parts of its range, especially peripherally.
SU	Status uncertain often because of low search effort or cryptic nature of the element; possibly in peril, unrankable, more information needed.

** Yukon Department of the Environment, Fish and Wildlife Branch 2005. Yukon NatureServe.*

Table 5.1-4. Introduced Plant Species Observed in the Faro Mine Complex Area

Scientific Name	Common Name	Introduced Species Invasiveness Rank *
Crepis tectorum	annual hawk's-beard	highly invasive - may displace or replace native ecosystems
Taraxacum officinale	common dandelion	aggressive - widespread, persistent, but may not replace native species or change ecosystem function
Thlaspi arvense	stinkweed	taxa present in the territory but not known to be invasive here - but have been found to be invasive in other jurisdictions
Agrostis scabra	hair bentgrass	taxa present in the territory but not known to be invasive here - but have been found to be invasive in other jurisdictions
Polypogon species	beard grass species	taxa present in the territory but not known to be invasive here - but have been found to be invasive in other jurisdictions
Potentilla biennis	biennial cinquefoil	species that likely don't persist
Festuca rubra	red fescue	native and introduced populations exist
Poa pratensis	Kentucky bluegrass	native and introduced populations exist

* *Introduced Plants of the Yukon - Source Cody, 1996 (Cody et al 1998, 2000 – 2005), revised by B.A. Bennett December 2008 - this is a tentative list for review purpose only*

5.2 Wildlife

5.2.1 Introduction

The diversity, distribution and migration patterns of wildlife play an important role in ecosystem function in the Yukon. Wildlife abundance and distribution on the land are influenced by habitat patterns, climate, forage, terrain, and predator-prey relationships.

The objectives of the wildlife baseline assessment for the Project Proposal for the Faro Mine Complex (the Project) are to identify the current baseline condition of wildlife. In particular, those conditions include population, distribution, abundance, migration patterns (at a local scale), and baseline contaminants presence (contaminants presence in wildlife from the Faro Mine Complex has been documented in detail by Gartner Lee Limited in 2006).

5.2.1.1 Regional Setting

The Faro Mine Complex is located within the Yukon Plateau-North Ecoregion, in the Boreal Cordillera Ecozone of the Yukon (Environment Canada 2005). Vegetation is predominantly white spruce (*Picea glauca*) with willow (*Salix* spp.), dwarf birch (*Betula glandulosa*), ericaceous shrubs, and occasionally, lodgepole pine (*Pinus contorta*). Characteristic wildlife includes woodland caribou (*Rangifer tarandus caribou*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), thinhorn sheep (*Ovis dalli*), moose (*Alces alces*), beaver (*Castor canadensis*), red fox (*Vulpes vulpes*), wolf (*Canis lupus*), snowshoe hare (*Lepus americanus*), common raven (*Corvus corax*), rock and willow ptarmigan (*Lagopus muta* and *L. lagopus, respectively*), and golden eagle (*Aquila chrysaetos*). Many wildlife species are important in the area for both economic and socio-economic reasons. Major communities in the area include Faro, Keno Hill, Mayo, and Ross River (Section 3 Project Location and Current Site Conditions in the Project Proposal; Environment Canada 2005).

5.2.2 Valued Ecosystem Components

Valued Ecosystem Components (VECs) can be defined as environmental attributes or components that are perceived as important for ecological, social, cultural, and/or economic reasons. The intent of selecting VECs is to focus the baseline programs on those species or species groups that are most closely associated with the issues identified by communities, First Nations, and/or regulators. First Nation and Community consultation activities are described in detail in Section 2 First Nation and Community Consultation in the Project Proposal. Several species of mammals, birds, and amphibians may occur in the vicinity of the Faro Mine Complex on a year-round or seasonal basis. Preliminary VECs were selected by incorporating information from numerous sources and considering a number of criteria, including:

- the legal status of the species at the Federal and Territorial levels;
- known presence and relative abundance within the study area;
- socio-economic value (hunting, trapping, wildlife viewing, public profile) and regional importance (regional conservation concerns);
- concerns of First Nations, local communities, and regulators;
- the professional judgment of project scientists;

- VECs chosen for previous environmental assessments and current wildlife monitoring programs in the region;
- vulnerability to potential project effects; and
- the role as an indicator species for a specific wildlife group.

The following is a list of VECs considered representative of important wildlife species:

- Fannin sheep (thinhorn sheep colour variant);
- Grizzly bear;
- Moose;
- Woodland caribou;
- Furbearers;
- Small mammals; and
- Migratory birds.

Among the VECs identified, moose, furbearers and Fannin sheep were considered especially important for their economic and cultural values, and subsistence harvest uses.

5.2.3 Study Area

5.2.3.1 Local Study Area (LSA)

The Local Study Area (LSA) captures direct effects on wildlife from the project activities in project impact assessment and is particularly concerned with habitat availability.. The LSA used in this baseline description varies by VEC.

For furbearers, small mammals, and birds, the vegetation LSA will be used. This area is illustrated in Figure 5.2-1 of the Project Proposal. This LSA is limited to the immediate project footprint and surrounding areas (i.e., within a 1 km radius surrounding the Faro Mine Complex. This area totals 81.2 km^2, of which 16.1 km^2 is made up of the footprint of the current mine infrastructure and roads.

For wide-ranging species, a larger LSA applies and corresponds to Game Management Subzones (GMS), which are legal boundaries that define an area by game management objectives established by Yukon Environment. The following list describes the LSA for each wide-ranging VEC:

- Moose: GMS 4-42 to 4-47, 4-51
- Thinhorn sheep: GMS 4-43 to 4-47, 4-51
- Grizzly bear: GMS 4-44 to 4-47, 4-42, 4-51

The LSA for the contaminant study is similar to the ones used for wide-ranging species (GMS 4-42 to 4-46) because particulate matter will be released into the atmosphere during closure activities and may have far-reaching effects.

5.2.4 Regional Study Area (RSA)

It was necessary to include regional data where feasible and appropriate, primarily to provide a context for local scale data. In some cases, there were no data available that were specific to the local area, and regional scale data were used to form conclusions regarding local conditions.

5.2.5 Wildlife Baseline Conditions

5.2.5.1 Data Collection Methods

There were no project-specific wildlife field studies conducted specifically for this baseline assessment. Data collection methods included: incidental sightings of wildlife during a vegetation classification survey conducted in August of 2007 and the use of existing data sources. Those existing data sources include published literature, government reports, reports from previous studies and Environmental Impact Assessments (EIAs), and available Community and Traditional Knowledge reports.

5.2.6 Baseline Conditions

5.2.6.1 Woodland Caribou

Overview

Both barren-ground and woodland caribou are found within the Yukon. In the vicinity of the Faro Mine Complex, caribou belong to the Northern mountain population of woodland caribou (*Rangifer tarandus caribou*). The Northern Mountain woodland caribou populations are listed as Sensitive in the Yukon (Canadian Endangered Species Conservation Council, 2006), and federally designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007); additionally they are listed as Special Concern on Schedule 1 of the *Species at Risk Act (SARA)*. The caribou in the vicinity of the Faro Mine Complex are likely from the Tay River caribou herd, of the Northern Mountain population. There are three other populations within the Region including the Finlayson herd located southeast of the Study area, the Pelly herd located south of the Study Area and the Moose Lake herd located west of the Study Area.

The Government of Yukon Department of Renewable Resources has formed a Caribou Management Team to develop interim caribou management guidelines for the Yukon. The guidelines outline management principles, concepts and assumptions regarding woodland caribou (Department of Renewable Resources, Government of Yukon 1996a). Commitment to caribou populations within the Faro region is demonstrated in the "Integrated Wildlife Management Plan - Ross River Traditional Territory" (Kaska Dena Traditional Territory, 1997). However, the management plan focuses on the management of the Finlayson caribou herd population rather than the Tay River herd, therefore demonstrating a concern for caribou but not one specific to the Tay River herd. The management plan also presents other caribou concerns, including harvesting of parturient wildlife and meat wastage caused by late rut harvesting, untrained hunters, or poor ammunition choice.

Population

The total number of woodland caribou in the Yukon is estimated between 30,000 and 35,000 (Department of Renewable Resources, Government of Yukon 1996a). These caribou are found within one of 23 recognized herds in Yukon, whose populations range in size from about 100 to 10,000 (Department of Renewable Resources, Government of Yukon 1996a). Woodland caribou in the Yukon occur at densities well below habitat carrying capacity and are held there by predation and human harvest (Department of Renewable Resources, Government of Yukon 1997a).

The population of the Tay River herd was last estimated to be 3,758 +/- 571 animals, based on a 1991 survey conducted by the Government of Yukon Department of Renewable Resources (1997a). This equates to approximately 0.15 caribou per square kilometre, although densities are likely much higher on winter ranges where caribou may congregate. An attempt to resurvey the area in 2003 was hampered by poor weather conditions, and no recent estimate is available (J. McLelland, pers. comm. 2007).

Within the LSA for this Project, only a handful of caribou are likely found at any time of the year, although the wintering distribution of caribou may result in concentrations of wintering caribou occurring close to the site.

Movements and Distribution

The range of the Tay River herd is approximately 25,000 km^2, covering the area north of the Pelly River, west of North Canol Road and south of the upper Stewart River (Figure 5.2-1; Department of Renewable Resources, Government of Yukon 1997a). The majority of caribou in the Tay River herd are found along the Tay and South Macmillan rivers (Department of Renewable Resources, Government of Yukon 1997a).

Tay River caribou move between winter ranges, and generally non-distinct calving, post-calving, and summer ranges over the course of the year. Cows in the Tay River herd calve and spend the post-calving period over an extensive area (Department of Renewable Resources, Government of Yukon 1997a). Surveys conducted twice a year from 1989 to 1991 found all calving locations for the herd to be located south of the upper Stewart River and north of the Pelly River. No calving locations fell within the LSA for the project; the closest recorded calving locations were within 50 km of the Project. The Tay River herd's summer and rutting distribution largely defines the outer boundaries of the herd range, and encompasses the Project LSA.

The winter range for the Tay River herd tends to be in the snow shadow region between mountain ranges where forage is more accessible. Winter distribution is generally characterized by a northward movement out of mountainous areas towards the forested drainages north of the LSA. The herd's winter range does not encompass the LSA, however the southwest toe of the winter range falls within close proximity to the Project. During the winter of 1991, a census found a concentration of caribou within 10 km of Faro town site, indicating a potential for wintering caribou to occur within the LSA.

Harvest

The harvest of caribou from the Tay River herd is relatively low, and is assumed to be limited by access in the fall hunting season. Over the past 16 years, the harvest ranged from 21 to 52 animals annually (Figure 5.2-2), with a mean annual harvest of 35.4 (Department of Renewable Resources, Government of Yukon 1997a; excluding subsistence harvest). This annual harvest is approximately one percent of the population, and is considered sustainable (i.e., <3% of adults, Department of Renewable Resources, Government of Yukon 1996a). Harvest of caribou in fall is typically via spur roads from the North Canol Road, and fly-in hunts based out of Ross River or Faro. Access to the winter range is minimal, and as such First Nation's harvest in winter is assumed to be quite low (Department of Renewable Resources, Government of Yukon 1997a). While harvest of caribou in the LSA is likely very low, it is a highly accessible area, therefore creating potential for harvest.

Habitat Use and Diet

During calving surveys conducted from 1989 to 1996 cows tended to be solitary (Department of Renewable Resources, Government of Yukon 1997a) and most often found in alpine habitats. These same alpine habitats were generally selected during the post-calving season. During the rut, caribou were found in many of the same areas chosen during the summer months, but with a wider distribution. In winter, caribou tended to move out of the alpine and mountainous areas and into drainages north of Faro. Collared caribou from the Tay River herd were found to be more confined to valley bottoms in late winter than compared with early winter (Department of Renewable Resources, Government of Yukon 1997a).

Spring and summer diets of caribou are generally varied, with use of sedges, forbs, grasses, mushrooms, and most nutrient-rich young shoots of willows, birch, or horsetails (Banfield 1974). Winter food for woodland caribou consists primarily of lichen, and most Yukon herds have about 70% lichen in the diet (Department of Renewable Resources, Government of Yukon 1997a). To date no specific data are available on the diet of caribou in the Tay River herd, however it is likely to be similar to that identified by Banfield (1974).

Summary

The Tay River caribou herd is relatively small and widely dispersed, but appears generally stable in population levels given the current harvest pressure. The Department of Renewable Resources, Government of Yukon (1997a) identified the conservation of the winter range as crucial to the long-term survival of the herd.

5.2.6.2 Moose

Overview

Moose are the largest and one of the most widespread mammals in the Yukon. Currently, moose are listed as Secure in the Yukon (Yukon Wildlife Act 2007), and federally they are listed Not At Risk (COSEWIC 2007; CE SCC, 2006). Moose have high socio-economic value in the Yukon as a game and subsistence species.

The Government of Yukon Department of Renewable Resources has developed interim moose management guidelines for the Yukon (Department of Renewable Resources, Government of Yukon 1996b). The guidelines focus on the protection of key habitats by establishing protected areas through the development and implementation of land use guidelines. The 1996 management plan committed to regular population and composition surveys. The plan also highlights concerns related to over-hunting in high priority areas. The moose populations in the LSA and RSA are considered a high management priority (R. Ward, pers. comm. 2007) although no Key Wildlife Areas have been designated within the Faro area.

Population

Moose populations in the Yukon are managed among Game Management Subzones (GMS), and moose in the Faro area generally occur within GMS 4-42 to 4-46 (Figure 5.2-3). Compared to other regions in the Yukon, moose in the Faro area occur at very high densities; approximately 405 moose per 1,000 km^2 (Department of Environment, Government of Yukon 2004). Earlier surveys conducted in 1997 and 1998 were limited to a portion of the region and documented extremely high densities of moose (Department of Renewable Resources, Government of Yukon 1997b, 1998). The 1997 survey documented the highest moose density in the Yukon; 586 moose/1,000 km^2, although the survey area was smaller than that of the 2004 survey. While the actual population of moose in the LSA is unknown (and may fluctuate during among years), regional data indicates that relative to other parts of the Yukon, high densities of moose are consistently present in LSA.

Movements and Distribution

Although moose may use different habitats among seasons, there are no distinct seasonal ranges for moose in GMS 4-42 to 4-46 (R. Ward, pers. comm. 2007). A satellite-telemetry study done in GMS 4-42 to 4-46 (Ward 2003a) found home range among the moose collared spanned from 64 km^2 to 274 km^2, with no obvious relationship between moose sex and home range size. Home range sizes and daily movement distances tended to be greater in the spring/summer period than in the winter period. Moose that summer in the sub-alpine tended to migrate a longer distance in comparison to moose that summer in the lowlands (Ward 2003b).

Harvest

The average annual reported harvest in GMS 4-42 to 4-46 is approximately 2% of the estimated moose population within the region. The sustainable range of harvest for moose populations in the Yukon is 3-4% (Government of Yukon Department of Renewable Resources 1996b), and overall harvest throughout the region is estimated to be within sustainable limits. From 1979 to 2006, total harvest (excluding subsistence First Nations harvest and unreported illegal kills and harvest) has averaged 34 moose per year, ranging from ten 61 animals (Data provided by Government of Yukon Department of Environment (unpublished data, 2002; Table 5.2-1 below).

However, due to access, harvest in the subzones north and west of the Project is at or above 5% of the estimated moose population, which is above the recommended maximum allowable rate (Department of Environment, Government of Yukon 2004). This is primarily within GMS 4-45, which is both an important

rutting and post-rutting area for moose, and an important hunting area for Faro residents (Department of Environment, Government of Yukon 2004). There is concern that if this trend continues and becomes more widespread, the local moose populations may be at risk of declining (Department of Environment, Government of Yukon 2004).

Moose are harvested by resident and non-resident (guided) hunters alike. Local inhabitants of the Town of Faro have expressed concern regarding the amount of non-resident hunting in the area. The average number of moose taken annually by non-residents (of the Yukon) in the Faro area averages approximately 25% of the total harvest (ranging from 3% to 52%, excluding First Nations; Figure 5.2-4).

Habitat Use and Diet

Satellite-telemetry data from 2002 and 2003 indicated that during the spring and early summer, moose spend the much of their time in the lowland areas (Ward 2003b). As summer progressed, moose generally moved from lowlands to sub-alpine habitats, although some remained in lowland areas year round (Ward 2003b). During the rut, moose concentrated in sub-alpine habitats. In the Faro area moose were observed in the sub-alpine plateau north of the Faro town site (2004 rut and post-rut survey; Department of Environment, Government of Yukon 2004). As winter commenced, moose in the Faro area moved into adjacent lowlands and/or concentrated in sub-alpine/willow and older post-burn habitats (Ward 2003b).

Terrain within the LSA tends to be primarily sub-alpine mid slope with lowland and high shrub cover areas riparian areas near most drainages and rivers. Seasonally, moose would most likely be found within the low-lying areas in the spring, and in lowland and sub-alpine areas in summer. However, evidence of moose browse and pellets were observed in all habitat types near the mine site however, and animals were observed on two occasions (in summer) in riparian lowland habitats during a vegetation classification survey conducted in August 2007.

Summary

Government, First Nations, and stakeholders consider moose populations in the area near Faro a high priority to manage and conserve. Moose densities are relatively high in the area, as is harvest pressure in some parts of the range. Thus far, the Government has closely regulated and monitored populations that encompass the LSA.

5.2.6.3 Thinhorn Sheep

Overview

Thinhorn sheep in the Yukon include two recognized subspecies; Dall sheep (*Ovis dalli dalli*), which are white in colour, and the generally darker Stone sheep (*Ovis dalli stonei*). In the Pelly Mountains and Ogilvie Mountains of the Yukon, fannin sheep occur, which are a colour variant of thinhorn sheep and are somewhat intermediate between Dall and Stone sheep in appearance. The genetic and evolutionary distinctions and subspecies designations among Dall, Stone, and fannin sheep are currently in question (Loehr *et al.* 2005, Worley *et al.* 2004), but locally in the LSA only fannin sheep are present, and are characterized by their saddle-shaped colourations. Fannin sheep in the LSA generally occur on Sheep Mountain, Rose Mountain,

and Mount Mye, although presence varies by season, as discussed below. Currently, thinhorn sheep are recognized as Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006), and federally they are listed Not At Risk (COSEWIC 2007). However, fannin sheep have high socio-economic value in the Yukon as a game and subsistence species, and for their non-consumptive value (wildlife viewing) shown in the sheep and sandhill crane (*Grus canadensis*) viewing festival currently supported by the Town of Faro.

The Government of Yukon Department of Renewable Resources developed sheep management guidelines for the Yukon in 1996 (1996c), and prepared a Management Plan Proposal for the Sheep Mountain population in 1988 (Department of Renewable Resources, Government of Yukon 1988). The primary objective of the management guidelines is the "conservation of sheep populations and their habitat within the framework of ecosystem biodiversity" (Department of Renewable Resources, Government of Yukon 1996c). Locally, interest in Fannin sheep has grown, and is demonstrated by the development of infrastructure and interpretative trails that support wildlife viewing near the Town of Faro. Managers have also focused efforts to reduce disturbance on wintering sheep, by declining woodcutting applications and barricading areas to deter snowmobile access.

Population Status

There are approximately 22,000 thinhorn sheep in the Yukon, with densities ranging from less than 2 sheep/100 km^2 to more than 30 sheep/100 km^2 (Department of Renewable Resources, Government of Yukon 1996c). The sheep are believed to be at, or near, historic population levels, and have recolonized some ranges where they had previously disappeared (Department of Renewable Resources, Government of Yukon 1996c). Of the Yukon thinhorn sheep population, about 2,500 are Fannin sheep (Department of Renewable Resources, Government of Yukon 1996c). Sheep population abundance is particularly affected by winter weather, and snow conditions affect both birth rate and lamb survival (Department of Renewable Resources, Government of Yukon 1996c).

Sheep have been studied near Faro since the mid-1970s. Estimates of the number of sheep utilising Sheep Mountain, Mount Mye and Rose Mountain (see Figure 5.2-5 for mountain locations) have been made through a combination of aerial surveys (Montreal Engineering Company Ltd. 1976; McLeod 1981; Department of Renewable Resources unpublished survey data (1980, 1987, 2002); Hoeffs 1988, 1990; Horejsi 1988; Department of Renewable Resources, Government of Yukon 2002) and field observations (detailed in Schweinsburg 1990). The number of sheep counted within each survey area has varied depending on factors such as season, technique, intensity, and survey conditions, and as a result, it is difficult to extrapolate demographic trends from those data sources.

The only recent estimate of sheep abundance in and near the LSA took place in 2002 (Department of Environment, Government of Yukon 2002), and included surveys of GMS 4-41, 4-43, and 4-44. In GMS 4-41 (largely to the northwest and beyond the LSA), 183 sheep were observed, including 94 nursery sheep (assumed to be ewes), 31 lambs, and 58 rams. While difficult to compare directly, the 2002 survey indicated that since 1981, the number of nursery sheep in GMS 4-41 increased from 44 to 94 (an annual increase near 3.5%), which was attributed in part to animal movements at the time of surveys (Department of Environment, Government of Yukon 2002). In portions of GMS 4-43 and 4-44 combined (i.e., Rose Mountain area, also

largely to the west and beyond the LSA), 73 sheep were observed (45 nursery sheep, 17 lambs, and 11 rams). Populations were considered stable in 4-43 and 4-44 due to similarities to a 1991 survey (71 sheep counted), and, in 2002 all GMS, populations were not thought to be over harvested.

It is believed that the sheep population using the ranges on Sheep Mountain and on Mount Mye (within GMS 4-51 and 4-46, respectively) remained relatively stable in the 1980s (Schweinsburg 1990) at between 60 and 80 individuals (Department of Renewable Resources, Government of Yukon 1987, 1988). Observed recruitment levels in the late 1980s (indicated by proportion of lambs/yearling in the population) were considered to be indicative of a growing population (Schweinsburg 1990), but given the variations in range use, it is difficult to be certain that sheep counts conducted over the years on Mount Mye and/or Sheep Mountain are representative of one sheep population. Prior to the work of Schweinsburg (1990) it was thought that one population of sheep wintered on Sheep Mountain and summered on Mount Mye. However, it appears that sheep that winter on Sheep Mountain can be found on either Sheep Mountain, Mount Mye or on the mine site (Vangorda) during summer as well as potentially in other areas, such as Rose Mountain (Schweinsburg 1990). There also appears to be some sheep that are independent of the Mount Mye/Sheep Mountain group that summer in areas around Blind and Swim lakes (approximately 15 km to the southeast of the Vangorda pit) and winter on windswept slopes near to their summer range (Schweinsburg 1990).

Movements and Distribution

Thinhorn sheep in the LSA occupy relatively distinct seasonal ranges during the early winter and rut, mid to late winter, lambing, and summer, and several identified migratory routes have been documented that link these areas in the LSA. Most migratory routes and winter, early winter and rut, and spring lambing ranges have been identified as Key Wildlife Areas by the Fish and Wildlife Branch of the Department of Environment.

Spatial information accumulated from published reports and unpublished observation records over 18 years, provided by the Yukon Territorial Government, were digitized to show movement and seasonal use of Thinhorn Sheep in the Faro Area in Gartner Lee Limited (2008b). A total of 1427 sheep observations have been recorded (327 Rams, 765 Ewes, 199 Lambs, 26 yearlings and 110 of unknown gender or age) using mostly aerial and some ground surveys. Observations were recorded during all seasons (spring, fall, summer and winter). Spring observations ranged from May 11 to June 26 with observations recorded in 1981 and 1997. The majority of observational data was summer observations from 11 years of records (Gartner Lee Limited 2008b). Summer counts ranged from July 11 to August 25. The only fall data available was from 1987 and ranged from September 16 to October 10. Winter data was available from October 20 to March 12 in 1980 and 1987, respectively.

A total of 118 telemetry locations were obtained from 9 collared ewes was also used to document movement. Age class of these individuals ranged from 4.5 to 12 years of age with telemetry data ranging from November 1989 to May 1990. Telemetry data was obtained during winter to spring season for four ewes (Figure 5.2-6 to Figure 5.2-9). Again the majority of the movement of these collared ewes showed use of southern slopes of Sheep Mountain and clumped distribution in spring.

Seasonal Ranges

- ***Winter Range***

  Winter habitat use patterns have been determined from: inferences based on habitat characteristics and local knowledge (Montreal Engineering Company Ltd. 1976); aerial counts of sheep during winter (Department of Renewable Resources, Government of Yukon 1980, 1987); inferences based on the interpretation of field sign and observations made by field worker and locals (McLeod 1981), radio tracking (nine ewes were radio tracked between 1989 and 1990), and visual observations of sheep and interviews with locals (Schweinsburg 1990).

  The southern slopes of Sheep Mountain have been identified as an area of sheep winter range (Figure 5.2-5; Montreal Engineering Company Ltd. 1976; Department of Renewable Resources, Government of Yukon 1980; McLeod 1981; Department of Renewable Resources, Government of Yukon 1987; Schweinsburg 1990). Telemetry locations and field observations indicate that nursery sheep (ewes, lambs and yearlings) spent early winter on the upper slopes of Sheep Mountain while rams spent this time on the western edge of Sheep Mountain. Of the nine ewes collared with a radio-telemetry device, only one had data solely from winter season (Figures 5.2-6 to 5.2-9). This individual's distribution over the winter months was relatively clumped and occurred on the southern slopes of Sheep Mountain. The sheep distribution and movement patterns digitized and mapped, from telemetry and observational data, further support the importance of Sheep Mountain during winter and spring season.

  Other wintering areas are located on Faro Peak and bluffs to the northwest of Sheep Mountain. The southern slopes of Mount Mye have also been designated as winter range, and are the closest wintering areas to the project, within 1 km of the Grum pit. Additional wintering areas include: the windswept slopes near Blind and Swim Lakes (Schweinsburg 1990), Pelly River Bluff, 2.5 km east of Faro (Schweinsburg 1990), Rose Mountain (GMS 4-43 and 4-44), and potentially areas northeast of Faro on Vangorda Creek (McLeod 1981; Schweinsburg 1990).

- ***Lambing Range***

  The location of lambing areas was determined from aerial surveys; inferences based on the interpretation of field sign and observations made by field worker and locals (McLeod 1981), radio tracking (nine ewes were radio tracked between 1989 and 1990), visual observations of sheep and interviews with locals (Schweinsburg 1990).

  Initial studies indicated that lambing areas on Sheep Mountain were found down slope of the early winter range (Montreal Engineering Company 1976). Schweinsburg (1990) later argued that ewes move from the lower slopes of Sheep Mountain in late winter, to lamb at higher elevations. There is also some indication that ewes may lamb on Mount Mye (Schweinsburg 1990). Telemetry and observational data digitized and mapped provide further evidence that the lower slopes of Sheep Mountain are used in winter and early spring whereas during late spring sheep are found at higher elevations during lambing season. Four sheep were tracked during spring season (Figure 4 to Figure 7 in Gartner Lee Limited 2008b). All these individuals were found using the southern slopes of Sheep Mountain during early spring. Two of these ewes were tracked moving to the western portion of Sheep Mountain and moving slightly higher elevations on Sheep Mountain during lambing season (Figure 4 and Figure 6 in

Gartner Lee Limited 2008b).There is also some indication that ewes may lamb on Mount Mye as a few observational data mapped show the use of this mountain during spring season (Schweinsburg 1990).

- ***Summer Range***
  Summer distribution of sheep has also been described based on aerial surveys, radio tracking, and visual observations of sheep (Schweinsburg 1990). Sheep were generally dispersed more widely over their summer range than the winter range. A large area has been identified as summer range and includes Mount Mye (Montreal Engineering Company Ltd. 1976, McLeod 1981, Hoeffs 1988, Hoeffs 1988, Schweinsburg 1990), Rose Mountain (McLeod 1981), Blind Creek and Swim Lakes area (Schweinsburg 1990), Sheep Mountain and the Anvil Mine Complex (Schweinsburg 1990). The summer range is not identified as a Wildlife Key Area, perhaps because of the more general and wider distribution of sheep.

- ***Early Winter and Rutting***
  Location of rutting areas was determined from visual field observations (Schweinsburg 1990). Rams were observed rutting on Sheep Mountain (Schweinsburg 1990) presumably during fall/early winter. Other rutting areas may be possible, as less study and observations have taken place during the rut, and given the relatively wide distribution of sheep in summer and the documented winter ranges, rutting is very likely not limited to Sheep Mountain.

Migratory/Movement Routes and Timing

Twice a year Fannin sheep migrate through the infrastructure of the Vangorda/Grum area of the Faro Mine Complex. Spring migration occurs between mid-May and late June, when Sheep migrate from their winter ranges to summering areas, often on Mount Mye (McLeod 1981; Schweinsburg, 1990). Fall migration takes place in mid-September to mid-October, when sheep move from summer range to early winter and rutting areas on Sheep Mountain. Nursery herds tend to migrate earlier than rams (Schweinsburg 1990). Sheep in the LSA have tended to show some resilience to disturbance and continue to re-use migratory routes (such as migrations through Vangorda mine area), despite ongoing anthropogenic disturbances.

Several migration routes have been documented by studies in the area. Three such routes are documented that navigate terrain between Mount Mye and Sheep Mountain through the LSA that are used in both spring and fall (Figure 5.2-5). They include:

- The main migration route (termed Route E in McLeod (1981)) between Mount Mye and Sheep Mountain for spring and fall migration goes from Sheep Mountain to the confluence of Shrimp Lake and Vangorda Creek, crosses the haul road 1 km west of Vangorda Creek and then continues to the base of Mount Mye (Montreal Engineering Company Ltd. 1976; McLeod 1981; Horejsi 1988; Schweinsburg 1990). This route directly passes between the Vangorda and Grum deposits.

- A second route (Route F in McLeod (1981)) was also identified by Montreal Engineering Company Ltd. (1976), McLeod (1981), and Schweinsburg (1990). From Sheep Mountain, this route goes to the confluence of Shrimp Lake and Vangorda Creek, it then follows a cat road, crosses the airstrip to the site of the proposed Vangorda open pit and continues to Mount Mye via the west side of Vangorda Creek.

- A third route (Route D in McLeod (1981)) was also identified by McLeod (1981), Horejsi (1988), and Schweinsburg 1990). From Mount Mye, this route goes south from Mount Mye and crosses the haul road 1 km east of the Grum Camp. The route then follows down to the confluence of Shrimp Lake and Vangorda Creek to on to Sheep Mountain.

McLeod (1981) also identified one addition migration route (route A), which is southwest of the LSA and runs parallel to the Project, following west from Sheep Mountain along the ridge to Rose Mountain.

The observation data and telemetry data mapped do not yield sufficient detail to either refute or support these mapped movement corridors described above. Data recorded in a format less spatially-specific data may have be used to document these movement corridors, and indeed four observations are noted among the fall or spring seasons that do occur within a mapped movement corridor.

Harvest

Licensed harvest of sheep in the Yukon is relatively small at less than 2% of the total estimated population (Department of Renewable Resources, Government of Yukon 1996c). In the Game Management Subzones (GMS) 4-46 and 4-47, licensed hunting has been closed since 1982 (J. Carey, pers. comm. 2007). GMS 4-46 encompasses Mount Mye, and is the zone in which the most western part of the LSA occurs. Harvest in GMS 4-41 to 4-45 is open to licensed and regulated harvest; in these zones the average total harvest is 7.9 sheep/year (range 3-15) (see Figure 5.2-6), including harvest recorded in 4-46 (It is not clear as to whether these harvests are legal as the area has been closed since 1982). Although total population estimates are uncertain, the harvests are assumed to be sustainable at current levels, as the number of sheep taken is relatively stable (Department of Environment, Government of Yukon 2004) and indices of sheep abundance also indicate stable to possibly increasing populations (Department of Environment, Government of Yukon 2004).

Habitat Use and Diet

Sheep typically require windblown and grassy slopes as winter range; steep, secure areas where ewes can safely bear their lambs; steep rugged cliffs where they can escape from predators; and access to mineral licks in spring (Government of Yukon Department of Renewable Resources 1996c). Because such habitats are used on a seasonal basis, areas of movement between the ranges are also recognized as important movement corridors. Unfortunately, there has been no formal habitat mapping conducted on sheep habitat within the LSA or on Mount Mye, Rose Mountain, Blind Creek or Swim Lakes. Although Staniforth (1988) classified vegetation communities on Sheep Mountain, there is no comprehensive and consistent habitat map of the LSA available. Thus, the boundaries of seasonal ranges are possibly imprecise.

In general terms, both Mount Mye and Rose Mountain are composed of upland vegetation types within alpine, subalpine and boreal forest habitats, while Sheep Mountain is composed of upland and lowland (riparian) vegetation types, within the a primarily boreal forest habitat type. The area around the Faro Mine Complex itself (i.e., the LSA) is largely comprised of upland boreal habitat. Sheep Mountain and the western

slopes above Blind Creek were burned in 1969, as were the areas near and covering the Vangorda/Grum deposits at the eastern extent of the LSA.

Vegetation mapping was conducted at a scale of 1:20,000 using 27 sample plots within an area of 42.7 km^2 on Sheep Mountain (Staniforth 1998). Vegetation characteristics were noted, as was the presence of water, litter, coarse woody material, elevation, slope, aspect, topography, and drainage. Staniforth (1998) identified three habitat units significant to sheep during winter. It is likely that the communities could be extrapolated to other areas within the LSA:

- A Sage-Graminoid community that occurs on the open windswept south-facing slopes and is considered the most important to sheep, as it would be the most snow-free during winter;
- A Rose/Forb community found mainly at the edges of south-facing aspen (*Populus tremuloides*) groves, in low-lying gullies and high snow accumulation areas; and
- A Grass-Forb community that occurs at the edge of the aspen groves but on the more northerly aspects.

Rocky outcrops that provide escape terrain occur in association with all three of the important winter range communities outlined above. As these vegetation communities occurred in very small patches, they could consistently be differentiated and were grouped into one habitat type, termed Rock/Grass/Forb, by Staniforth (1998). This unit covered a total of 4.9 km^2 or 11% of the Sheep Mountain study area. The Sheep Mountain study area was located south of the Vangorda/Grum area.

In spring, sheep that winter on the southern slopes of Mount Mye are found on the lower slopes of Sheep Mountain to feed on sage (*Artemesia frigida*) and later on new herbaceous growth and aspen leaves (Schweinsburg 1990).

Summary

Fannin sheep are highly important to stakeholders as an economic resource within the region, and are the most-visible species that interact directly with the project. The population appears generally stable, given the current harvest regulations, and a reasonable understanding of seasonal ranges and movement patterns is available. In consideration of the implementation of the Project, it is expected that the potential direct impacts to migrating sheep will be scrutinized, and will necessitate detailed mitigation planning.

5.2.6.4 Grizzly Bears

Overview

Grizzly bears are found throughout the Yukon, and belong to the northwestern population of Canadian bears (Ross 2002). The northern interior grizzly population range encompasses northern British Columbia, most of the Yukon and into the southern Mackenzie District of Northwest Territories. The Government of Yukon Department of Renewable Resources developed interim management guidelines for grizzly bears in 1997 (1997c), and identified a primary principle of “the conservation of grizzly bears as an integral part of northern ecosystems and biodiversity”. Federally, grizzly bears are designated as Special Concern (COSEWIC 2007) due to habitat loss, low reproduction, and slow recovery rates. Under the *Species at Risk Act* grizzly bears

are not currently scheduled, although they were proposed for inclusion under Schedule 1 in 2004. Currently, grizzly bears are considered Sensitive in the Yukon (Canadian Endangered Species Conservation Council, 2006).

Population

To a large degree, the availability and quality of forages, in addition to mortality rates, influences reproductive rates and population densities of bears. Northern interior grizzly bears in the Yukon have the lowest recruitment rates of all terrestrial mammals, due to low reproduction rates and litter size, and high mortality (Department of Renewable Resources, Government of Yukon 1997c). The current territory-wide estimate of grizzly bears in the Yukon is 6,000 to 7,000 grizzly bears (Department of Renewable Resources, Government of Yukon 1997c). This is consistent with the 6,300 bears estimated by Banci (1991, in Ross 2002). Since 1991, the grizzly population in the Yukon is considered to have remained stable, with some local exceptions (Ross 2002).

The population of the LSA is arguably too small a scale to estimate abundance within, as the LSA (81 km^2), is much smaller than the average grizzly bear home range. It would not be uncommon to have up to a few bears occur on occasion in the LSA, but in general, few bears (if more than one) are expected to be present within the LSA at any one time. Seasonal changes in bear foraging may result in more or less bears in the area, such as during times when bears may pursue moose calves or sheep lambs.

Harvest

The harvest of grizzlies is regulated by the Yukon Hunting Regulations. Harvest data available from 1980 to 2001 (Department of Environment, Government of Yukon, unpublished data; Table 5.2-2) indicates that the average bear mortality in the GMS that encompass the LSA (4-44 to 4-46, 4-51) ranged from 0.34 to 0.83 bears/year (more current data was not available from the Yukon Territorial Government at the time of report preparation). Within GMS 4-51, in which the Vangorda/Grum deposits are located, all mortalities (10 bears between 1990 and 2001) were due to problem kills rather than hunting. Most other GMS had predominately hunting related mortalities (Table 5.2-2). According to the Yukon Grizzly Bear Management Guidelines (Department of Renwable Resources, Governement of Yukon,1997c), females are being harvested in many areas at, or above sustainable levels while fewer than the allowable males are taken. In GMS 4-44 to 4-46, 4-51, the overall male to female harvest ratio is approximately 2:1, although more female bears were taken than in males in GMS 4-45. As population estimates are unknown in the region, is difficult to comment on whether the harvest is sustainable, but the area-based mortality measure of 6.31 bears/year/1,000 km^2 in GMS 4-51 is exceedingly high in comparison to neighbouring GMS.

Movements and Distribution

Grizzly bears are known to utilize large home ranges averaging over 1682 km^2 for males and 491 km^2 for females (Department of Renewable Resources, Government of Yukon 1997c). The LSA (81 km^2) would comprise only 16% of a female home range, and less than 5% of a male bear's home range.

Habitat associations of grizzly bears generally reflect local plant phenology and are strongly seasonal. In a mountainous region like Faro this may result in elevational movements in response to seasonal changes in vegetation (LeFranc *et al.* 1987). Bears may den at relatively high-elevations and in spring descend to valley bottoms to forage on young plants, previous-year berry crops, and pursue ungulates or ungulate carcasses. Then, as snowmelt proceeds, they may ascend upslope to follow the emergence of fresh vegetation (Ross 2002).

Terrain within the LSA is primarily made up of moderately sloped upland areas with low-lying and riparian habitats around Rose and Vangorda Creeks, and several tributaries and drainages. Seasonally, grizzly bears may found within the low-lying areas in the spring and on mid to upper slopes in early summer, and in upland areas of berry production in later summer and fall.

Habitat Use and Diet

Grizzly bears typically have a wide-ranging diet that is primarily herbivorous in most areas. MacHutchon (1996) quantified grizzly bear food habits in Ivvavik National Park in the Yukon, and found important spring foods to include hedysarum roots (*Hedysarum spp*.) and over-wintered berries. Summer diet focused on horsetails (*Equisetum spp*.) and bearflower (*Boykinia richardsonii*), while ripened berries primarily made up the diet in fall, with a focus on roots when berries were not available. Prey included arctic ground squirrels (*Spermophilus parryii*) during summer and fall and caribou when migrating through in spring and summer. Bears within the RSA would likely have comparable food habits, although the growing season in the southern Yukon is comparably longer than in the north, therefore an increase in plant diversity and food availability may be expected. Bears in the LSA would likely still rely heavily on berries, and berry-laden bear scat (Figure 5.2-7) was observed during a vegetation classification survey conducted in the LSA in July 2007. Bears in the LSA would also likely prey on alternative ungulate species as sheep and moose are much more common to this area than caribou.

Summary

With the exception of harvest data, there is a general lack of specific information regarding grizzly bears in the LSA. However, the habitats within the LSA appear to support high densities of prey species such as moose and thinhorn sheep, in addition to vegetation cover that often included berry-producing plants. Combined with the unfortunate but regular problem kill rates of near one bear/year in the LSA, it is likely that the area including and surrounding the LSA has a relatively high production and/or density of grizzly bears.

5.2.6.5 Furbearers

Overview

Trapper harvest of furbearers is an important economic activity in much of the Yukon, including in and near the LSA. The largest portion of trappers' incomes is from the sale of lynx (*Lynx canadensis*) and marten (*Martes americana*) pelts, but wolverine (*Gulo gulo*) red fox, wolf, muskrat (*Ondatra zibethicus*) and beaver are also important. As indicated in Figure 5.2-8, relatively few lynx are taken but their high pelt prices means greater income. Other species of furbearers harvested by trapping may include mink (*Mustela vison*), ermine (*Mustela erminea*), and red squirrel (*Tamiasciurus hudsonicus*).

From 1999 to 2005, Yukon-wide trapping records collected by Statistics Canada (2007) indicated that the number of marten trapped annually far exceeds all other species, with the exception of squirrel in some years (Figure 5.2-8). Annual marten harvest's ranged from 1,646 to 4,362. Although not necessarily an indication of abundance (as harvest numbers are influenced by pelt prices, trapper effort, and other factors), trapping records can indicate species presence, and potentially broad population trends (Poole and Mowat 2001).

All of the furbearers identified above occur in the Faro area, and could potentially occur in the LSA. Among these animals, wolverines are listed as Sensitive in the Yukon (Canadian Endangered Species Conservation Council, 2006) and as Special Concern by COSEWIC (2007). All other species are considered Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006), although no population or abundance surveys for furbearers have taken place in the Faro area in recent years (H. Slama, pers. comm. 2007). Local data on fur harvest was not available from the Yukon Government at the time of report preparation.

Furbearer habitat preference varies by species. Marten tend to be associated with late successional coniferous stands, especially those dominated by spruce (*Picea spp*.) and fir (*Abies spp*.), similar to that of the LSA, which is composed of a mixture of mature spruce and fir forests on upland slopes.

5.2.6.6 Birds

Of the Yukon's 279 know bird species (60 of which are casual or accidental; Birds of the Yukon Database, Canadian Wildlife Service 2007), 68 species have been recorded in or near the LSA (see Tables 5.2-3 and 5.2-4), based on data records compiled for NTS mapsheets 105K3 and 105K6 (Canadian Wildlife Service 2007). These data include bird records from the 1860s to 1998, and are a compilation of incidental sightings and survey data.

The most common birds in the CWS database include dark-eyed junco, common raven, American robin, Swainson's thrush, lesser yellowlegs and the sandhill crane. None of the birds are currently listed in under the Yukon Wildlife Act or scheduled federally under SARA. Five species have been listed by COSEWIC as "Not at Risk" including: American coot, common loon, golden eagle, bald eagle and great grey owl. One species, rusty blackbird, has been listed by COSEWIC as Special Concern.

Based on the CWS database, ten species have confirmed breeding status in LSA, however it is likely that most of the 68 species recorded near the LSA are breeding birds. Much of the data available is sourced through road-based surveys, and breeding confirmation is likely difficult. The ten confirmed breeding species include; pacific loon, American widgeon, Northern shoveler, lesser scaup, Barrow's goldeneye, golden eagle, American coot, spotted sandpiper, violet-green swallow and red-winged blackbird. None of the species are listed as At Risk under the Yukon Wildlife Act, SARA, or COSEWIC.

Waterbirds

Many waterbirds are migratory and, as such are protected under the federal Migratory Birds Convention Act (MBCA). Areas of the Yukon make up the Pacific Flyway, a migratory route known to provide critically important areas for large numbers of waterfowl that migrate north to nest and raise young. Waterbird species that have been observed in the Faro region either through survey or by incidental sightings are found in Table 5.2-3. The most abundant birds included the sandhill crane and the lesser yellowlegs, with nine sightings of the sandhill crane and six sightings of the lesser yellowlegs (Canadian Wildlife Service 2007).

Several gulls (unknown species) were observed at the mine site near the tailing areas, where pooled water in the containment areas may provide habitat in the LSA. The observations were recorded during a vegetation classification survey conducted in August 2007.

Waterbirds need suitable habitat for staging and congregation behaviours. These tend to be areas that have abundant food and are ice-free in early spring. Waterbird habitat in the LSA is restricted to the lowland areas around Rose, Next and Vangorda Creeks as most of the LSA is made up of mid slopes that do not provide suitable habitat for waterbirds. Most creeks in the LSA are too small for much of the staging and congregation behaviours exhibited by waterbirds.

Waterbirds are of low concern in the development of the project as the LSA is not likely to contain much suitable habitat. Upland breeding birds a higher concern as they utilize a wide variety of habitats some of which are likely to be contained within the LSA.

- ***Trumpeter Swan***

  Currently the trumpeter swan (*Cygnus buccinator*) is listed as Specially Protected under the Yukon Wildlife Act, and warrants some discussion. It is not listed under the Species at Risk Act and COSEWIC (2007) designates it as Not at Risk. COSEWIC de-listed the bird in 1996 from its previous rank of Vulnerable as its populations recovered. The trumpeter swan is usually found on lakes and marshes with permanent water and or slow moving creeks or rivers with semi-permanent flow, having emergent and submergent vegetation (Sinclair *et al.*, 2003). Prime breeding, brood rearing or moulting habitat can be found within the shallow wetlands of river floodplains. The Rocky Mountain population utilizes central and southeastern portions of the Yukon as breeding habitat (Sinclair *et al.*, 2003), and there have been 76 confirmed breeding bird records of trumpeter swans in the Yukon (Yukon Zinc Corporation 2005), although none of these records were located within the LSA. The LSA contains only three relatively small creeks, and is unlikely to contain suitable trumpeter swan habitat.

Landbirds

Many landbirds (including upland game birds, passerines, woodpeckers, and raptors) are migratory, and, as such are protected under the federal Migratory Birds Convention Act (MBCA). Landbird species that have been observed in the Faro region either through survey or by incidental sightings (Canadian Wildlife Service 2007) are identified in Table 5.2-4. The LSA is made up primarily of upland areas containing mature spruce, fir, and pine forests, and likely contains suitable habitat for many landbirds, and the bird species observed in the region (Table 5.2-4) could be considered potentially present in the LSA. The most abundant birds included the common raven, Swainson's thrush, American robin and dark-eyed junco, with nine sightings of the common raven, eight sightings of the dark-eyed junco and five sightings each for the American robin and Swainson's thrush (Canadian Wildlife Service 2007).

A Harlan's hawk (*Buteo jamaicensis harlani;* a red-tailed hawk subspecies) was also observed on site (Figure 5.2-9) in August of 2007. Although not recorded previously in the Faro region, the sighting is not unexpected; the dark morph of the hawk occurs regularly in northwest Canada and Alaska (Preston and Beane 1993). The red-tailed hawk is considered Not at Risk by COSEWIC (2007), and is identified as Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006). As a subspecies of the red-tailed hawk the Harlan's hawk was not referenced by either COSEWIC or the Yukon Government.

A colony of bank swallows was also observed at the Faro Mine Complex (Figure 5.2-10) along a road cut adjacent to the water retention ponds in the Tailings Impoundment. The cut created a small, sandy cliff that appears to provide suitable nesting habitat for swallows, which typically nest in cut banks of rivers and other waterbodies. The LSA is within the known range of bank swallows (Garrison 1999), and they have been previously documented in the region (Table 5.2-4). Bank swallow's are not listed by COSEWIC (2007), and are identified as Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006).

5.2.6.7 Small Mammals

Small mammals are considered an important species in the Yukon due to their significance as both furbearing species (primarily squirrels) as well as prey species for carnivores. In a contaminant-related study conducted from 2004 to 2005 Gartner Lee Limited (2006) documented the presence of several small mammal species. 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*). During this study, four trapping programs were conducted. A total of 121 small mammals were trapped including: 77 small mammals in September 2004; 12 in November 2004 (in the Swim Lake reference area, beyond the LSA); 29 in July 2005; and 3 in September 2005. Few samples were collected in September 2005, as the trapping program focused on shrews from under-represented sites. Of the total small mammals trapped, the most common species collected were northern red-backed vole (65), followed by common shrews (30), deer mouse (15), heather voles (6), least chipmunk (2), and Siberian lemming (1). All species observed in 2004 and 2005 are considered Secure by the Government of Yukon (Canadian Endangered Species Conservation Council 2006).

5.2.6.8 Amphibians

While amphibians were not identified as a preliminary VEC, it should be noted that a wood frog (*Rana sylvatica*) was observed on site during a vegetation classification survey conducted in July 2007 (see Figure 5.2-11). Wood frogs are likely the only amphibian present in the LSA, although western toads (*Bufo boreas*), boreal chorus frog (*Pseudacris maculata*), Columbia spotted frog (*Rana luteiventris*) and long-toed salamander (*Ambystoma macrodactylum*) have also been observed in the Yukon (Department of Environment, Government of Yukon 2005), although primarily at the far southern extent of the Yukon.

5.2.7 Incidental Wildlife Sightings

Incidental wildlife sightings were recorded in and around the Faro Mine Complex from 2004 to 2007. Wildlife which observed but not identified to species included; weasel, hare, fox, eagle, duck, ptarmigan, swan, seagull, shore bird, and loon. The following wildlife were observed and identified:

- Grizzly bear (*Ursus arctos*)
- Black bear (*Ursus americanus*)
- Wolf (*Canis lupus*)
- Wolverine (*Gulo gulo*)
- Lynx (*Lynx canadensis*)
- Coyote (*Canis latrans*)
- Moose (*Alces alces*)

- Fannin Sheep (Thinhorn sheep subspecies or colour variant, *Ovis dalli* spp.)
- Caribou (*Rangifer tarandus*)
- Otter (*Luntra canadensis*)
- Porcupine (*Erethizon dorsatum*)
- Marmot (*Marmota caligata*)
- Beaver (*Castor canadensis*)
- Muskrat (*Ondatra zibethicus*)
- Harlan's Hawk (Red-tailed hawk subspecies, *Buteo jamaicensis harlani*)
- Bank Swallow (*Riparia riparia*)
- Raven (*Corvus corax*)
- Canada Goose (*Branta canadensis*)
- Surf Scoter (*Melanitta perspicillata*)
- Northern Hawk Owl (*Surnia ulula*)
- Common Merganser (*Mergus merganser*)
- Wood Frog (*Rana sylvatica*)

5.2.8 Contaminants in Wildlife

5.2.8.1 Baseline Conditions

The level of contaminants in wildlife (lead and zinc primarily, but also other metals) is an important wildlife issue associated with the current state of the Faro Mine Complex (Middler 2007). The airborne transportation of tailings related contaminants is likely the greatest source of elevated concentrations of mine-related contaminants in the LSA (Gartner Lee Limited 2006). Information on contaminant presence in wildlife near the Faro Mine Complex is primarily drawn from two studies: Gartner Lee Limited (2006) and Gamberg (2008).

5.2.9 Data Collection Methods

5.2.9.1 2004 to 2005 Wildlife Contaminant Study

The influence of the current state of the Faro Mine Complex on terrestrial resources, including wildlife, was evaluated in a multi-year study, completed in 2006 (Gartner Lee Limited 2006). That work documented in detail the contaminant release pathways, and elevated concentration and deposition rates of contaminants in and beyond the LSA in small mammals and hunted wildlife.

During this study, small mammals were collected and tested for heavy metal concentrations, including lead, zinc, copper, arsenic, iron, silver, thallium, barium, chromium, mercury, nickel, selenium, antimony, cadmium, and cobalt (Gartner Lee Limited 2006).

Among hunted and trapped wildlife, ten species were collected for tissue analyses in 2004 and 2005 (Gartner Lee Limited 2006). Those species included woodland caribou, moose, sheep, American marten, hoary marmot (*Marmota caligata*), Arctic ground squirrel, muskrat, beaver, willow ptarmigan (*Lagopus lagopus*), and ruffed grouse (*Bonasa umbellus*). Ungulate tissue samples were obtained from animals hunted in fall 2004 and 2005; American marten and willow ptarmigan were obtained from local trappers, and the

Faro Yukon Environment office provided the marmot, ground squirrels and two beavers (Gartner Lee Limited 2006).

5.2.9.2 2005 to 2007 Moose and Caribou Contaminant Study

Muscle, liver and kidney tissue samples were collected from moose and caribou from 2005 to 2007 to contribute to data collected during the 2004 to 2005 wildlife contaminant study (see Section 5.2.9.1) (Gamberg 2008). Frozen tissue samples from hunting zones 4-42 to 4-46 were chosen for analysis, which was conducted by CanTest Laboratories in Burnaby, British Columbia. More caribou tissue samples (muscle [n=6], liver [n=7], and kidney [n=7]) were collected and tested than moose tissue samples (muscle [n=2], liver [n=2], and kidney [n=1]). Tissue samples were tested for the following 26 contaminates: aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, uranium, vanadium, and zinc (Gamberg 2008).

5.2.9.3 2004 to 2005 Wildlife Contaminant Study

Among small mammals sampled, the study concluded that lead was elevated in the muscle, liver and kidney of northern red-backed voles and in whole bodies of common shrews in areas affected by the mine. The magnitude of the elevated concentrations of lead in comparison to the reference area ranged from 11 times greater in vole muscle tissue to over 157 times greater in whole bodies of shrews. Moderately elevated levels of copper, iron, thallium and nickel were also observed in small mammals. Metal elevations considered low or similar to reference levels were observed for all other metals tested for.

Similar to the results for small mammals, high elevations of lead were detected in the liver and kidney of caribou, ranging from 1.1 to 1.6 times greater than samples from the Finlayson herd. The Finlayson herd, located east of the LSA, are not likely exposed to the effects of the mining facility. Lead was also elevated in American marten, willow ptarmigan, and beaver. Lead elevations ranged from 4.6 times for beaver kidney to 18.7 for willow ptarmigan livers. Moderate elevations were also detected for mercury and selenium in American marten, willow ptarmigan, and moose. For all other metals, low elevations (samples that were difficult to statistically compare to reference samples) were found, with the exception of antimony, in which no elevations were found in comparison to reference samples. However, elevations of iron in sheep kidney in comparison to the Yukon Hunter Survey data were 1.1 times greater, and silver concentrations were 5.1 times greater in woodland caribou muscle than in the nearby Finlayson herd.

5.2.9.4 2005 to 2007 Moose and Caribou Contaminant Study

Results from this study were analyzed and compared to the results of the 2004 to 2005 wildlife contaminant study (see Section 5.2.9.1) and to tissue results from Finlayson caribou and Yukon-wide moose sample data (Gamberg 2008). Little to no change occurred in moose and caribou tissue sample concentrations for the majority of the tested contaminants (Gamberg 2008). However, some changes were detected in aluminum, arsenic, selenium, silver, cadmium, lead, mercury, and zinc concentrations (Gamberg 2008). Aluminum was elevated in moose muscle by 1.9 µg/g. Arsenic concentrations were higher in all tissue samples. Selenium levels decreased in moose and silver levels were variable. Cadmium concentrations increased in all samples except moose liver. Lead concentrations in moose clearly increased and are higher than Yukon-wide moose concentrations. Mercury concentrations were elevated in caribou liver and kidney. Zinc levels were markedly elevated in all tissues and were higher than levels found in Yukon-wide moose. These results suggest that

moose and caribou tissue samples appear to be accumulating more arsenic and zinc. In addition, mercury may be accumulating in caribou and lead concentrations appear to be rising in moose. Continual contamination monitoring in wildlife was highly recommended.

5.2.10 Summary

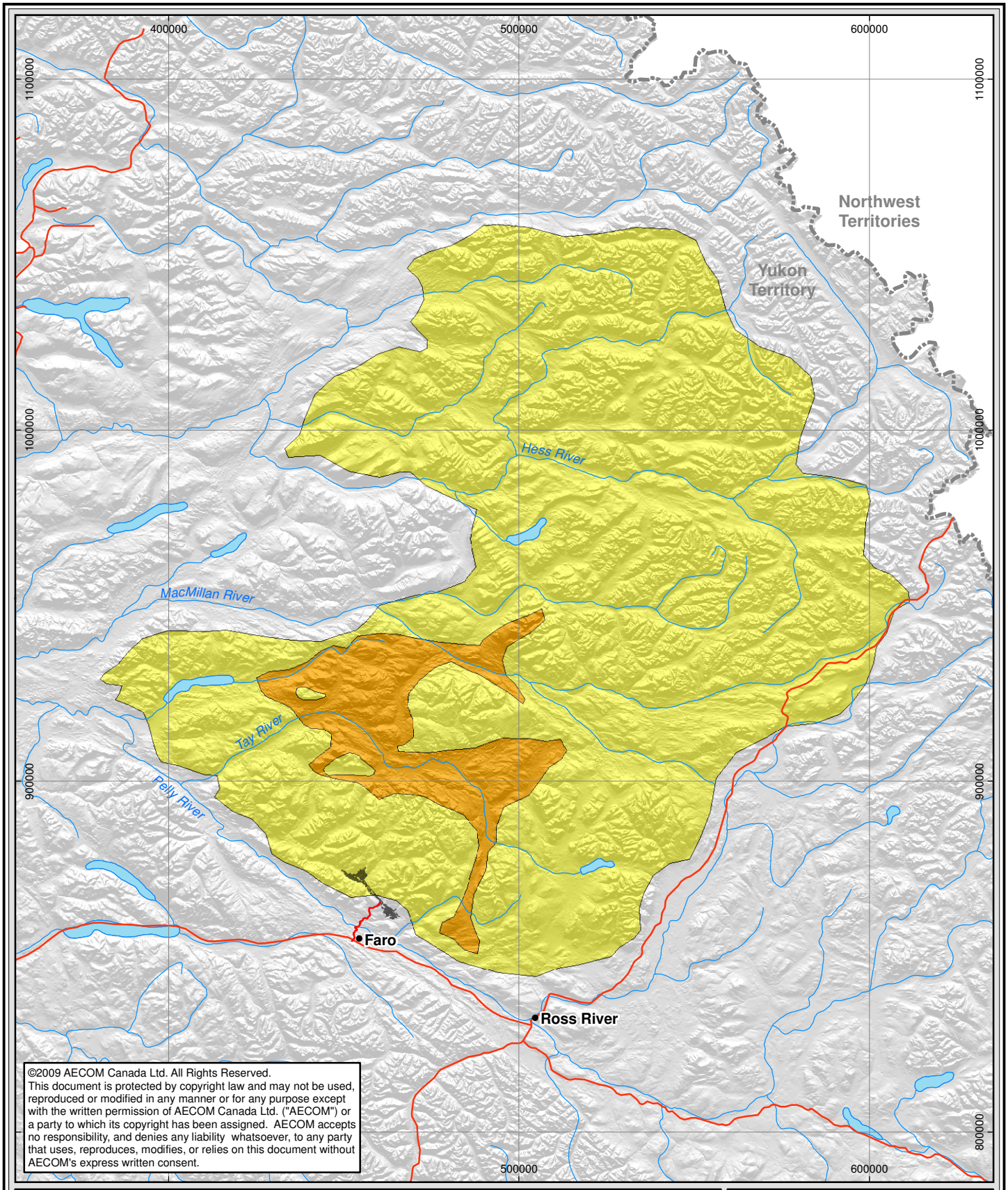
Based on a review of existing literature and known data sources, this report summarizes baseline condition of wildlife in the area of the Faro Mine. Grizzly bears and wolverine are the only listed species that may occur within the LSA on a regular basis. It is difficult to assess the predictable numbers of those species that may occur in the LSA, as site-specific studies for those and most other species do not exist in the LSA. From known distributions and breeding habitat, it is unlikely that any bird species of concern will occur within the LSA. Small mammals have been found throughout the LSA in abundance.

Fannin sheep are a species of concern to stakeholders of the Project, as both an economic resource within the region, and because they are the most-visible species that interact directly with the project. A reasonable understanding of seasonal ranges and movement patterns is available, as sheep are known to migrate directly through the Vangorda and Grum infrastructure.

Ungulate winter range for caribou and sheep is a management concern due to heavy snowfall in the region. The Tay River herd and fannin sheep range have the greatest potential to interact with the LSA in winter, as those Key Wildlife Area ranges are in the closest proximity to the LSA. Information is available on winter range distribution and population for both Fannin sheep and the Tay River herd, and may be used to develop project mitigation plans.

Increased harvest pressure on moose, grizzly bear and caribou is a concern of both local stakeholders and the Yukon Government. The moose harvest rate in particular in the GMSs near the LSA tends to be near the limit of sustainable levels. The Tay River population appears stable, however because the herd is small and widely dispersed an increase in hunting pressure may have more immediate impacts. Grizzly bear populations face pressure as there is a high problem kill rate in several of the GMSs within the LSA. Careful project mitigation planning should be employed to address an increase in hunting pressure and to reduce human-bear conflicts.

The presence of contaminants in wildlife from the Faro Mine indicates that high elevations of levels of lead are present in red-backed voles and shrews, and moderately elevated levels of copper, iron, thallium and nickel have been observed in most small mammals. Among hunted and trapped wildlife, elevations of lead have been observed in caribou, American marten, willow ptarmigan, and beaver. Moderate elevations of mercury and selenium are also present in American marten, willow ptarmigan, and moose.



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Map Sources/Notes:
Base data obtained from the Yukon Department of Environment, Information Management & Technology Branch.
Project footprint delineated by AECOM Canada Ltd.
Tay river caribou herd range provided by AECOM Canada Ltd.
Boundaries are approximate.

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Yukon Albers

Legend

Existing Features
- Community
- Road

Tay River Caribou Herd Range
- Herd Range
- Winter Range

Boundaries
- Territorial Boundary
- Project Footprint

Hydrological Features
- Watercourse
- Waterbody

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

Range of the Tay River Caribou Herd

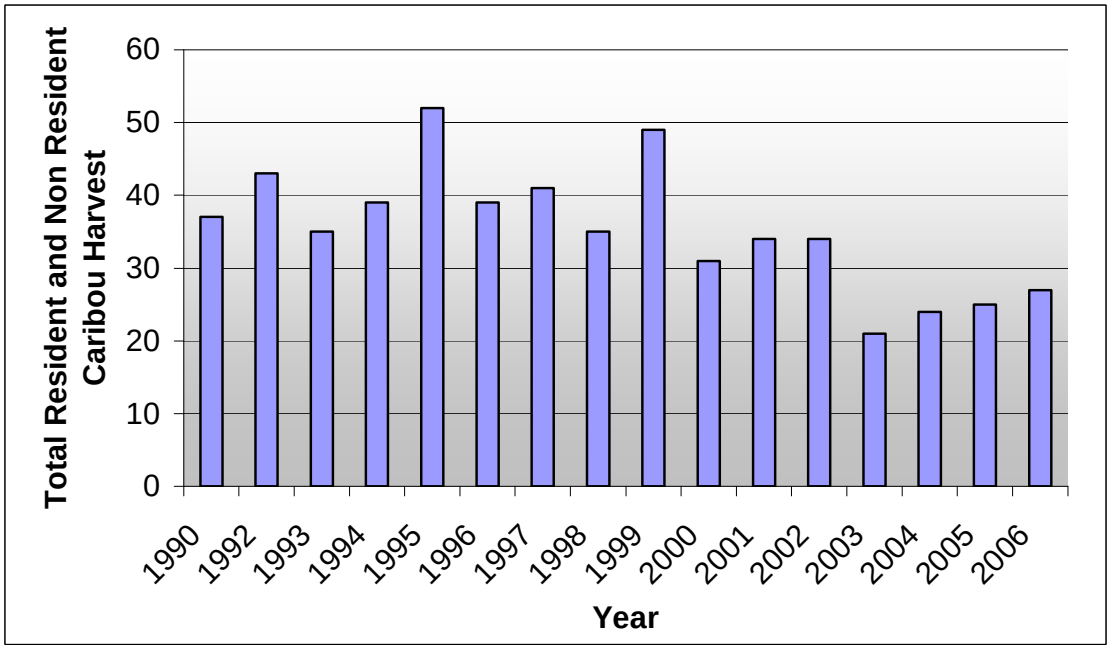
March, 2009

AECOM

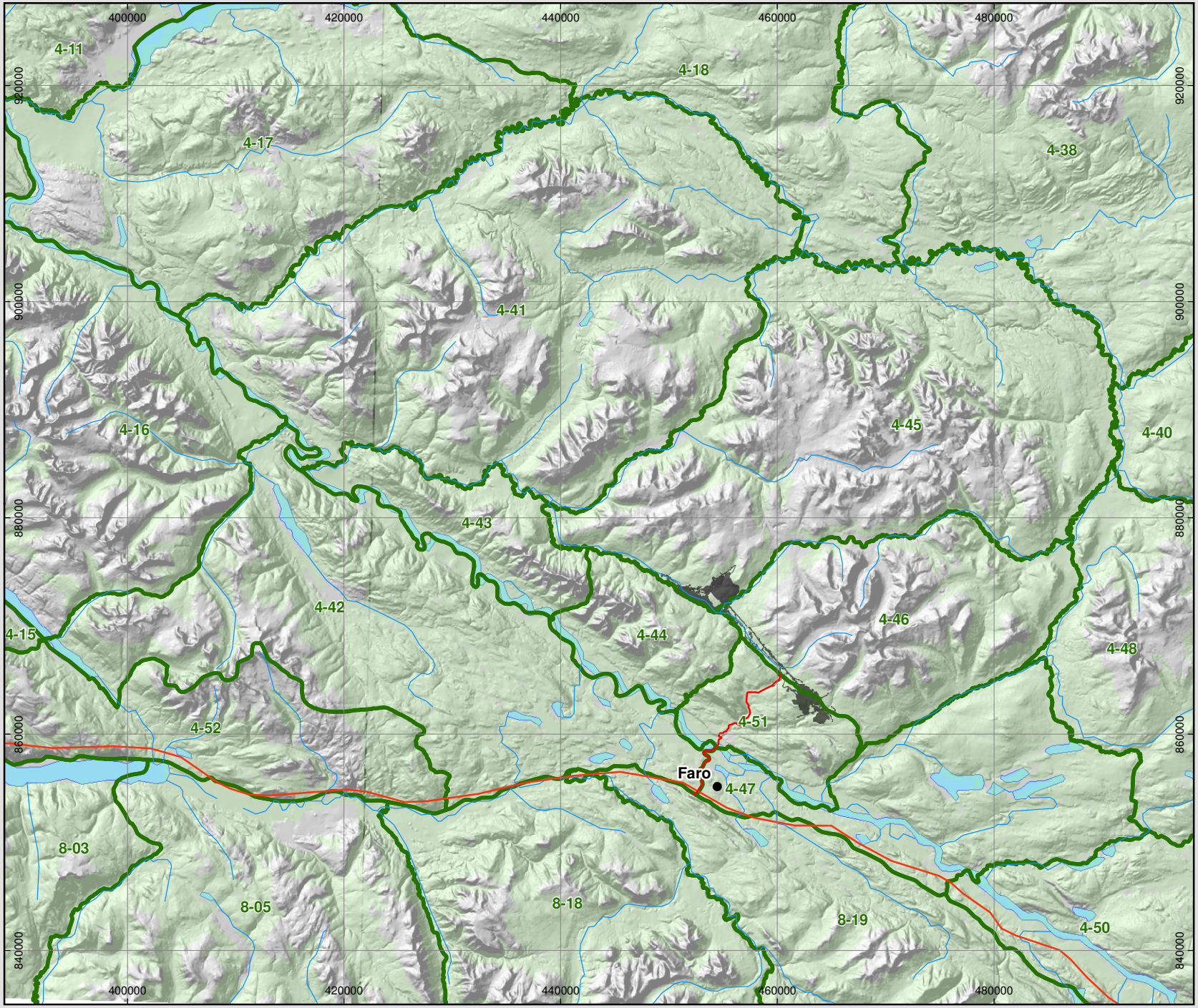
Figure 5.2-1

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Wildlife\107403_C1_Fig_5.2-1_TayRiverCaribouRange_01Apr09.mxd Prepared by: AM Project: 107403 (80642-1)
Date Revised: April 2, 2009

Figure 5.2-2 Harvest of the Tay River Caribou Herd, 1990 to 2006



Note: Data from 1991 was not available at the time of report preparation.



Legend

Existing Features

- Community
- Road

Boundaries

- Project Footprint
- 4-44 Game Management Subzones
- Vegetation

Hydrological Features

- Watercourse
- Waterbody

Map Sources/Notes:
Base data obtained from the Yukon Department of Environment, Information Management & Technology Department.
Project footprint delineated by AECOM Canada Ltd.
Game management subzones obtained from the Yukon Department of Environment, Information Management & Technology Department.

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Yukon Albers

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Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

Game Management Subzones

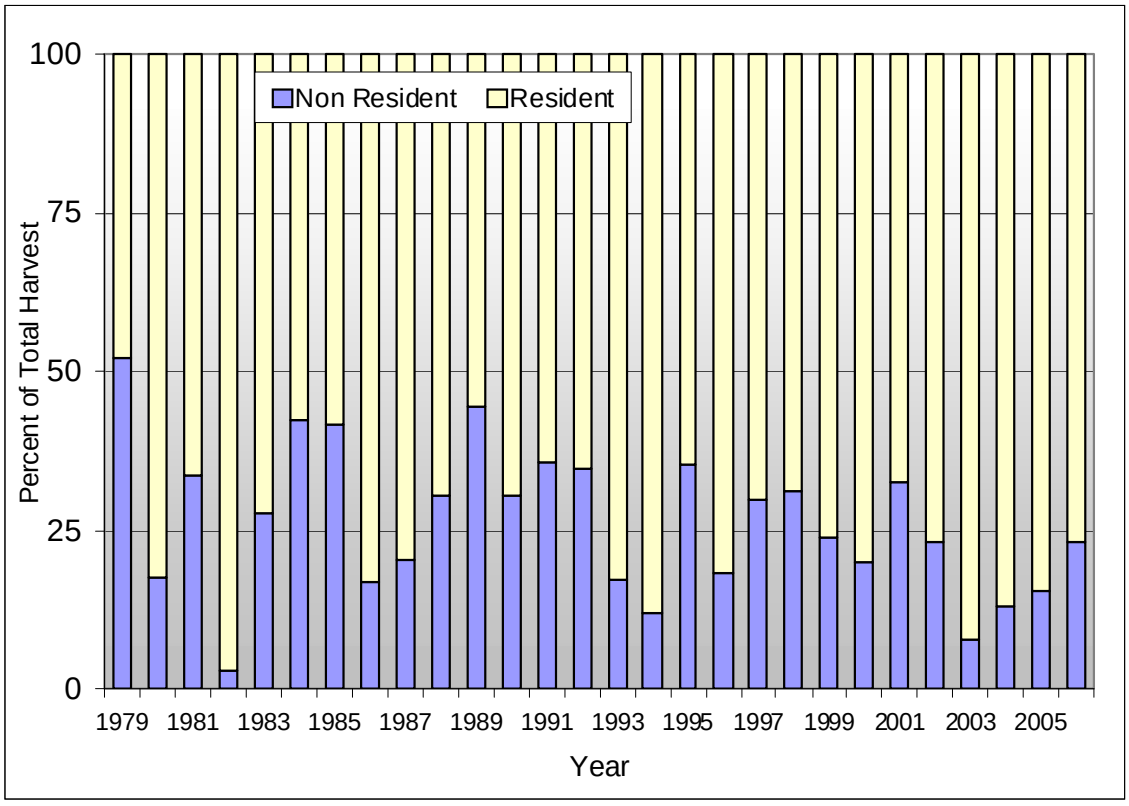
March, 2009

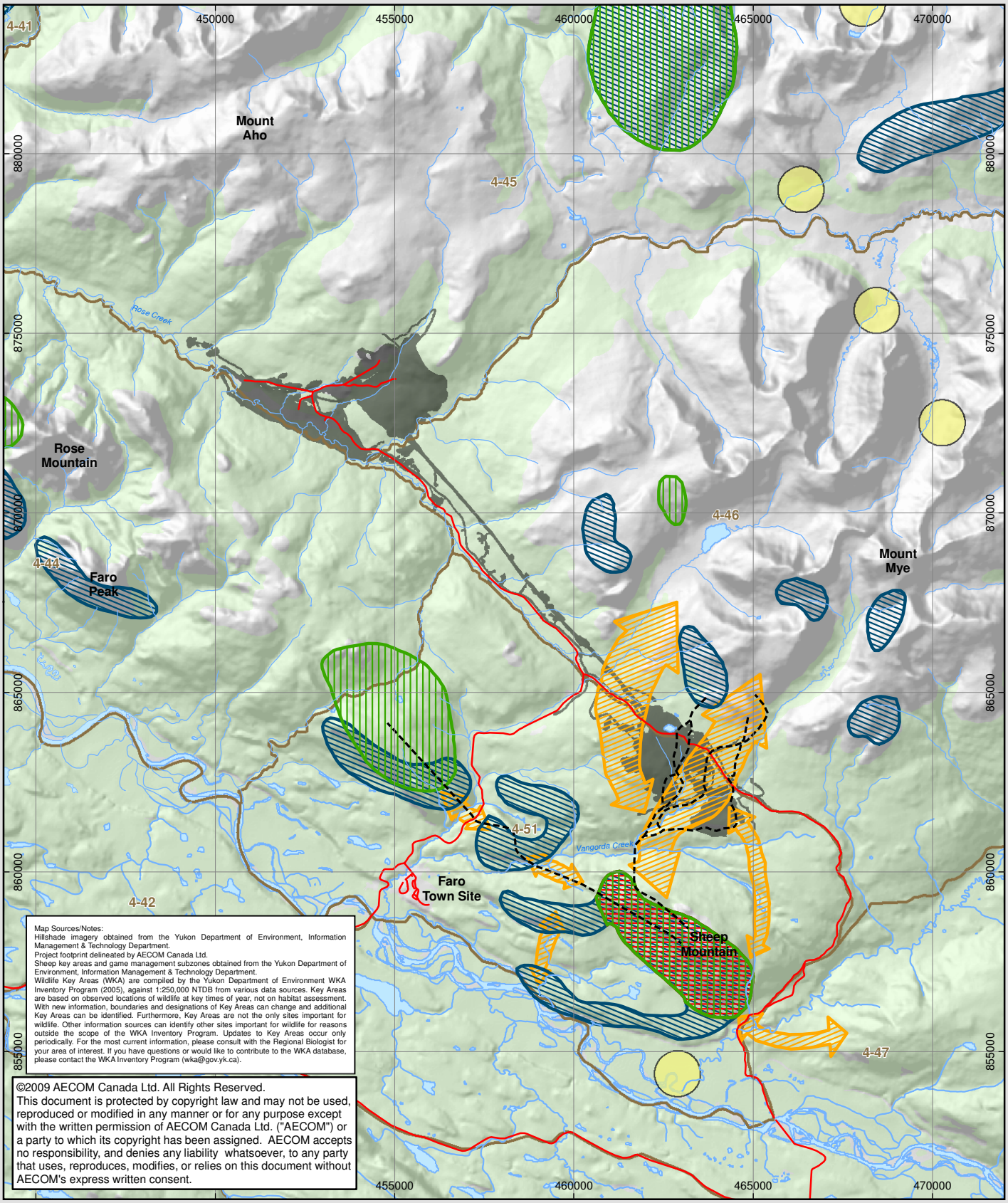
AECOM

Figure 5.2-3

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Wildlife\107403_C1_Fig_5.2-3_GameMgmtSubZones_01Apr09.mxd Date Revised: April 2, 2009 Prepared by: CA

Figure 5.2-4. Percent of Total Moose Harvest by Yukon Residents and Non-Residents,1979 to 2006





Map Sources/Notes:
Hillshade imagery obtained from the Yukon Department of Environment, Information Management & Technology Department.
Project footprint delineated by AECOM Canada Ltd.
Sheep key areas and game management subzones obtained from the Yukon Department of Environment, Information Management & Technology Department.
Wildlife Key Areas (WKA) are compiled by the Yukon Department of Environment WKA Inventory Program (2005), against 1:250,000 NTDB from various data sources. Key Areas are based on observed locations of wildlife at key times of year, not on habitat assessment. With new information, boundaries and designations of Key Areas can change and additional Key Areas can be identified. Furthermore, Key Areas are not the only sites important for wildlife. Other information sources can identify other sites important for wildlife for reasons outside the scope of the WKA Inventory Program. Updates to Key Areas occur only periodically. For the most current information, please consult with the Regional Biologist for your area of interest. If you have questions or would like to contribute to the WKA database, please contact the WKA Inventory Program (wka@gov.yk.ca).

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Map Sources/Notes:
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Yukon Albers

Legend

Existing Features
- Road

Thinhorn Sheep Key Areas
- Spring Lambing
- Early Winter Rut
- Winter Range
- Movement Corridor
- Mineral Lick

Migration Routes
- Sheep Migration Route

Boundaries
- Project Footprint
- Vegetation
- Game Management Subzones

Hydrological Features
- Watercourse
- Waterbody

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

Key Wildlife Areas for Thinhorn Sheep

March, 2009

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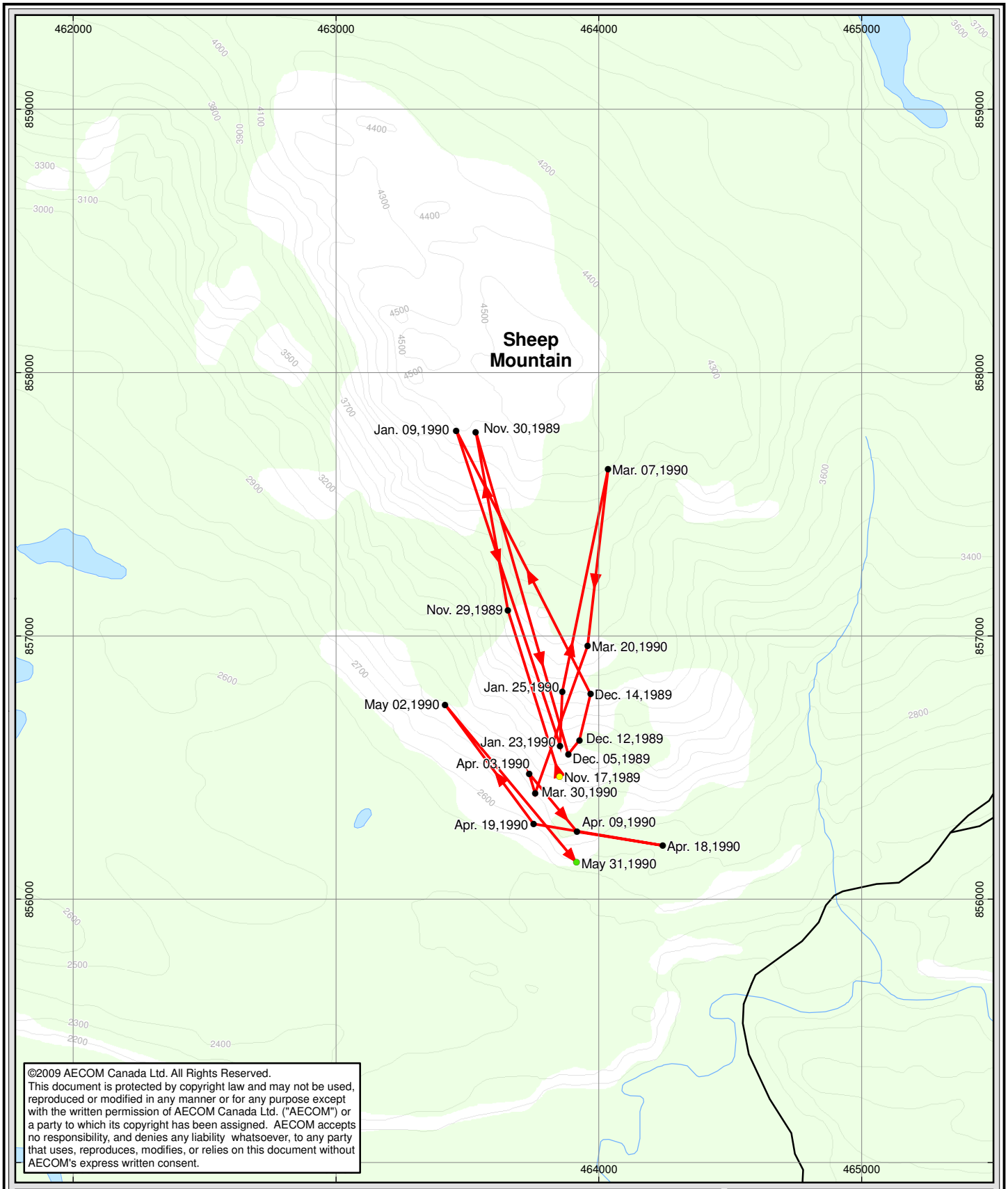
Figure 5.2-5

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Wildlife\107403_C1_Fig_5.2-5_KWAThinhornSheep_01Apr09.mxd Prepared by: CA Project: 107403 (80642-1) Date Revised: April 2, 2009



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Telemetry data reproduced from Schweinsberg, R.E., 1990.

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Legend

Existing Features
- Road

Sheep Telemetry
- Sheep Location
- Start Location
- End Location
- Sheep Movement Path

Boundaries
- Vegetation

Hydrological Features
- Watercourse
- Waterbody

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

Radio-telemetry Locations, Yellow Collared Individual Winter-Spring, 1989-1990

March, 2009

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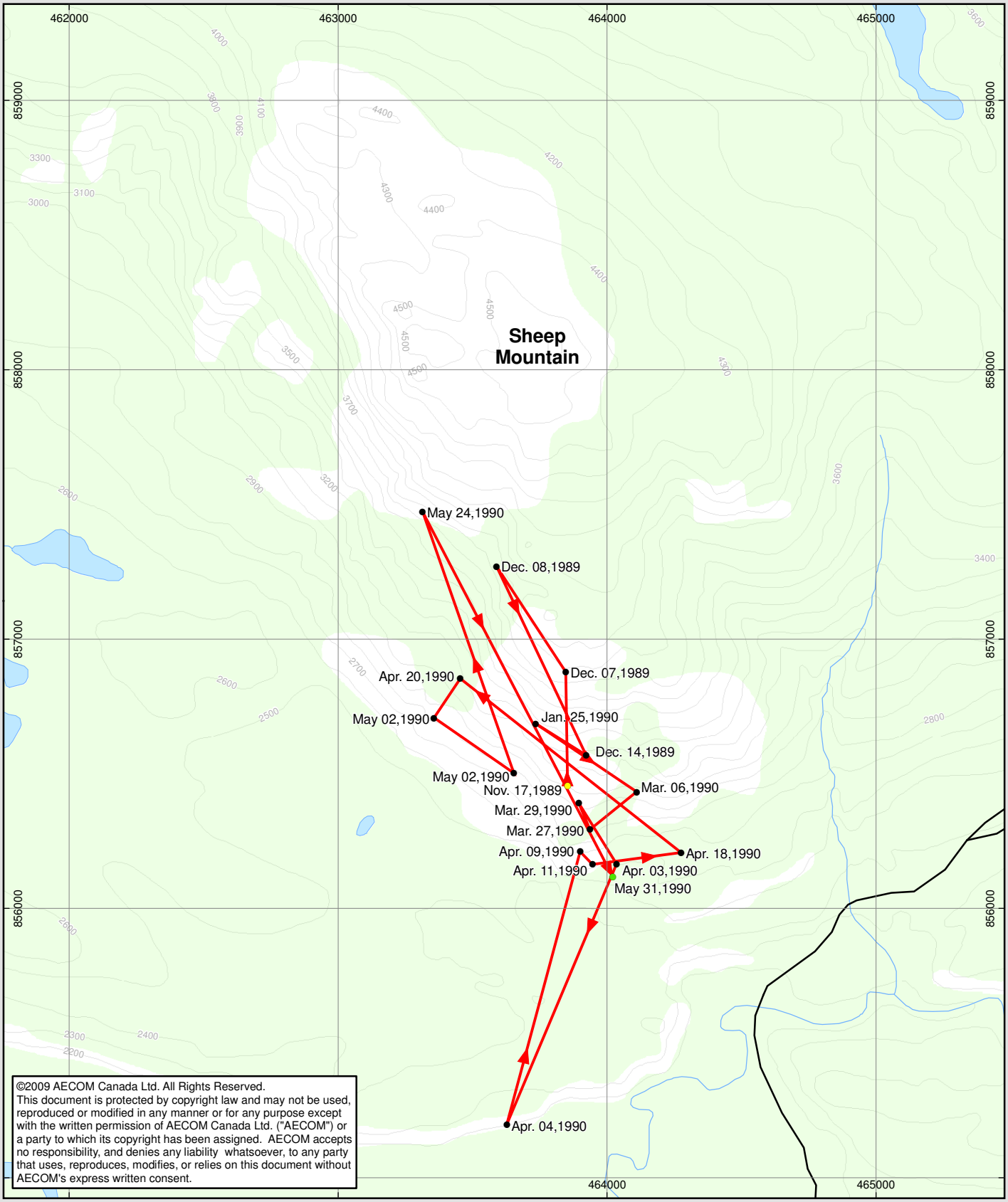
Figure 5.2-6

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Wildlife\107403_C1_Fig_5.2-6_YellowSheep_01Apr09.mxd Date Revised: April 1, 2009 Prepared by: CA Project: 107403 (80642-1)



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Yukon Albers

Legend

Existing Features
- Road

Sheep Telemetry
- Sheep Location
- Start Location
- End Location
- Sheep Movement Path

Boundaries
- Vegetation

Hydrological Features
- Watercourse
- Waterbody

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

Radio-telemetry Locations, Black Collared Individual Winter-Spring, 1989-1990

March, 2009

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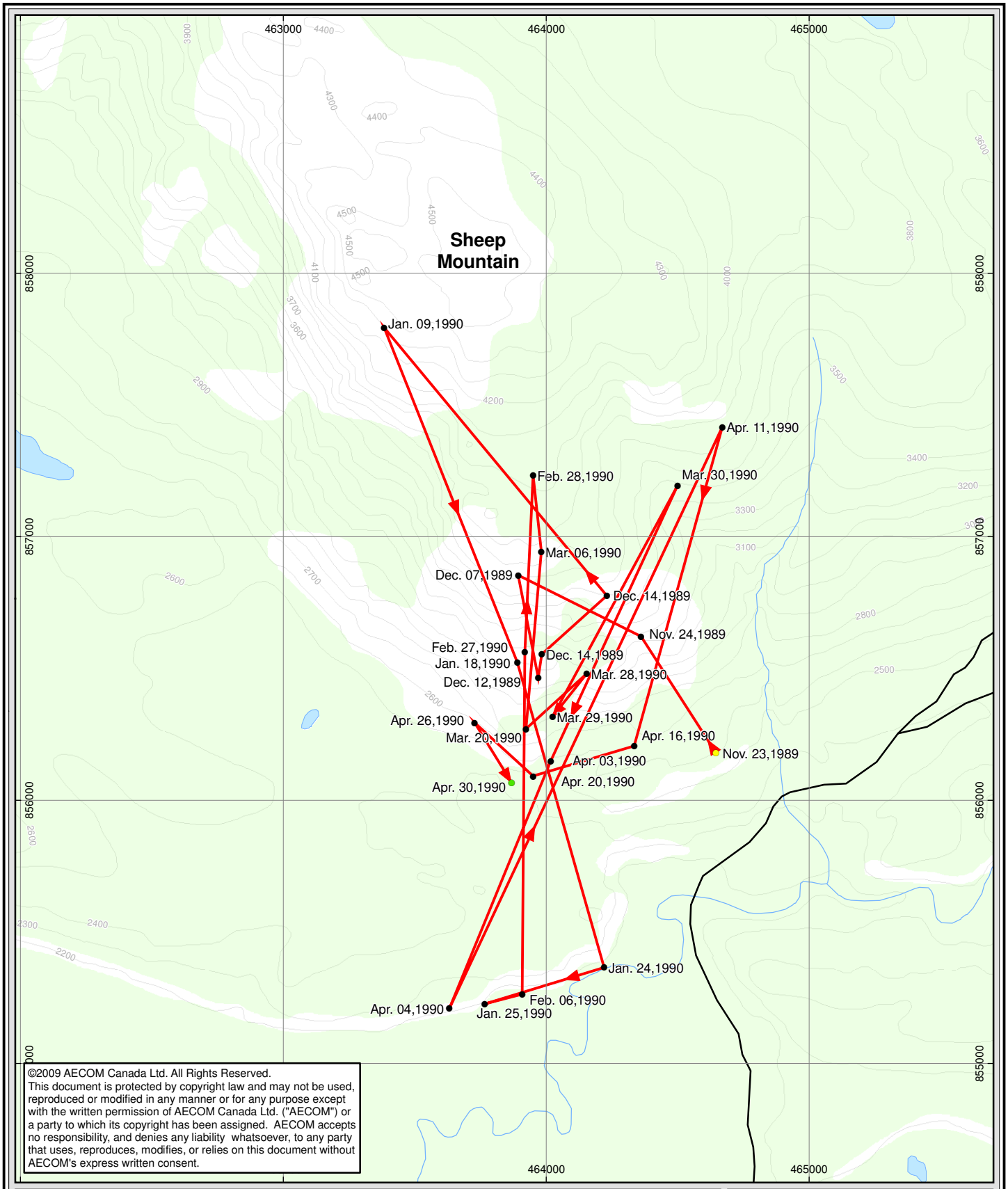
Figure 5.2-7

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Wildlife\107403_C1_Fig_5.2-7_BlackSheep_01Apr09.mxd Date Revised: April 1, 2009 Prepared by: CA Project: 107403 (80642-1)



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Telemetry data reproduced from Schweinsberg, R.E., 1990.

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Yukon Albers

Legend

Existing Features
- Road

Sheep Telemetry
- Sheep Location
- Start Location
- End Location
- Sheep Movement Path

Boundaries
- Vegetation

Hydrological Features
- Watercourse
- Waterbody

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

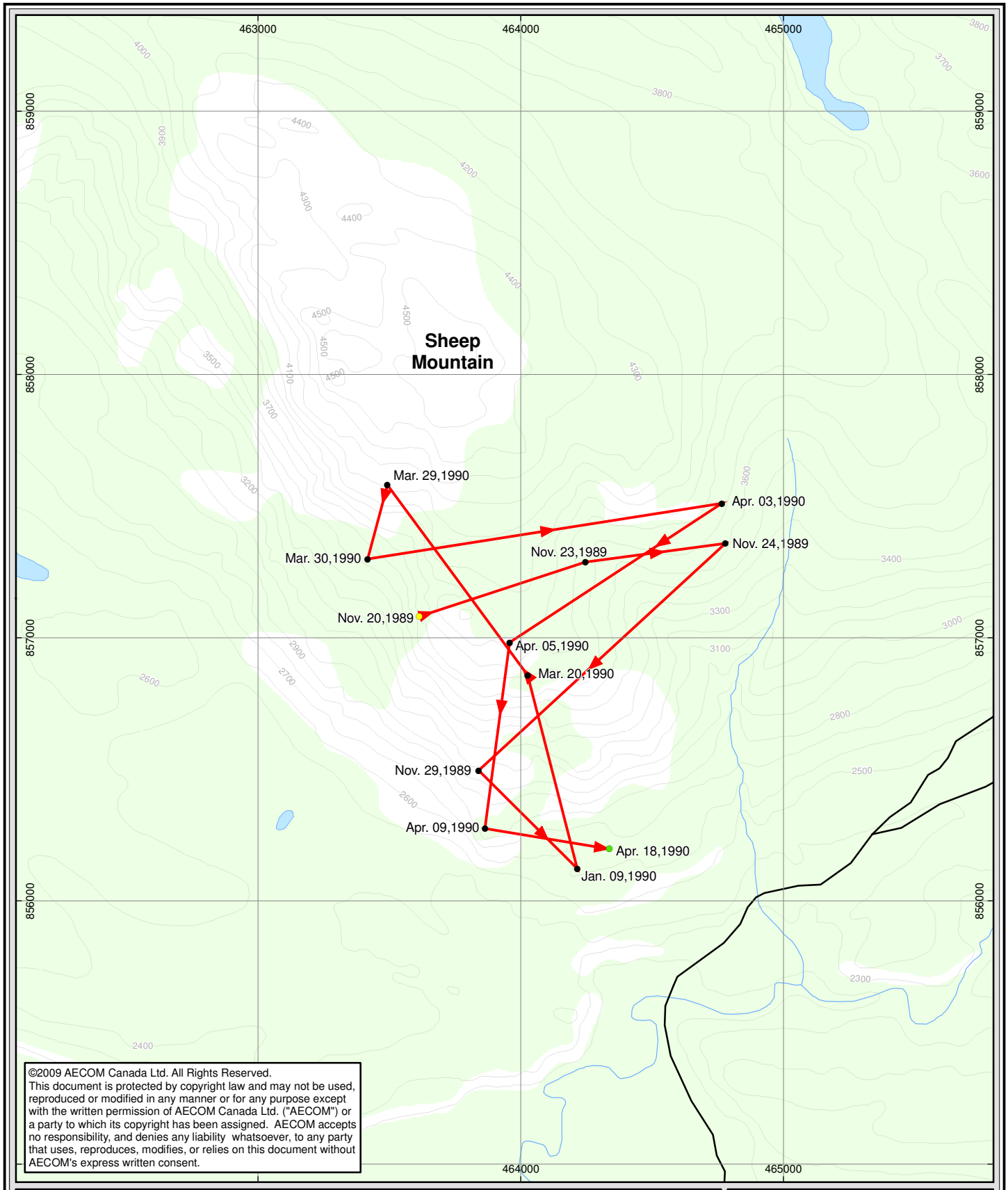
Radio-telemetry Locations, Red Collared Individual Winter-Spring, 1989-1990

March, 2009

AECOM

Figure 5.2-8

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Wildlife\107403_C1_Fig_5.2-8_RedSheep_01Apr09.mxd Date Revised: April 2, 2009 Prepared by: CA Project: 107403 (80642-1)



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Telemetry data reproduced from Schweinsberg, R.E., 1990.

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Metres

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Yukon Albers

Legend

Existing Features
- Road

Sheep Telemetry
- Sheep Location
- Start Location
- End Location
- Sheep Movement Path

Boundaries
- Vegetation

Hydrological Features
- Watercourse
- Waterbody

Faro Mine Closure
Fermeture de la mine Faro
Faro Mine Complex Closure and Reclamation

Radio-telemetry Locations, Yellow-green Collared Individual Winter-Spring, 1989-1990

March, 2009

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Figure 5.2-9

File Location: M:\GIS\GIS_proj\Y2007\P70384_Faro\ArcMap\Wildlife\107403_C1_Fig_5.2-9_YellowGreenSheep_01Apr09.mxd Date Revised: April 1, 2009 Prepared by: CA Project: 107403 (80642-1)

Figure 5.2-10 Total Harvest of Fannin Sheep in GMS 4-41 to 4-46,1980 to 2006

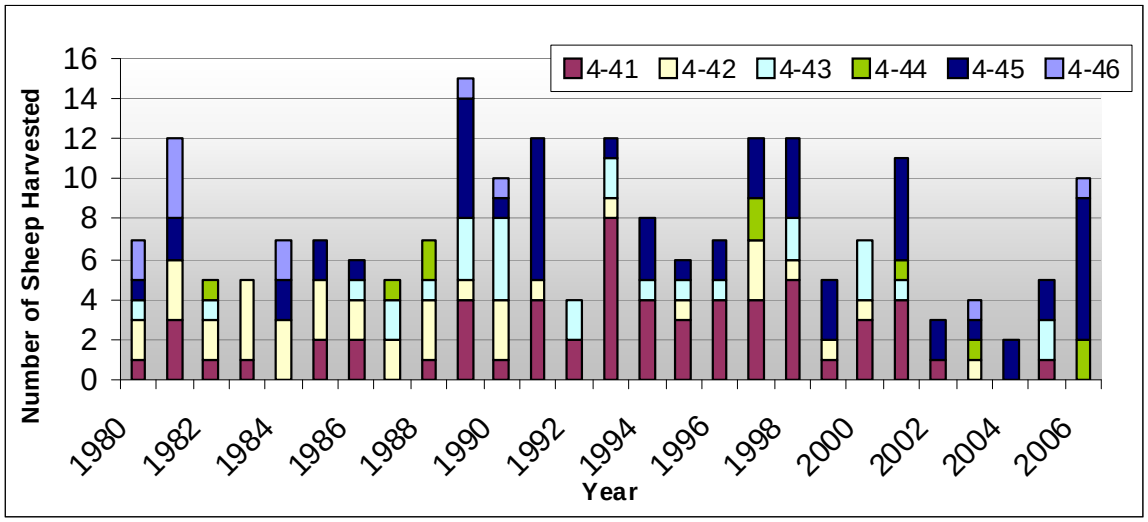

Figure 5.2-11. Bear Scat Observed, August 2007, Vangorda/Grum Area

Figure 5.2-12 Number of Wild Harvested Fur Pelts in the Yukon Territory, 1999-2005

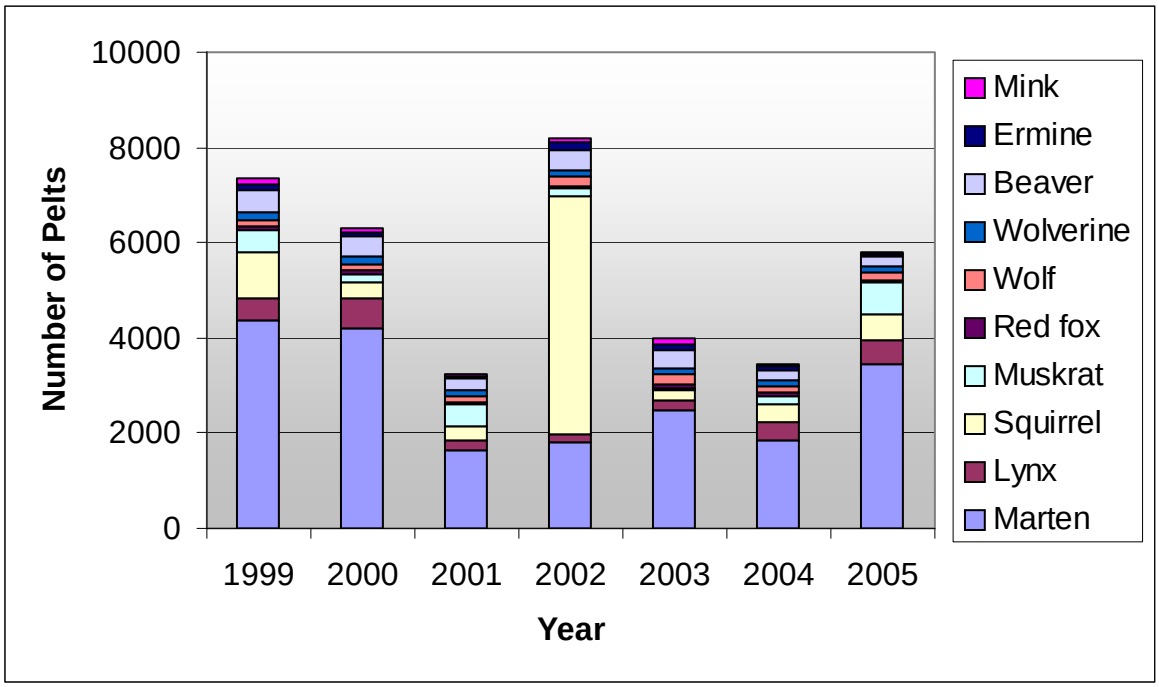

Figure 5.2-13 Harlan's Hawk Observation, Haul Road Between Faro and Vangorda/ Grum Deposits, August 2007

Figure 5.2-14. Bank Swallow Colony Observation, Faro Tailings Area, August 2007

Figure 2.5-15. Wood Frog Observation, Vangorda/Grum Area, August 2007

Table 5.2-1. Total Resident and Non-Resident Moose Harvest in GMS 4-42 to 4-46

GMS	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
4-41	1	1	0	4	5	11	9	6	7	11	8	6	8	4	7	3	14	10	15	18	12	9	15	7	2	1	5	4
4-42	1	2	0	5	5	5	5	4	1	2	2	3	5	0	4	0	5	7	6	6	6	3	3	6	5	6	7	4
4-43	1	2	1	1	0	0	1	2	3	1	0	1	2	0	6	1	2	0	1	0	0	1	6	0	1	2	0	0
4-44	1	4	3	6	1	2	7	5	3	7	3	0	1	1	2	1	0	4	9	6	1	6	2	0	1	3	3	2
4-45	3	2	6	5	6	9	5	11	3	6	14	4	7	3	14	10	23	13	19	21	15	20	21	9	21	16	24	36
4-46	2	3	4	8	1	3	1	1	3	4	3	1	1	1	2	6	3	2	4	6	7	0	10	2	6	6	7	3
4-47	0	2	1	5	4	3	1	0	0	2	5	2	5	1	3	2	1	2	3	4	1	1	1	2	2	4	4	3
4-51	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0
Total	**10**	**17**	**15**	**35**	**22**	**33**	**29**	**29**	**20**	**33**	**36**	**20**	**31**	**12**	**41**	**25**	**48**	**38**	**57**	**61**	**42**	**40**	**58**	**26**	**38**	**38**	**51**	**52**

Table 5.2-2. Reported Grizzly Bear Mortalities from 1980 – 2001

GMS	4-41		4-42		4-43		4-44		4-45		4-46		4-47		4-51*		All GMS**	
Area (Km2)	1299.8		825.5		170.3		147.9		1035.8		422.5		420.8		132		4454.6	
Sex	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Reported Hunts	15	8	8	5	1	2	6	0	5	6	4	2	2	1	0	0	41	24
Problem kills, Defence of Life/ Property	3	1	1	2	0	0	2	0	0	1	1	0	1	0	6	4	14	8
Annual Mortality (bears/year)	0.82	0.41	0.41	0.32	0.05	0.09	0.36	0.00	0.23	0.32	0.23	0.09	0.01	0.05	0.50	0.33	2.5	1.46
Annual Mortality (bears/year/1,000 km^2)	0.63	0.31	0.50	0.39	0.27	0.53	2.46	0.00	0.22	0.31	0.54	0.22	0.32	0.11	3.79	2.52	0.56	0.33
Total Annual Mortality (bears/year/1,000 km^2)	0.94		0.89		0.80		2.46		0.53		0.76		0.43		6.31		0.89	

Notes: **Includes data between 1990 and 2001 only.*

***Although GMS 4-51 included data only between 1990 and 2001, it was assumed that mortalities recorded represented data from a time period equal to that of other GMS's in order to calculate annual mortality rates. Thus, the total annual mortalities/year, and total annual mortalities/year/1,000 km^2 are slightly underestimated.*

Table 5.2-3. Status of Waterbird Species Potentially Present in the LSA (Canadian Wildlife Service 2007)

Species	Scientific Name	Species Status		
		Yukon	SARA Schedule	COSEWIC
American coot	*Fulica americana*	Not currently listed	Not currently scheduled	Not at risk
American wigeon	*Anas americana*	Not currently listed	Not currently scheduled	Not assessed
Arctic tern	*Sterna paradisaea*	Not currently listed	Not currently scheduled	Not assessed
Barrow's goldeneye	*Bucephala islandica*	Not currently listed	Not currently scheduled	Not assessed
Blue-winged teal	*Anas discors*	Not currently listed	Not currently scheduled	Not assessed
Bonaparte's gull	*Larus philadelphia*	Not currently listed	Not currently scheduled	Not assessed
Bufflehead	*Bucephala albeola*	Not currently listed	Not currently scheduled	Not assessed
Common loon	*Gavia immer*	Not currently listed	Not currently scheduled	Not at risk
Glaucous gull	*Larus glaucescens*	Not currently listed	Not currently scheduled	Not assessed
Green-winged teal	*Anas crecca*	Not currently listed	Not currently scheduled	Not assessed
Herring gull	*Larus argentatus*	Not currently listed	Not currently scheduled	Not assessed
Hooded merganser	*Lophodytes cucullatus*	Not currently listed	Not currently scheduled	Not assessed
Horned grebe	*Podiceps auritus*	Not currently listed	Not currently scheduled	Not assessed
Lesser scaup	*Aythya affinis*	Not currently listed	Not currently scheduled	Not assessed
Lesser yellowlegs	*Tringa flavipes*	Not currently listed	Not currently scheduled	Not assessed
Mallard	*Anas platyrhynchos*	Not currently listed	Not currently scheduled	Not assessed
Mew gull	*Larus canus*	Not currently listed	Not currently scheduled	Not assessed
Northern pintail	*Anas acuta*	Not currently listed	Not currently scheduled	Not assessed
Northern shoveler	*Anas clypeata*	Not currently listed	Not currently scheduled	Not assessed
Pacific loon	Gavia pacifica	Not currently listed	Not currently scheduled	Not assessed
Redhead	*Aythya americana*	Not currently listed	Not currently scheduled	Not assessed
Ring-necked duck	*Aythya collaris*	Not currently listed	Not currently scheduled	Not assessed
Ruddy duck	*Oxyura jamaicensis*	Not currently listed	Not currently scheduled	Not assessed
Sandhill crane	*Grus canadensis*	Not currently listed	Not currently scheduled	Not assessed
Semipalmated plover	*Charadrius semipalmatus*	Not currently listed	Not currently scheduled	Not assessed
Sora	*Porzana carolina*	Not currently listed	Not currently scheduled	Not assessed
Spotted sandpiper	*Actitis macularius*	Not currently listed	Not currently scheduled	Not assessed
Tundra swan	*Cygnus columbianus*	Not currently listed	Not currently scheduled	Not assessed

Table 5.2-4. Status of Landbird Species Potentially Present in the LSA (Canadian Wildlife Service 2007)

Species	Scientific Name	Species Status		
		Yukon	SARA Schedule	COSEWIC
Alder flycatcher	*Empidonax alnorum*	Not currently listed	Not currently scheduled	Not assessed
American pipit	*Anthus rubescens*	Not currently listed	Not currently scheduled	Not assessed
American robin	*Turdus migratorius*	Not currently listed	Not currently scheduled	Not assessed
American tree sparrow	*Spizella arborea*	Not currently listed	Not currently scheduled	Not assessed
Bald eagle	*Haliaeetus leucocephalus*	Not currently listed	Not currently scheduled	Not at risk
Bank swallow	*Riparia riparia*	Not currently listed	Not currently scheduled	Not assessed
Belted Kingfisher	*Ceryle alcyon*	Not currently listed	Not currently scheduled	Not assessed
Bohemian waxwing	*Bombycilla garrulous*	Not currently listed	Not currently scheduled	Not assessed
Boreal chickadee	*Poecile hudsonica*	Not currently listed	Not currently scheduled	Not assessed
Chipping sparrow	*Spizella passerina*	Not currently listed	Not currently scheduled	Not assessed
Cliff swallow	*Petrochelidon pyrrhonota*	Not currently listed	Not currently scheduled	Not assessed
Common raven	*Corvus corax*	Not currently listed	Not currently scheduled	Not assessed
Common Yellowthroat	*Geothlypis trichas*	Not currently listed	Not currently scheduled	Not assessed
Dark-eyed junco	*Junco hyemalis*	Not currently listed	Not currently scheduled	Not assessed
Golden eagle	*Aquila chrysaetos*	Not currently listed	Not currently scheduled	Not at risk
Gray jay	*Perisoreus Canadensis*	Not currently listed	Not currently scheduled	Not assessed
Gray-cheeked thrush	*Catharus minimus*	Not currently listed	Not currently scheduled	Not assessed
Gray-crowned rosy finch	*Leucosticte tephrocotis*	Not currently listed	Not currently scheduled	Not assessed
Great Gray Owl	*Strix nebulosa*	Not currently listed	Not currently scheduled	Not at risk
Great Horned Owl	*Bubo virginianus*	Not currently listed	Not currently scheduled	Not assessed
Hermit thrush	*Catharus guttatus*	Not currently listed	Not currently scheduled	Not assessed
Lapland longspur	*Calcarius lapponicus*	Not currently listed	Not currently scheduled	Not assessed
Lincoln's sparrow	*Melospiza lincolnii*	Not currently listed	Not currently scheduled	Not assessed
Northern flicker	*Colaptes auratus*	Not currently listed	Not currently scheduled	Not assessed
Northern shrike	*Lanius excubitor*	Not currently listed	Not currently scheduled	Not assessed
Northern waterthrush	*Seiurus noveboracensis*	Not currently listed	Not currently scheduled	Not assessed
Red-winged blackbird	*Agelaius phoeniceus*	Not currently listed	Not currently scheduled	Not assessed
Ruby-crowned kinglet	*Regulus calendula*	Not currently listed	Not currently scheduled	Not assessed
Rusty blackbird	*Euphagus carolinus*	Not currently listed	Not currently scheduled	Special concern
Savannah sparrow	*Passerculus sandwichensis*	Not currently listed	Not currently scheduled	Not assessed
Swainson's thrush	*Catharus ustulatus*	Not currently listed	Not currently scheduled	Not assessed
Three-toed Woodpecker	*Picoides dorsalis*	Not currently listed	Not currently scheduled	Not assessed
Townsend's solitaire	*Myadestes townsendi*	Not currently listed	Not currently scheduled	Not assessed
Tree swallow	*Tachycineta bicolor*	Not currently listed	Not currently scheduled	Not assessed
Violet-green swallow	*Tachycineta thalassina*	Not currently listed	Not currently scheduled	Not assessed
White-crowned sparrow	*Zonotrichia leucophrys*	Not currently listed	Not currently scheduled	Not assessed
White-winged crossbill	*Loxia leucoptera*	Not currently listed	Not currently scheduled	Not assessed
Yellow warbler	*Dendroica petechia*	Not currently listed	Not currently scheduled	Not assessed
Yellow-rumped warbler	*Seiurus noveboracensis*	Not currently listed	Not currently scheduled	Not assessed

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6.1 Glossary and Abbreviations

6.1.1 Glossary

Active layer Material that freezes in the winter and thaws in the summer, located above permafrost.

Biodiversity The variety of life, from genes and species to communities, ecosystems, functions, and processes

Critical levels The concentration of pollutants in the atmosphere above which direct adverse effects on receptors such as plants and ecosystems may occur according to present knowledge. Critical levels relate to direct effects on plant physiology, growth and

	vitality and are expressed as atmospheric concentrations or cumulative exposures over a given period of time (WHO, 2000).
Critical load	A quantitative estimate of an exposure in the form of deposition for one or more pollutants, below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. Critical loads relate to ecosystem structure and functioning and are expressed as annual depositions of mass or acidity. Typically, critical loads relate to the potential effects over periods of decades.
Discontinuous permafrost	A region has continuous permafrost if all land is covered by permafrost at some depth
Ecosystem	An integrated and stable complex of living organisms and the non-living components of their environment, functioning together to circulate nutrients and create energy flow.
Environmental receptors	Living and non-living components of the environment that can absorb pollutants.
Ericaceous shrub	Low woody shrubs that are part of or related to the heather family (*Ericaceae*)
Exotic	A species that has been moved beyond their natural range as a result of human activity.
Forb	A non-woody, leafy plant not related to the grass-like plants.
Herbaceous	Non-woody
Hydraulic conductivity	A measure of the ease with which water can move through the pore spaces in a material. Hydraulic conductivity is a function of fluid properties and of the size and shape of pore spaces in a rock or soil.
Hydraulic gradient	The change in groundwater pressures over a certain distance (e.g., the slope of the water table).
Hydraulic head	A measure of the energy of groundwater per unit weight. Hydraulic head represents the pressure exerted by a fluid and is the sum of gauge pressure and elevation.
Overburden	The amount of material lying above bedrock.
Packer Testing	Method used to characterize properties of a formation at discrete intervals within a groundwater well or borehole.
Permeability	A measure of the ability of a material to transmit fluid.
pH	A measure of acidity based on the presence of hydrogen ions. Acidic waters have a pH less than 7 and alkaline waters have pH greater than 7.
Piezometer	An instrument used to measure the hydraulic head of groundwater at a specific depth
Recharge area	A region receiving water, defined by downwards moving flow.
Tailings	Waste material left over from processing rock, often from material extraction.

Till Sediment containing a range of grain sizes, deposited by a glacier.

Faro Mine Complex Includes the Faro Mine Area and the Vangorda/Grum Area
Tailing Impoundment Tailing areas on site of the Faro Mine Complex
Project Faro Mine Complex Closure and Reclamation Project
Project Proposal Project Proposal Faro Mine Complex Closure and Reclamation Project

6.1.2 Abbreviations

Abbreviation	Term
Masl	Metres Above Sea Level
Bgs	Below Ground Surface
CSR	Contaminated Sites Regulation
Btoc	Below Top Of Casing (referring to well casing for groundwater wells – usually ground level plus well stickup)
K	Hydraulic Conductivity (see glossary)
µg/L	Micrograms per Litre
LSA	Local Study Area
mg/L	Milligrams per Litre
MMER	Metal Mining Effluent Regulation
NFRC	North Fork Rose Creek
RSA	Regional Study Area
SO4	Sulphate
Zn	Zinc